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Based on the study of the scientific literature on the performance indicators of safety management systems, it emerged that to date there is no standardization of indicators capable of providing a systemic assessment. However, in the literature, several indicators have been proposed to evaluate the performance of the safety management system: lagging, monitoring and leading indicators.

The lagging indicators are result indicators in terms of the consequences deriving from situational and contextual factors. The monitoring and leading indicators, on the other hand, have the function to direct (guide) the activity of an organization towards proactive safety. The monitoring indicators provide a view of the dynamics of the organization in terms of practices, skills and motivation of staff, or the organizational potential for safety.

In a previous scientific paper, the authors have proposed a correlation table between the elements of a safety management system according to UNI EN ISO 45001 and the elements that characterize a resilient organization according to ISO 22316. In this paper, the authors want to identify, for each correlation element, the leading and lagging indicators that are used to monitor same aspects of the safety management system, since, providing useful information to “anticipate” the behaviour of the system. Therefore, based on correlation table, they should be able to provide indications on the resilience of the organization.

Keywords: Safety management system, organizational resilience, performance indicators, leading indicators, lagging indicators.

1. Background

In recent years, organizational resilience has been defined in different ways. For the purposes of this work, organizational resilience will be evaluated from the perspective of “Engineering Resilience” according to which a system is resilient if return quickly to the functional “acceptable” state from a disruptive event. According to Somers (2007), disruptive event could cause “alteration, degradation or cessation of organizational operations”, while McManus et al. (2008) define it as “an event that prevents an organization from delivering its products or services properly, has a negative impact on its operational environment and causes an interruption in its normal workflow”. The method proposed by Hollnagel and Wood (2017), instead, consists in assessing four abilities of a resilient organization: the ability

to respond, to anticipate, to monitor and to learn. Despite the interest in this topic, in the literature there is no specific framework to assess organizational resilience, as well as indicators to measure it. In this paper, the authors want to show that the leading indicators, used to measure the performance of the safety management system, are also suitable to measure the organization’s ability to anticipate the behaviour of the system. Furthermore, lagging indicators simultaneously enhance the organization’s ability to monitor and learn from them. Even the organization’s ability to respond to an adverse event depends on a performing management system that allows planning mechanism, practices, skills, strategies and processes to stay alert to possible threats, to ensure business continuity and minimize risks (Somers, 2007).

In this work, the authors embrace the conceptualization of resilience by Hollnagel and

Wood (2006), according to which resilience is not a property of the organization, but a characteristic that is developed and nurtured using knowledge, skills and resources and that requires a continuous monitoring of system performance. Starting from this perspective, the authors want to highlight how the abilities of a resilient organization, as defined by Hollnagel, could be assessed through the leading and lagging indicators used to measure the performance of Safety Management Systems (SMS). Performance indicators are the fundamental tool for measuring and monitoring the performance of a safety management system, in order to implement intervention actions. However, to date, there is no standardization of performance indicators. Based on a previous scientific work, proposed by the authors (Pera et al, 2020), a correlation table between the elements of a safety management system, according to UNI EN ISO 45001, and the elements that characterize a resilient organization, according to ISO 22316, shows that these aspects in common can be measurable with the same performance indicators. In particular, leading indicators identify early signs of vulnerabilities, provide useful information that “anticipate” the behaviour of the system and, therefore, should be able to provide indications on the resilience of the organization.

2. A resilient organisation’s abilities.

According to Hollnagel, an organization must be able to respond to any unexpected event, monitor ongoing evolutions, anticipate future threats and opportunities, and learn from past successes and failures. From this perspective, the authors have schematised (Fig.1) a complex sociotechnical system and have tried to define its resilient response as a function of four capabilities of the system that is to respond, monitor, anticipate and learn from a disruptive event.

The system will be even more able to effectively monitor its processes, resources, machines if it adopts a monitoring system that is based on the

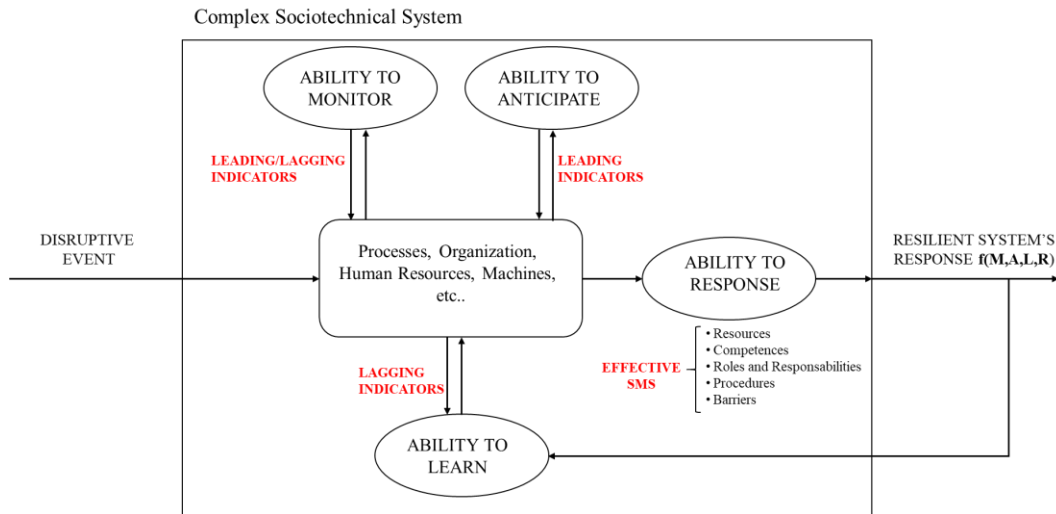
use of lagging and leading indicators. Similarly, its ability to detect deviations of the system from normal functioning will be enhanced if it makes use of leading indicators that are able to give early warning signals, allowing the system to respond promptly to the disturbance. Moreover, the system’s response will be more prompt the more effective its management system will be, by enabling it, because of clearly defined roles and responsibilities, to implement the action plans with the necessary resources. The lagging indicators instead increase the ability of the system to learn from past events, allowing to take actions to mitigate the risks.

2.1.1 Ability to respond

The ability to respond to external and internal disturbances is a fundamental requirement for any system in order to maintain productivity and ensure safety. The system must be able to recognize an event that requires timely and effective responses. The system, to better respond to unforeseen events, requires knowledge of the necessary skills and resources. Competence refers to management’s ability to identify potential threats, to make the right decision and actions to respond rationally to disturbances. In addition, employees’ work experience and their ability to be creative, help organizations to face disruptive events. An adequate response also depends on the right assignment of roles and responsibilities: know who has to do what.

However, leadership decisions must be supported by organization’s capacity to mobilize internal and external resources through networks and partnerships (Rahi, 2019). Based on these considerations, it is worth noting that more efficient the organization management system is, more the system will be able to respond promptly to an unexpected with its own resources, skills and planned procedures.

2.1.2. Ability to monitor



The ability to react accurately and timely is linked to an effective monitoring of the state of the system. In the safety management system, monitoring usually involves the use of indicators such as the number of accidents and near-accidents. At present, there is no list of standardized indicators to assess the performance of management systems, however researchers agree in considering mainly two types: leading indicators, which are precursors of future events, and lagging indicators such as observations of events that have already occurred.

From a resilience engineering point of view it is necessary to collect data from the intermediate state, by monitoring the system performance during normal operation (Øien et al., 2010).

According to the authors, leading and lagging indicators, used in management systems, are suitable for monitoring the functioning of the system and its main parameters (Haad&Yorio, 2016). The identification of relevant indicators makes it necessary to gain an understanding of the current working environment.

The continuous monitoring of the internal and external organization's situation (its competitors, the laws and regulations, internal changes, etc.) increases an organization's ability to assess the change in its surrounding in order to manage it.

2.1.3. Ability to anticipate

A system without the ability to anticipate is a system that is limited to purely reactive

behaviour. The ability to anticipate is closely related to the ability to predict future events. In this perspective, the leading indicators seem to be able to detect early warnings, allowing the system to prepare to respond to the disturbance in terms of availability of resources and skills.

In general, what distinguishes anticipation from monitoring are the different time scales of observations and perspective. Leading indicators allow the organization to evaluate and detect changes in its environment so as to be proactive in managing possible disruptive events.

2.1.4. Ability to learn

Individuals and/or organisations increase their capacity to manage threats by adapting (Weick) their previous knowledge to handle unexpected situations based on lessons learned. At the same time, the selection of lagging indicators allows the organization to develop the ability to recognize potential threats and opportunities based on similar events already happened. The accurate analysis of the consequences of a disturbing event guides the organization in a continuous process of adaptation, reviewing priorities, processes, management, resources, etc.

3. Relationship between Safety Management System and Organizational Resilience

On previous paper (Pera et al., 2020), the authors have correlated principles, attributes and

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ISO 22316:2017 – ORGANIZATIONAL RESILIENCE-PRINCIPLES ATTRIBUTES	Table 1 – Examples of leading and lagging indicators	LEADING INDICATORS.
5.2 Shared vision and clarity of purpose	5.2 OH&S policy 6.2.1 OH&S objectives	<ul style="list-style-type: none"> Number of Organization's policy reviews and updates out by top management Percentage of workers declaring good knowledge of Organization's policy
5.3 Understanding and influencing context	4.1 Understanding the organization and its context	<ul style="list-style-type: none"> Number of issues of company's bulletin or other internal publications concerning organization's problems Number of external informational materials (reports, articles, regulations, etc.) distributed internally
5.4 Effective and empowered leadership	5.1 Leadership and commitment 5.3 Organizational roles, responsibilities and authorities 7.2 Competence	<ul style="list-style-type: none"> Number of meeting conducted by managers to inform workers on program goals Percentage of work posts with defined roles, competences and responsibilities
5.5 A culture supportive of organizational resilience	5.1 Leadership and commitment 5.2 OH&S policy 5.4 Consultation and participation of workers	<ul style="list-style-type: none"> Percentage of workers participating in refresher courses on policy reviews and updates Number of improvements proposed by workers Percentage of training courses reviewed and improved for their quality and effectiveness
5.6 Shared information and knowledge	7.4 Communication	<ul style="list-style-type: none"> Rating of the effectiveness of communication via workforce survey
5.7 Availability of resources	7.1 Resources	<ul style="list-style-type: none"> Number of maintenance plans Percentage of material stock
5.8 Development and coordination of management disciplines	7.4.2 Internal communications	<ul style="list-style-type: none"> Number messages, by means of emails, bulletins, etc., distributed among workers of different departments/operational unit
5.9 Supporting continual improvement	10.3 Continual Improvement	<ul style="list-style-type: none"> Number of new policy goals and objectives established Number of organizational solutions ensuring continual improvement
5.10 Ability to anticipate and managing change	8.1.3 Management of change 8.2 Emergency preparedness and response	<ul style="list-style-type: none"> Number of procedures and instructions verified/modified in course of introduction of organizational changes, new technologies, machinery, modification of work processes Percentage of workers trained on emergency procedures, including first aid
6.3 Monitoring and assessment 6.3.1 Methods and processes	9.1 Monitoring, measurement, analysis and performance evaluation	<ul style="list-style-type: none"> Number of leading and/or lagging indicators monitored to measure organization performance Percentage of definitions of leading and lagging performance indicators subject to periodical review and update
6.3 Monitoring and assessment 6.3.2 Review	9.3 Management review	<ul style="list-style-type: none"> Number of components or processes subject to analysis at reviews Number of policy items and strategic goals reviewed by top management at reviews
6.4 Reporting	7.5 Documented Information	<ul style="list-style-type: none"> Number of new instructions implemented on new workstations Number of operational procedures reviewed and improved in course of corrective actions

activities, established in the organizational resilience standard (ISO 22316), with the requirements of the standard of the safety management system (ISO 45001). The correlation between the two standards have showed how resilience principles could be

integrated into safety management practices, as they carries within itself the principles of organizational resilience. This correspondence means that the methods and tools of a safety management system could be used to strengthen the principles of resilience and implement related activities. From this point of view, indicators already used for the safety management system can also be adapted to measure organisational resilience.

In this work, the authors, starting from the correlation table between ISO 22316 and ISO 45001 already developed, have made a step

forward, by adding a column containing some examples of lagging and leading indicators used to measure the performance of safety management systems. The indicators shown in the table are extracted from the relevant literature, in particular have been adapted from those proposed by Podgorski (2015), because there are no standardized indicators, nor a precise number of indicators to use. It is worth noting, based on the considerations made above, how some of these indicators also give an assessment of the capabilities that a resilient organization must have (responding, monitoring, anticipating, and learning) as well as being an effective system monitoring tool.

The close correlation between safety management system and organisational resilience has also emerged from the analysis of a resilient organisation's abilities: The more effective is the safety management system implemented, the more appropriate will be the system's ability to respond to an adverse event. An effectively structured SMS, in fact, implies maintenance plans, barriers and safeguards, updated procedures, availability of resources, commitment and competence of management, employee involvement, definition of roles and responsibilities, etc. These elements are measurable by leading and lagging indicators, as shown by way of example in the correlation table. At the same time, these elements also allow you to explore an organization's resilient response capability.

Conclusion

Having established that organisational resilience can be enhanced through the safety management system and that leading and lagging indicators allow it to be measured, future research must develop an approach to assess it (Di Nardo et al., 2020). According to Patriarca et al. (2018), measuring resilience is a challenging task, considering that resilience is something that a system does, rather than something it has.

The authors have outlined an idea of how to measure organizational resilience through performance indicators, but it remains the still unsolved problem of defining standardized indicators for general aspects applicable to all organizations. Standardisation is working in this direction to develop a standard providing

performance indicators for safety management systems. Hence, the applicability of these to measure the resilience of an organization becomes effectively desirable.

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