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Using lagging and leading indicators for the evaluation of occupational safety and health performance in industry

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Improvement of occupational safety and health (OSH) management is closely related to the development of OSH performance measurement, which should include OSH outcomes (e.g., occupational accidents), OSH inputs (including working conditions) and OSH-related activities. The indicators used to measure the OSH outcomes are often called lagging indicators, and the indicators of inputs and OSH activities are leading indicators. A study was conducted in 60 companies in order to determine what kinds of indicators were used for OSH performance measurement by companies with different levels of OSH performance. The results reveal that the indicators most commonly used in all of the companies are those related to ensuring compliance with the statutory requirements. At the same time, the leading indicators are much more often adopted in companies with a higher performance level. These companies also much more often monitor on a regular basis the indicators adopted for the evaluation of their OSH performance.

Keywords: OSH performance evaluation; OSH performance measurement; lagging indicators; leading indicators; activities indicators; input indicators

1. Introduction

Effective occupational safety and health (OSH) management requires appropriate and reliable OSH performance measurement. The tools used for the measurement of the performance are indicators. An indicator can be defined as ‘a concise definition of a concept, meant to provide maximal information on an area of interest’,[1, p.36] or a ‘quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor’.[2, p.32] The indicators designed to measure OSH performance in companies are intended to provide information on the extent to which a desired outcome is achieved or the quality of processes leading to that outcome. Different types of indicators showing OSH inputs, processes and outcomes are used for the measurement of OSH performance.

The indicators reflecting OSH outcomes and applied during the process of reactive monitoring, with a focus on the measurement of losses incurred as a consequence of inappropriate OSH performance, are frequently called lagging indicators and this term is applied in this article. In the literature on the subject, the term outcome indicators is also used [3,4] along with the term negative performance indicators [5] or trailing indicators.[6,7] Examples of this type of indicator include the number of accidents at work or their frequency rates, the cost of compensations

for workers, the number of days of absence owing to accidents at work, the number of occupational diseases and so forth. For years, numerous researchers have emphasized that timely and accurate analysis of these indicators is essential for successful prevention (e.g., [8]). These traditional indicators are usually easy to calculate on the basis of data collected in company’s registers according to legal requirements. To receive other lagging indicators, such as the number of incidents, number of work-related illnesses or costs of occupational accidents, an additional system of data collection is necessary. The lagging indicators can provide information on the effectiveness of actions performed in the past and do not enable their current monitoring and correction.

The OSH inputs are defined as all of the preventive potential and working conditions in a given company, which can be presented using input indicators. A commonly known input indicator is the number of workers exposed to harmful factors in the working environment. This indicator can be based on objective data received from measurements or on subjective data from questionnaire surveys [9] and can be used, among others, as a predictor of future outcomes.

The OSH processes comprise strategies, policies and measures implemented with a view to improving employees’ OSH and are monitored thanks to the use of activities indicators. Activities indicators characterize different

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actions directed at improvement of OSH management in a company. For example, activities indicators related to actions taken with the aim of increasing employee involvement in OSH, which is thought to be one of the most important and still insufficient implemented elements of the OSH management system,[10] can be the number of employees participating in OSH training courses, consultations or the number of OSH improvements proposed by workers. The activities indicators are related to OSH objectives established in a company and are defined in planning processes. The indicators showing the inputs and processes are included in a group collectively called leading indicators [3,4,6,7] and this term will be used in this article. In the subject literature, these are also called positive performance indicators.[11,12]

In general it is assumed that using and improving leading indicators influences lagging indicators. Some research seems to confirm this assumption, among other research related to modifying unsafe behaviours in which positive changes in indicators of safety culture were accompanied by positive changes in lagging indicators.[13] A general model for measuring OSH performance using lagging and leading indicators is presented in Figure 1.

For years, guidance has been developed to support companies in OSH performance measurement, among others by the British Health and Safety Executive [3,4] and the Australian National Health and Safety Commission.[11,12] The OECD also published Guidance on Safety Performance Indicators to assist companies in implementing measures to prevent chemical accidents.[14] In the ILO-OSH 2001 guidance on OSH management systems [15] and other guidance or requirements for OSH management systems provided in various standards developed at international or national levels, such as, e.g., voluntary Polish PN-N-18000 series standards,[16,17] the necessity of appropriate OSH performance measurement is emphasized. To evaluate the impact of adopting OSH management rules according to these standards on using leading and lagging indicators for OSH performance measurement and to check whether a relationship exists

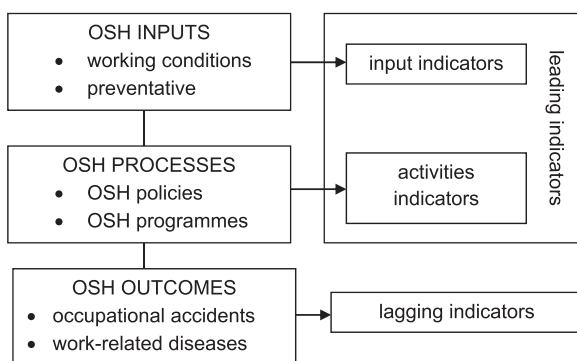


Figure 1. General model for measuring occupational safety and health (OSH) performance using lagging indicators and leading indicators.

between using these indicators and the achieved OSH outcomes, a study was conducted in 60 companies with different levels of OSH performance.

2. Method

To collect information on company OSH performance and indicators used for its assessment, a questionnaire was developed in electronic form and circulated amongst executives in the studied companies. The questionnaire contained questions concerning the following:

- the company's size, sector and management systems implemented;
- the company performance in the following areas of OSH management, identified taking into account the OSH management rules defined in the ILO-OSH guidance:
 - commitment of the company's top management to OSH matters, including ensuring resources for OSH, participation in training activities, receiving and analysing the OSH information, taking up initiatives and personal involvement in the OSH activities;
 - the OSH policy, including establishment of documented OSH policy, its adjustment in line with the adopted requirements and its understanding by the company employees;
 - participation of workers in efforts to enhance the OSH, including information, consultation and participation in the decision-making process, appointment of representatives for the OSH matters and direct involvement of employees in the health and safety efforts;
 - planning in the area of OSH, including the setting of long-term and short-term goals and plans considering current analyses of the company functioning and the employees' opinions along with the documents updates, participation of company executives and employees in the goal-setting process;
 - assignment of responsibilities and rights related to the OSH efforts and activities for employees as well as subcontractors and suppliers;
 - training in the area of OSH, including performance of training courses required by law, identification of training needs on a regular basis and assessment of the training activities performance and quality;
 - communication process, including the flow of information in all directions within the organization, in particular from the company personnel to management;
 - procedures, including the development of documented procedures for crucial activities that ensure proper functioning of the company;

- management of occupational risks, including the assessment of occupational risks while ensuring the participation of employees and taking their opinions and feedback into consideration along with the implementation of measures resulting from risk assessment;
- preparedness and response to work accidents and failures, including the established principles of responsiveness, providing first aid and cooperation with external entities;
- investigation of accidents at work, occupational diseases and incidents, including the use of appropriate methods to identify their primary causes resulting from management deficiencies;
- monitoring in the area of OSH, including regular inspections, reviews, measurements, researching health complaints related to work, incidents and so forth;
- corrective action, including successful elimination of non-compliances detected in the monitoring process; and
- audits.

Each of these listed areas was evaluated on a scale from 1 to 5 (where 5 denotes the highest level).

The questionnaire also contained questions concerning the following:

- Lagging indicators used for the assessment and monitoring of OSH performance in the company, identified on the basis of reviews with OSH consultants supporting companies in the development of OSH management systems, including:
 - number of occupational accidents,
 - incidence rate of occupational accidents,
 - severity rate of occupational accidents,
 - number of sickness absence days,
 - number of nonconformities with the legal requirements,
 - cost of accidents at work,
 - number of incidents,
 - number of nonconformities with the requirements for the OSH management system, and
 - number of workers reporting work-related diseases.
- Leading indicators used for evaluating and monitoring the OSH performance, identified on the basis of reviews with OSH consultants supporting companies in the development of OSH management systems, including:
 - a number of employees working in hazardous conditions (in which maximum admissible concentrations or intensities are exceeded), and
 - a number of workers reporting stress at work:
 - a number of OSH training courses for the company executives,

- a number of OSH reports referred to the company's top management,
- a number or percentage of employees provided with the OSH training courses,
- a number OSH-related issues reported by workers,
- a number of occupational risk assessments,
- a number of workplaces where protection measures were improved, and
- a number of OSH inspections.

The questions asked about each indicator were whether it had been adopted for the measurement of OSH performance, and whether it was regularly monitored and recorded. A question was also asked about some other output and leading indicators if they were not included in the questionnaire but were used in a given company.

A purposive sample of 60 companies was subject to the study. Fifty per cent of them employed more than 250 workers, 35% fewer than 250 but more than 50 workers and 15% of companies employed more than 50 workers. Thirty-two of the studied companies have implemented an OSH management system according to the voluntary standards and have received certificates confirming the implementation, whereas the other companies in the sample have not implemented this system. The level of compliance with the standard was assessed in line with the responses to the questionnaire on the basis of the self-assessment performed by a representative of the company management. Next, the self-assessments were verified and confirmed by OSH management systems consultants that cooperate with the companies.

The safety level in the studied companies, measured by the occupational accidents rate (calculated as the number of occupational accidents related to 1000 workers), was very different: in over 20% of the companies, no occupational accident was registered in 2011; however, in the majority of them the occupational accident rates were higher than average at a national level (which amounted to 8.35 in 2011).

3. Results

3.1. Lagging and leading indicators used to evaluate OSH performance in companies

To evaluate the impact of the implementation of the OSH management rules according to the voluntary standards PN-N-18000 on using leading and lagging indicators for OSH performance measurement, the surveyed companies were divided into two groups: one for which the level of adopting these rules was rated higher than the median calculated for all the companies subject to the survey (hereafter 'high-performing companies'); and the second group, for which the rating was lower than the median (hereafter 'low-performing companies').

All of the high-performing companies and less than 60% of low-performing companies used more than four lagging indicators to measure their OSH performance. The relationship between the level of adopting OSH management rules according to the voluntary standards and the number of adopted lagging indicators is statistically significant (Kendall's $\tau_B = 0.72$, $p < 0.01$). [18] The most frequently applied lagging indicators are the number of accidents at work (in almost 97% of all the surveyed companies) and the number of the absence days (in over 61% of all the companies). There are no statistically significant differences between using these indicators in high-performing and low-performing companies. For the other lagging indicators, a χ^2 test of independence indicates that the differences in using them are statistically significant; the strongest correlation was found for the indicator 'number of incidents' ($\varphi = 0.68$; $p < 0.01$, Goodman and Kruskal's $\tau = 0.48$; $p < 0.01$). The percentages of high-performing and low-performing companies in which specific lagging indicators are employed are shown in Figure 2.

Leading indicators are applied less frequently than lagging indicators in all of the surveyed companies. The number of leading indicators used increases in line with the level of adopting OSH management rules according to the voluntary standards; this relationship is statistically significant (based on a χ^2 test of independence: Kendall's $\tau_B = 0.68$, $p < 0.01$). [17] The most frequently applied leading indicator – the number of employees working in hazardous conditions – refers to OSH inputs. This indicator is employed in more than 70% of high-performing as well

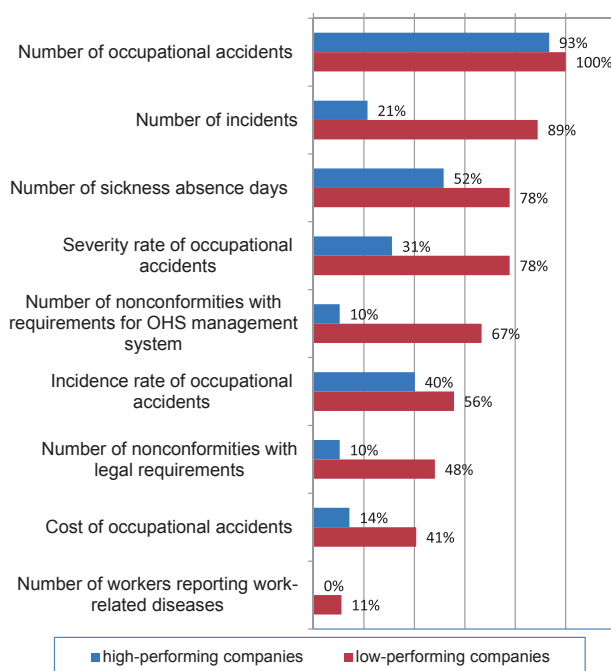


Figure 2. Percentages of high-performing and low-performing companies in which specific lagging indicators are used. Note: OHS = occupational health and safety.

as low-performing companies. For the other leading indicators included in the survey which refer to OSH activities, the χ^2 test of independence confirmed statistically significant differences regarding the frequency of using them in both groups of companies. The strongest relationship was found for the following indicators:

- 'The number of documented procedures and/or safety instructions developed or verified at a given time' ($\varphi = 0.67$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.45$, $p < 0.01$).
- 'The number of reports on the OSH situation submitted to top management (e.g., per year)' ($\varphi = 0.61$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.37$, $p < 0.01$).
- 'The number or percentage of employees participating in training on health and safety' ($\varphi = 0.60$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.36$, $p < 0.01$).
- 'The number of work stations for which risk assessment was carried out' ($\varphi = 0.59$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.35$, $p < 0.01$).
- 'The number of non-compliances with the requirements of the OSH management system' ($\varphi = 0.58$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.34$, $p < 0.01$).
- 'The number of work stations, where better measures of protection against risks were implemented' ($\varphi = 0.56$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.31$, $p < 0.01$).

The percentages of high-performing and low-performing companies in which specific leading indicators are employed are shown in Figure 3.

Even though the performance indicators are defined and used for OSH performance evaluation, they are not regularly monitored in over 40% of the surveyed companies. Approximately 46% of the high-performing companies and only 5% of the low-performing companies regularly monitor at least three indicators. The relationship between the number of indicators monitored regularly and the level of adopting OSH management rules according to the voluntary standards is not only statistically significant, but also the strongest of all the presented relationships (Kendall's $\tau_B = 0.86$, $p < 0.01$). The greatest differences between the high-performing and low-performing companies occur for the following indicators [18]:

- The number or percentage of employees participating in training on occupational health and safety ($\varphi = 0.75$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.56$, $p < 0.01$).
- The number of work stations for which risk assessment was carried out ($\varphi = 0.75$, $p < 0.01$, Goodman and Kruskal's $\tau = 0.56$, $p < 0.01$).

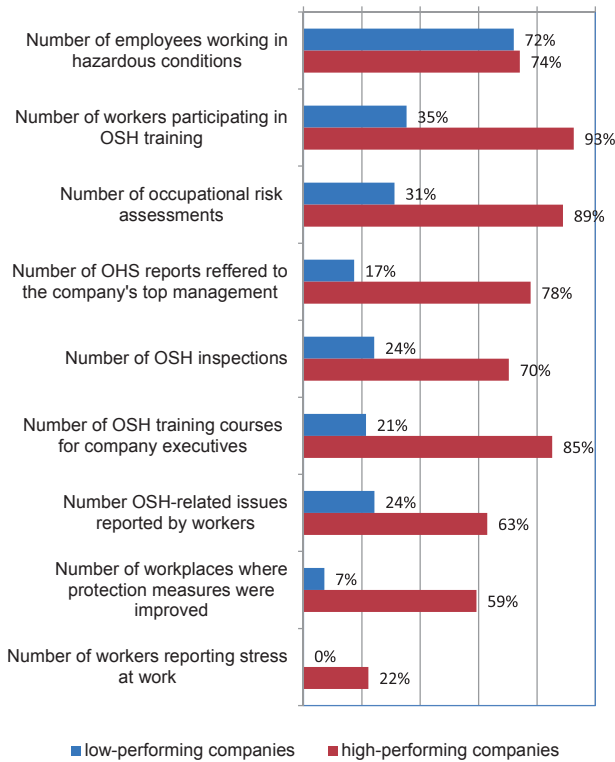


Figure 3. Percentages of high-performing and low-performing companies in which specific leading indicators are used. Note: OHS = occupational health and safety; OSH = occupational safety and health.

- The number of reports on the OSH situation submitted to the top company management in a given year ($\varphi = 0.73, p < 0.01$, Goodman and Kruskal's $\tau = 0.53, p < 0.01$).

3.2. Relationships between leading and lagging indicators

The number of leading indicators used for OSH performance evaluation is growing together with the number of

lagging indicators used, and the relationship is statistically significant (Pearson's correlation coefficient $r = 0.70; p < 0.001$). Looking for the relationship between occupational accident rates and the number of leading indicators applied, statistical analysis of differences between groups of companies with different accident rates was performed. The strongest differences was identified between the groups of companies with occupational accident rates higher than 10 (mean number of applied leading indicators 3.5; SD 2.9) and lower than 10 (mean number of applied leading indicators 5.5; SD 3.3) (Table 1). The strength of this relationship measured using Cohen's d effect size (0.7) is moderate.

The differences in occupational accident rates were also identified between companies grouped into clusters as follows:

- the companies which use the majority of the leading indicators listed in the questionnaire, and
- the companies which use only three of the indicators that are the most frequently used.

The quality of the clustering was sufficient (silhouette measure = 0.4).

In the first group of companies the mean occupational accident rate amounts to 11, and in the second group the rate is 26. This result indicates that companies which use more indicators for evaluating their performance can achieve a higher level of safety.

When analysing the influence of a particular, single leading indicator on occupational accidents rates, only for one of them – 'number of risk assessments' – have statistically significant differences been identified between companies which use this indicator and the companies not using it (Table 2), confirmed by the Mann–Whitney U test ($U = 238; p < 0.05$). The Cohen's d effect size (which amounts to 0.83) indicates that the relationship is strong.

Table 1. Differences between the number of leading indicators applied by the groups of companies with occupational accident rates (per 1000 workers) over and under 10.

Occupational accident rates (per 1000 workers)	Number of companies	%	Number of leading indicators applied			
			Statistics	SE		
≤ 10	31	51.7	<i>M</i>	5.5	0.59	
			<i>Mdn</i>	6.0		
			<i>SD</i>	3.3		
			Interquartile range	6.0		
			Asymmetry	-0.3		0.42
			Kurtosis	-1.2		0.82
> 10	29	48.3	<i>M</i>	3.5	0.53	
			<i>Mdn</i>	3.0		
			<i>SD</i>	2.9		
			Interquartile range	4.0		
			Asymmetry	0.6		0.43
			Kurtosis	-0.8		0.84

Table 2. Differences in occupational accident rates (per 1000 workers) between the group of companies which use the leading indicator 'number of risk assessments' and the group of companies which do not use this indicator.

Group of companies	Number of companies	%	Occupational accident rates (per 1000 workers) for the groups of the companies			
			Statistics		SE	
Companies in which the indicator 'number of risk assessments' is not used	22	38	<i>M</i>	22.9	4.06	
			<i>Mdn</i>	27.8		
			<i>SD</i>	19.0		
			Interquartile range	30.4		
			Asymmetry	0.8		0.49
			Kurtosis	1.3		0.95
Companies in which the indicator 'number of risk assessments' is used	36	62	<i>M</i>	10.3	1.67	
			<i>Mdn</i>	7.8		
			<i>SD</i>	10.1		
			Interquartile range	16.2		
			Asymmetry	0.99		0.39
			Kurtosis	0.16		0.78

4. Conclusions

The performance indicators commonly used in the studied companies include the number of accidents at work (this lagging indicator is adopted in almost all companies) and the number of people working in hazardous conditions (this input indicator is used in more than 70% of all companies). Both indicators are used equally often in the high-performing and the low-performing companies. These indicators have to be determined in line with law provisions that require the company to present relevant data for national statistics and for the needs of insurance. The leading indicator that is among the most frequently used is the number of employees participating in training courses on health and safety issues. The indicator is also linked to ensuring compliance with the requirements set out in the law under which companies have to conduct periodical training courses on health and safety matters. These results point to the important role statutory requirements play in determining the indicators used to assess the OSH performance in all companies.

The indicators that are in use even though they are not directly linked to achievement of compliance with the law requirements, in particular leading indicators related to OSH activities, are adopted significantly more often in the companies which are better adjusted to the OSH management rules presented in the standards for voluntary use (such as PN-N-18000). In this group, the most frequently adopted indicators are those directly required by the standards or reflecting the activities aimed at achieving compliance with them, e.g., the number of incidents.

Regular monitoring of indicators adopted for performance evaluation is necessary to make sure that responses to changes follow early enough. The study shows that the adoption of a particular indicator does not always mean it is regularly monitored, especially in the companies with

a low level of OSH performance. The basic indicator adopted by almost all companies, which is the number of accidents at work, is regularly monitored in all companies with a high level of performance, and only in less than 60% of other companies. In addition, over 80% of the companies with a highly rated performance monitor regularly some other indicators related to the law requirements or voluntarily adopted standards. They include a number of risk assessments, a number of incidents and a number of employees participating in training activities. This type of indicators is monitored in only about 10–20% of other companies. Therefore, better adjustment to the requirements and guidelines related to the OSH management system means that the ongoing development of planning and monitoring processes is in place, which supports continuous improvement of the OSH management. Some results achieved can also indicate that companies with lower occupational accidents rates more frequently employ more indicators to measure their OSH performance.

The OSH performance indicators are valuable tools in managing safety and health in a company. This research confirms that companies with better OSH performance usually employ more performance indicators. The differences are particularly visible in the case of leading indicators, which can provide valuable information for proactive OSH management. However, it is rather difficult to evaluate the relationship between the various OSH leading indicators and OSH outcomes measured using lagging indicators. In this survey the significant differences in accident rates have been identified between companies using the leading indicator 'number of risk assessments' and companies not using it. Further research is needed to identify the most effective OSH performance indicators and to support their practical implementation in companies.

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Disclosure statement

No potential conflict of interest was reported by the author.

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