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Sustainable occupational safety and health interventions: A study on the factors for an effective design

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ABSTRACT

Effective interventions are a priority in continuously changing occupational environments, particularly in companies struggling to manage health and safety in the workplace. Practitioners may consider practical solutions for Occupational Safety and Health (OSH) improvement as a panacea for all major problems. However, they may overlook a range of other factors that affect the success of such solutions. The way in which a solution is developed, designed, implemented, and evaluated determines its impact. Participatory interventions are one way of ensuring better results. Consequently, this study proposes a way of establishing sustainable, effective, and efficient interventions by defining the required processes and actively involving responsible actors (i.e., *who*, *when*, and *how*).

A national OSH intervention for introducing a near-miss management system, funded by the Italian National Institute for Insurance against Accidents at Work (INAIL), is used as a reference because its development process includes an accurate design stage. Based on this intervention, a multistep design process is built to answer *how* (how the intervention will persist by defining the context, processes, and scenarios), *who* (who will be the responsible actors actively participating), and *when* (when actors will be involved) questions.

The design process established for the intervention, although within a specific context, provides clues to discriminant factors that would enable effectiveness in general interventions, and the proposed system for near-miss management generates insights that may be generalizable to other OSH interventions developed in different environments.

1. Introduction

Occupational Safety and Health (OSH) faces a range of challenges—limited human, economic, and technological resources—that give rise to new types of risk, requiring further competencies to promote and ensure OSH (Micheli and Cagno, 2010; Rodrigues et al., 2020). Therefore, organizations should adapt to and actively manage the ongoing challenges in continuously changing occupational environments (Badri et al., 2018; Zwetsloot et al., 2020). Moreover, with the shift from a prescriptive to a goal-oriented approach, organizations are moving from prescriptive directives towards self-regulation, and more active employees are entitled to participate in the decisional regulatory process of their organizations.

In recent years, the research and the actions undertaken for health and safety in the workplace are moving from 'protection' to 'prevention' of injuries and illnesses. In this context, the opportunity to monitor risks is crucial for implementing effective prevention policies (Asadzadeh et al., 2020; Micheli et al., 2022). Recently, the International Labor Organization (ILO) (ILO, 2023) and the European Commission (EC) (EC, 2023) have emphasized the need to shift the monitoring focus from harmful events, such as injuries and diseases, to the causes that determine them. This attention and the resulting knowledge can effectively

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direct policies and prevention strategies in the workplace. The International Organization for Standardization (ISO) 45000 standards are moving in this direction by providing instruments to improve employee safety, reduce workplace risks, and create better and safer working conditions.

The recent release of the ISO 45001:2018 standard (ISO, 2018), replacing the Occupational Health and Safety Assessment Series (OHSAS) 18001:2007 standard (BSI, 2007), has increased the attention to OSH management procedures by committing organizations to enhance their workplace health and well-being. For example, near misses have been considered valuable in ISO 45001:2018 (ISO, 2018) and OHSAS 18001:2007 (BSI, 2007), which define them as events (incidents) that occurred and did not result in an injury. Near misses are also viewed as accident precursors because they often share the same direct causes and contributing factors as accidents (Gnoni et al., 2022; Saleh et al., 2013). According to Saleh et al. (2013), "A near miss is a special type of accident precursor for which the truncation is minimal (close to the accident end state or suffix of the accident sequence) and the accident is close to being released." In other words, the accident nearly occurred, but a few missing elements in the accident sequence prevented it from transforming into injuries (Gnoni et al., 2022; Gnoni and Saleh, 2017; Saleh et al., 2013). Analyzing near misses can facilitate the development of more effective prevention strategies (Gnoni and Saleh, 2017); when properly managed, "the identification of precursors provides an opportunity to interrupt an accident sequence from unfolding" (Saleh et al., 2013) by identifying deficiencies before accidents occur (Andriulo and Gnoni, 2014). Therefore, near-miss events should be considered important safety-leading indicators that anticipate serious events (e.g., accidents or machine anomalies) and enable safety managers to intervene on time (Shen and Marks, 2016). Certainly, OSH would significantly advance in prevention and continuous improvement if work environments and stakeholders were enabled to identify near-miss events. However, the management of these events has not yet been fully exploited, especially in small and medium-sized enterprises (SMEs), where human and financial resources are limited and OSH culture is still not widespread. In this context, effective interventions are a priority, particularly for companies struggling to manage health and safety in the workplace. Public institutions are also showing growing interest in OSH management performance and are allocating substantial funds for national interventions aimed at improving OSH conditions in the workplace.

The impact of interventions is crucial for all stakeholders—employers, practitioners, associations, and public institutions. However, the effectiveness of interventions is rarely monitored because it is often assumed without proper assessment or considered too difficult to measure as interventions are context-dependent and reliant on several, mostly qualitative, factors that are difficult to track (Fridrich et al., 2015; Robson et al., 2007; von Thiele Schwarz et al., 2021). Failing to assess the effectiveness of interventions hampers the ability to learn about what interventions work and how they should be implemented by ultimately hindering their continuous improvement, thereby not succeeding in maximizing their potential impact. Therefore, it is essential to ensure a controlled design for interventions that would lay the groundwork for more effective implementation and more successful outcomes. This study focuses on how interventions are designed; considering an Italian national intervention as an example, we propose *a way to establish effective interventions by addressing major driving factors that are often ignored.*

The remainder of this paper is organized as follows. In Section 1.1, the literature on the effectiveness of OSH interventions is discussed, and in Section 1.2, the research gap and aim are stated. *Section 2* presents the proposed methods for effective designing of national OSH interventions. *Section 3* presents the results of the intervention development based on the processes and actors involved. *Section 4* discusses the findings and demonstrates shareable practices in other contexts and countries. *Section 5* draws conclusions by discussing the implications and future development of the proposed method.

1.1. Effectiveness of OSH interventions

A significant portion of OSH literature covers the development of interventions for improving workplace conditions. The scope of interventions is diverse, ranging from general interventions (Andersen et al., 2019; Hale et al., 2010; Robson et al., 2007), which may be generalizable to many work environments, to interventions tailored to specific contexts such as SMEs (Curtis Breslin et al., 2010; Zwetsloot et al., 2020). The categories of interventions are highly variegated, ranging from technology development to workers' well-being.

The development of each intervention comprised three equally important stages: **design**, **implementation**, and **evaluation** (Micheli et al., 2018; Olsen et al., 2012; von Thiele Schwarz et al., 2021). However, among these stages, the implementation process, which typically brings short-term benefits due to a temporary peak in resource availability, has received more attention. Consequently, OSH interventions implemented in the past tended to neglect both the detailed design and rigorous evaluation of the outcomes achieved (Micheli et al., 2018). Fortunately, the intervention design and evaluation phases have been gradually reconsidered in recent years, leading to measures that are more impactful in the field (von Thiele Schwarz et al., 2021). A significant portion of the literature focuses on evaluating interventions, which is a crucial phase because besides monitoring the success of a specific intervention, has the potential to generate knowledge that can be used for future interventions, thus improving their design and implementation (Biron and Karanika-Murray, 2014; Olsen et al., 2012). Randomized controlled trials (RCT) widely used for evaluation only measure intended consequences (Bamberger et al., 2016) and ignore the real causes of an intervention's success or failure that may be due to many factors and unintended consequences (Nielsen and Miraglia, 2017). Therefore, interventions should be active and responsive to contextual factors and emerging processes rather than passive programs where context is a confounding variable and participants are simply passive recipients (Blamey and Mackenzie, 2007; Nielsen and Miraglia, 2017). Contextual factors are an active component of an intervention's development and need to be controlled to effectively deliver an intervention (Chambers et al., 2013; Glasgow and Chambers, 2012). The intervention cannot be optimized before implementation, and practitioners should realize it through an iterative process of development, evaluation, and refinement in diverse contexts (Chambers et al., 2013; Cohen et al., 2008).

Some authors (Aarons et al., 2011; Biron and Karanika-Murray, 2014; Chambers et al., 2013; von Thiele Schwarz et al., 2016) extend beyond the three traditional stages of intervention development (i.e., design, implementation, and evaluation) by proposing a fourth element, **sustainment**. This element encompasses the long-term sustainability of an intervention, including its outcomes and retention (Aarons et al., 2011). For example, Chambers et al. (2013) distinguished between the initial implementation effort which relates "to the initial process of embedding interventions within settings" and the long-term sustainability phase which relates "to the extent to which these interventions can continue to be delivered, while institutionalized within settings, and having the necessary capacity built to support their delivery." Moreover, Chambers et al. (2013) stated that "sustained practice change and broader scale-up of interventions are rarely investigated, often due to the constrained timeframes for research set by grant mechanisms and the budgetary and political necessity of many decision-makers to take on a short-term lens." They differentiated between **sustainability** and **sustainment**, defining sustainability as the extent to which "an evidence-based intervention can deliver its intended benefits over an extended period of time after external support […] is terminated," and sustainment as "the continued use of intervention within practice".

However, scientific attention in understanding and improving the sustainability of health interventions is limited (Chambers et al., 2013; Ipsen et al., 2020), and only a few conceptual sustainability models have

been proposed (Aarons et al., 2011). Two cases were reported by Aarons et al. (2011) and Chambers et al. (2013). Aarons et al. (2011) proposed a multi-level, four-phase model that explicitly recognizes the crucial role of variables at different stages of intervention development. The last phase, "sustainment," determines future implementation efforts and is influenced by previous experiences and lessons learned. This phase is also known as **the 'maintenance' of the model** as it supports the effective maintenance or sustenance of health interventions in the long term (Aarons et al., 2011). Chambers et al. (2013) built a Dynamic Sustainability Framework (DSF) that adopts a continued-learning and problem-solving approach for the ongoing adaptation and improvement of interventions, in contrast to the traditional static approach with a defined beginning and end and outcomes that typically decline over time. The DSF relies on an innovative paradigm, which considers the long-term use and ongoing improvement of interventions, sustaining the continuous exposure of the intervention to new populations, contexts, and innovations. The DSF focuses on three primary components: the intervention itself, context surrounding the intervention, and broader **'ecological system'** within which the practice settings operate (e.g., legislative and regulatory environments and local, regional, state, and national market characteristics). Furthermore, DSF emphasizes that intervention settings (i.e., context and ecological system) change over time, necessitating the periodic evaluation of these elements. The main novelty is the ecological system seen as a driving force for the sustainability of interventions.

A shared opinion among researchers (Abildgaard et al., 2020b, 2020a; Nielsen, 2013) identifies participation as a great value addition. **Participatory Organizational Interventions** (POIs) would ensure higher results in improved employee well-being and overall intervention effectiveness. POIs are tailored to specific contexts, address issues at the source rather than after the implementation when it is overdue, and consider the interdependence of organizational levels, potentially identifying areas of intended change at multiple levels (LaMontagne et al., 2007; Nielsen, 2013). This fosters a co-creation process in which participants create value early, rather than merely receiving it (Payne et al., 2008).

1.2. Research gap and aim

Improving workers' well-being is the most important impact in the workplace. Many authors have stated the **lack of evidence of interventions' effectiveness** as various factors such as the type of intervention, workplace characteristics, and external environment influence success making it challenging to determine actual effectiveness in the workplace (Fridrich et al., 2015; Robson et al., 2007; von Thiele Schwarz et al., 2021). Therefore, understanding the mechanisms and context that determine outcomes is crucial in ensuring the success of interventions. Unfortunately, the culture and prior experience of OSH practitioners may compromise their understanding of these factors and bias their decision making (Baril-Gingras et al., 2006; Teufer et al., 2019; Verbeek, 2018). Companies may introduce new procedures or software tools regardless of the context in which they will be implemented, often based solely on prior success in similar environments. How a solution is applied, that is, how well it is designed and managed, can greatly affect its impact, either by enhancing or hindering its actual efficiency. Consequently, by ensuring effectiveness (i.e., how the intervention is developed), the efficacy (i.e., outcomes) of implementation is controlled.

As a result, focusing on the initial stages of the intervention development, this study offers *a way of establishing sustainable, effective, and efficient interventions by defining the processes and activities that should be implemented by actively involving responsible actors.*

A national OSH intervention for introducing a near-miss management system was used as a reference. It provides a practical tool for the daily detection and management of near misses for companies, including SMEs and large companies. The real value of this intervention, funded by the Italian National Institute for Insurance against Accidents at Work (INAIL), does not only lie in the near-miss management tool itself but rather in how it has been developed for effective implementation. This is not trivial if the common outcomes of ordinary interventions are considered. The intervention, 'I SHARE' (CONDIVIDO in Italian), reflects its aim of developing an intelligent tool through virtuous ecosystems for knowledge sharing and management of near misses in industrial sectors. As proof of the relevance of this intervention, a new one in line with CONDIVIDO, still funded by INAIL, is already ongoing, namely, "PMP 5.0 (Prevention Plans)—development of technical and organizational tools to support prevention interventions for the development of resilient network ecosystems." Therefore, this study focuses on the design of the intervention rather than the practical development of the near-miss management tool itself. Although the intervention has a specific scope, how it has been developed and the findings demonstrating the built near-miss management system provide evidence on how to enable the sustainability of other OSH interventions (also initiatives) developed in different contexts.

2. Methods

This section describes the process of sustainably establishing the Italian national OSH intervention for near-miss management in the environment, thus fostering its success in the long run.

A multistep design process was developed by assigning a specific goal to each phase, with the intention of identifying a productive environment (system), **ensuring sustainability of the intervention effects**. Therefore, different design steps in analyzing the context in which the intervention will be physically implemented have led to the definition of possible configurations for its deployment in Italy.

The process aims to determine *how* the intervention is built to survive in a stable equilibrium and continuously adapt to a changing environment, comprising identifying the processes supporting the launch, operational management, evaluation, ordinary maintenance, and improvement of the intervention. It also involves investigating *who* should be responsible for and actively participate in previously identified processes and *when* they should be involved. Moreover, it is essential to involve a wide range of stakeholders, from public institutions to private organizations. Adopting a participatory research approach (Cornwall and Jewkes, 1995) involving several stakeholders during the design process ensures a more comprehensive understanding of contextual factors that may affect intervention development. This enables gathering timely feedback from participants, which will often provide suggestions on achieving higher effectiveness in the processes and higher efficacy in the results.

In line with the aim of this study, a multimethod qualitative research was adopted (Creswell, 2015), which combines methods within qualitative-based studies to emphasize the value of different approaches (Silverman, 2020). This approach enables the use of ad hoc methods at each step of the analysis (Mik-Meyer, 2020), rather than following a single-method research design (McDonnell et al., 2017), and contributes to a deeper understanding, stronger trustworthiness, and better unbiased analyses (Mik-Meyer, 2020). Silverman (2017) pointed out that there are no right or wrong methods; the suitability of a method depends on the research topic and model being used. Based on this view, this study defines the design process for a near-miss management system by identifying the key parameters and then selecting appropriate methods to build a multi-step design strategy. Based on this logic, three key parameters were identified.

- Processes are actions required for the correct detection, analysis, and knowledge sharing of near misses from companies to the entire network.
- Scenarios determine the possibility of running a near-miss management system in different ways to meet the specificities of the context.

Table 1
Methods involved in the initial stages of the near-miss management national intervention.

	STEP 1	STEP 2	STEP 3
Methods			
	Focus Group	Workshop Series	Formative and refining events
Design			
Activities	Definition of the processes, scenarios, and main activities for near-miss management at the national level	Identification of main actors involved in the processes	Refining previous findings
Main applied tools	Microsoft Teams, Miro virtual space	Microsoft Forms	Poll Everywhere
Where	Online	Premises of two of the three ASL partners (located in Taranto and Saronno)	Online, then premises of the third ASL partner (located in Thiene)
When	January–February 2022	June 2022	July 2022 + December 2022
Who	CONDIVIDO partners	CONDIVIDO partners + selected external stakeholders	CONDIVIDO partners + selected external stakeholders

- OSH actors are key players that play a prominent role in near-miss management at different levels of the Italian national OSH system: national, territorial, and company.

Consequently, the design process consists of three major steps (Table 1):

1. definition of processes, scenarios, and leading activities for the correct operation of the system
2. identification of the main actors involved; and
3. the final design refinement.

All Italian official partners involved in the intervention participated in each of the three steps: three INAIL specialists, five scholars from two Italian universities, and two to five representatives of three local health units (ASLs).

Different methodologies agreed upon by all the partners were applied according to the objectives, surrounding environment, and available resources at each step (Table 1). The processes and scenarios were discussed through a focus group among the partners of the CONDIVIDO intervention (Step 1), while the definition of the main actors was discussed with several people actively involved in the territory through the development of workshops in different parts of Italy (Step 2). The fine-tuning of the findings consisted of two phases: an internal discussion among the official CONDIVIDO partners and an external discussion with the actors involved once the intervention started (step 3). The methodological choices are discussed below.

2.1. Step 1: The focus group for processes and scenarios' selection

A focus group is a research technique involving a group of experts engaged in a structured discussion on a topic specified by the promoters of a research activity (Cagno et al., 2014; Tong et al., 2007). The decision to use a focus group was based on several factors. In exploratory studies such as this one, it is essential to draw on the knowledge of experts to deepen topics that are not fully explained. Focus groups provide an opportunity to explore findings in the literature and generate finer perspectives through the exchange of ideas (Tong et al., 2007). Participants benefit from group interaction, as it helps them compare and contrast their viewpoints (Morgan, 1997) and clarify their own perspectives (Tong et al., 2007). In this regard, a focus group was chosen for this step of the design process because it is considered suitable for the scope, in which the processes and scenarios for near-miss management systems were first hypothesized and then agreed upon.

The organization of an effective focus group includes inviting a small group of carefully selected individuals, defining a clear agenda, appointing at least one meeting moderator, using data collection tools, and analyzing the collected data at the end of the discussion. The focus group should last approximately 1–2 h, which is sufficient time for a detailed discussion without participants losing interest. The number of participants should be between 4 and 12, an ideal number for maintaining a lively discussion (Tong et al., 2007).

2.1.1. Focus group design

The focus group involved eight people, all of whom were partners in the CONDIVIDO intervention. The group consisted of two senior researchers, one junior researcher from Politecnico di Milano, two senior researchers from Università del Salento, and three senior specialists from INAIL. The Miro platform, an online collaborative whiteboard, was used during the focus group to encourage the exchange of ideas and to enable participants to work on a shared worksheet. The focus group was semi-structured, and preliminary hypotheses of the processes and scenarios were proposed to the participants to make the first meeting more effective. The initial framework is presented in Appendix A. Starting from scratch without any hypotheses would have required much more time and increased the probability of losing participants in the debate, ultimately not reaching a shared point of view. There was a non-fixed moderator, and participants took turns playing the moderator role allowing all participants to contribute. The focus group consisted of two two-hour sessions both conducted through Microsoft Teams. Both sections were recorded and transcribed, and the tenured moderator took written notes to guide the participants during the discussion. The first session resulted in preliminary results. Separate in-time sessions were incorporated to allow all participants, at the end of the first session, to think about preliminary findings and propose new questions and solutions for the second (last) session.

2.2. Step 2: Two workshops for scenarios' definition and actors' identification

Participatory research emphasizes the direct engagement of local priorities and perspectives (Cornwall and Jewkes, 1995) by collaborating with people affected by the concerned issue (Cargo and Mercer, 2008). It also generates temporary partnerships between people actively involved in the research process and other stakeholders with insider knowledge and lived expertise and represents the interests of all stakeholders (Jagosh et al., 2012). The key strength of this study is its exploration of local knowledge and perceptions. Researchers have recognized the added value of integrating local knowledge and experience in research planning (Cornwall and Jewkes, 1995).

Therefore, to determine the actors involved in the intervention, the CONDIVIDO partners engaged people who would be directly affected by the near-miss management intervention. The decision to design workshops enabled the collection of opinions and feedback from a wide range

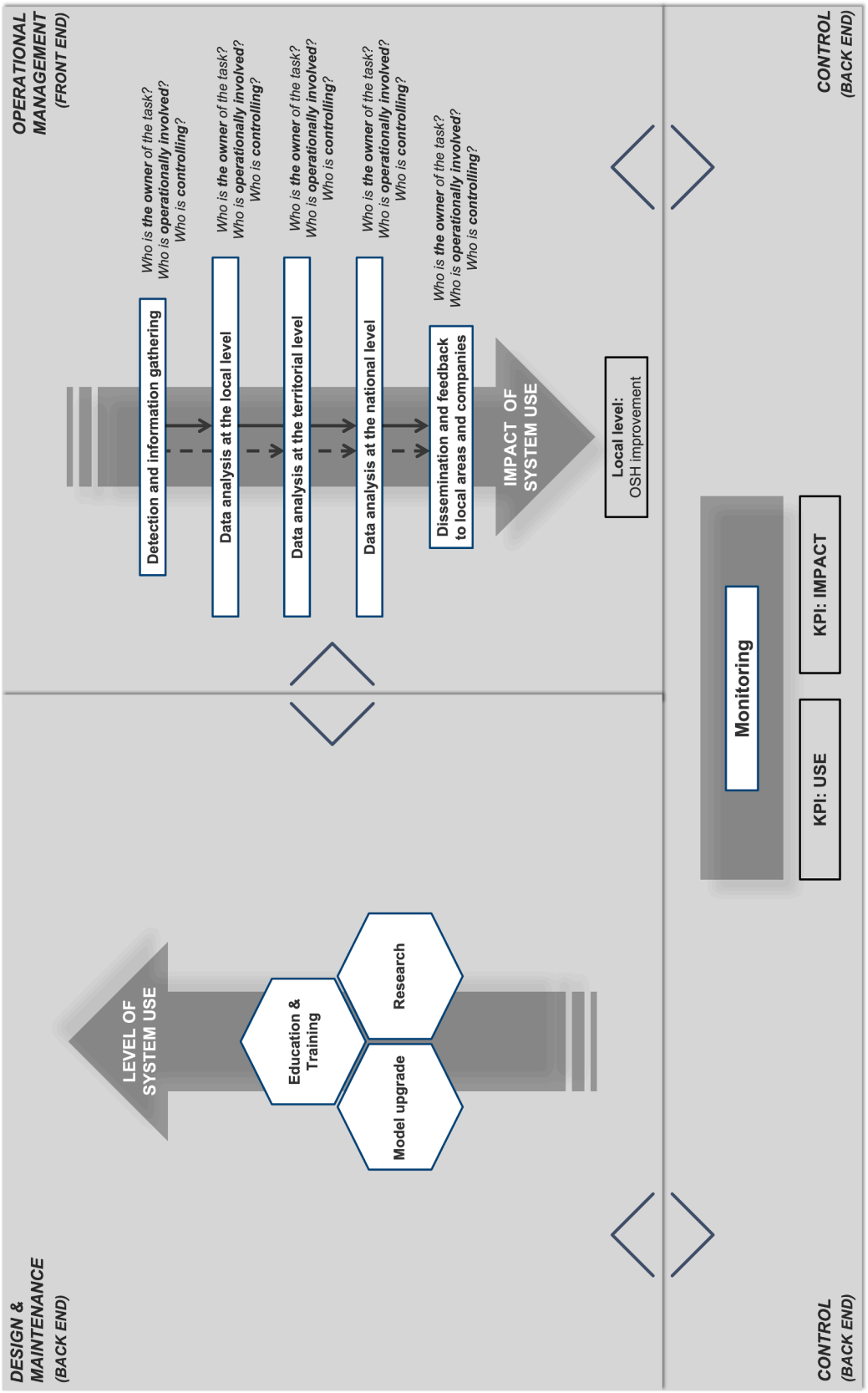

Fig. 1. The near-miss management system: processes and scenarios.

of stakeholders representing different realities, which increased the awareness of the needs of various interest groups. This makes the intervention more aligned with stakeholders' needs and expectations, and its implementation in the field might be easier.

To organize effective workshops, it is important to select the right participants, define a detailed agenda, appoint a workshop facilitator, use the necessary (technological) tools to carry out the planned activities, and collect feedback from the participants at the end of the workshop (Slocum-Bradley, 2003). The length of the workshops should be between two and eight hours, sufficient to cover the content and planned activities and maintain a high level of attention and participation of the people involved (Lauttamäki, 2014). The number of participants in the workshops should be maintained between 10 and 30 to ensure efficient discussions and avoiding chaos (Lauttamäki, 2014).

2.2.1. Workshop design

Two workshops were held in June 2022 within the premises of two of the three ASL partners (located in Taranto, then in Saronno) to define the actors responsible for the daily management of near misses. Following the first focus group (Step 1), the processes and possible scenarios for near-miss management were not questioned again, whereas the network of actors and their specific roles in the processes were discussed among selected participants following a preset structure agreed upon by the CONDIVIDO partners. The second workshop determined a satisfactory picture of key actors who would run the intervention daily at different (from local to national) levels. The invited participants included employers, employer and trade union association representatives, independent OSH consultants, internal representatives responsible for the OSH service (SPP), ASL representatives, INAIL specialists, and CONDIVIDO partners. The first workshop in Taranto saw a prevalence of people coming from the construction sector, whereas the second workshop in Saronno involved more people from the manufacturing sector. In both cases, an introductory event was held before each workshop in preparation for the workshop, which included an overall presentation of the intervention's scope.

To identify suitable actors, an online questionnaire was distributed to the participants of each workshop via Microsoft Forms. The questionnaire asked participants to select only one actor for each process and scenario for the daily near-miss management. Appendix B presents the questionnaire protocols for the two workshops. After all participants completed the questionnaire, the aggregate results of the questionnaire were discussed. Questions with low convergence rates were prioritized in the discussion to debate different opinions and look for possible convergence on a single actor. As discussed in the next section, convergence was not always achieved, and in some cases, more than one option was maintained according to contextual differences in Italy.

2.3. Step 3: Final design refinement

The last phase adopted a participatory approach by involving official partners and people who were operatively involved and interested in the near-miss management intervention. Similar to previous approaches, this step was selected for the same reasons. This step is built on previous steps to evaluate what has been obtained in terms of processes and actors, and further discusses open issues to be addressed in preparation for the implementation phase.

2.3.1. Event design

The final step comprised two working sessions. After the end of the two workshops, an internal meeting was held in July 2022 among the partners of the CONDIVIDO intervention (i.e., participants from the initial focus group). In December 2022, a formative external event was held within the premises of a third ASL partner (located in Thiene), organized in collaboration with one of the ASLs in the intervention. Approximately 30 participants were selected, as in the previous workshops.

The difference between the internal and external sessions was the participants' level of involvement. The discussion among the internal intervention partners had the decision-making power to confirm or slightly modify the results of the previous steps, while the second event involved gathering suggestions and potential criticalities from participants who, however, did not have any decision-making power. The first internal session ended with a list of major open issues for further discussion with an external audience during the second external event. In the latter, three open questions were asked to participants through an online platform called Poll Everywhere, a real-time audience response system in which participants can view all responses and agree or disagree with them. It is a great tool for creating interactions and fostering debates among people. All questions referred to a particular scenario, where data analysis at the local company level was managed by external entities because previous workshops and subsequent internal meetings raised some criticalities. Hence, the following questions were asked.

- How can assistance associations support companies in gathering information and analyzing data on near-miss events?
- What are the main advantages of companies sharing their data on near-miss events with third parties (e.g., employer associations)?
- What are the minimum requirements for companies to share their data on near misses?

Through this design process, it was possible to manage the complexity of the problem and ensure that the solution would work properly in the existing environment, even after the end of the intervention, and would suit the specificities of various geographic areas.

3. The near-miss management system: CONDIVIDO intervention

The near-miss management system is detailed below, based on the main characteristics investigated through the design process: definition of the processes and scenarios (Section 3.1 and Fig. 1) and the identification of suitable actors and their related dynamics (Section 3.2 and Table 2). The processes and actors might be both intervention- and context-specific because they were built to manage near misses through the Italian national health and safety legislative framework. Nonetheless, the structure and processes of near-miss management may be replicated in other contexts beyond Italy.

3.1. Processes and scenarios

A near-miss management system identifies different processes and relationships as shown in Fig. 1. The design of the system was based on the first design step, with a focus group developed among the intervention partners. To be sustainable in the long term, the system should comprise three strategic areas, *Design & Maintenance* (back-end), *Operational Management* (front-end), and *Control* (back-end) that coexist and effectively interact with each other.

Front-end and back-end terms, which are typically used in the context of software development, have been applied to differentiate the strategic areas. Front-end areas identify activities and processes that end users directly see, whereas back-end areas are the infrastructure behind the scenes that make the front-end areas work. Both areas are necessary and their close interaction allows the entire system to operate effectively. The end users of the near-miss management system are the actors involved in the daily management in terms of detecting, reporting, analyzing, and taking action. Based on this classification, the three strategic areas are detailed as follows.

The *Design & Maintenance* area enables the initial creation of a near-miss management system (design) and its subsequent implementation among companies (maintenance). Within this area, *research*, *model upgrade*, and *education & training* are the three main processes that maintain the intervention and detection of near misses in companies. During

Table 2
Actors involved in the near-miss management system: two scenarios *[Acronyms: the OSH service (SPP); the national institute for insurance against accidents at work (INAIL); **in bold**, new figures emerged after the workshops and the final design refinement phase]*.

Operational Management processes	ACTORS: Scenario 1 Internal near-miss detection	ACTORS: Scenario 2 External near-miss detection
Phase 1. Detection and information gathering		
Who is the owner of the task?	Internal and external SPP, delegate *(complementary to the supervisor)*	external assistance figure, assistance association's responsible
Who is operationally involved?	Internal and external employee, worker in charge	external assistance figure, assistance association's technician
Who is controlling?	Internal and external SPP, delegate *(complementary to the responsible)*	external assistance figure, assistance association's technician
Phase 2. Data analysis at the local level		
Who is the owner of the task?	Employer, internal and external SPP, delegate *(choice dependent on companies and contextual factors; complementary to the supervisor)*	external assistance figure, assistance association's responsible
Who is operationally involved?	Internal and external SPP	external assistance figure, assistance association's technician
Who is controlling?	Employer, internal and external SPP, delegate *(choice dependent on companies and contextual factors; complementary to the responsible)*	external assistance figure, assistance association's technician
Phase 3. Data analysis at the territorial level		
Who is the owner of the task?	assistance association's responsible	
Who is operationally involved?	assistance association's technician	
Who is controlling?	assistance association, surveillance body, regional coordination committee *(choice dependent on the territorial areas, each has its specificities)*	
Phase 4. Data analysis at the national level		
Who is the owner of the task?	INAIL research	
Who is operationally involved?	INAIL research	
Who is controlling?	INAIL research, **regional coordination committee**	
Phase 5. Dissemination and feedback to local areas and companies		
Who is the owner of the task?	assistance association, regional committee, **INAIL research** *(choice dependent on the territorial areas, each has its specificities)*	
Who is operationally involved?	assistance association, **INAIL research**	
Who is controlling?	INAIL research	

the design and initial adoption phases of the near-miss management system, *research* and *model upgrade* processes play a major role, whereas *education & training* of new and existing users is an ongoing process that enhances the level of use of the near-miss management system.

The *Operational Management* area comprises all front-end processes necessary for the daily management of near-miss detection, analysis, and dissemination. Five sequential processes identify the operations for the daily management of near misses and are executed at different local, territorial (regional and sectoral), and national levels. *Local-level* processes occur at the company level, where near-misses are detected and improvement actions are pursued, whereas *territorial-level* processes are activities performed at the geographical or sectoral levels by gathering data from several companies. *National-level* processes aggregate the data of all the participating companies in the country and disseminate knowledge and good practices at the local level. Collecting data at the national level enables monitoring of national trends in near-miss events and making appropriate policy choices across industries in Italy.

3.1.1. Processes

The focus group defined five sequential processes and two scenarios for the front-end area of *Operational Management* (Fig. 1). Processes start with near-miss detection and end with the return of knowledge at the local level after data analysis. The *Operational Management* area comprises five sequential phases/processes.

1. The first phase involves reporting detected near misses and gathering relevant information about the event. The person involved in the near-miss event or an eyewitness of the event reports how and under what conditions it occurred.
2. The second phase involves data analysis at the local company level. Hereafter, information becomes data as it is classified and analyzed at different levels of aggregation.
3. During the third phase, local data, after being locally analyzed and the first improvement actions implemented, are aggregated and analyzed at the territorial level by associations and committees that collect data from various sources.
4. In the fourth phase, data reach the national level, where near-miss events are collected and more powerful, statistically valid analyses are possible.
5. The last phase refers to the return of knowledge to local areas and companies after aggregated data analysis. Informative returns would increase the local impact of using such a system for near-miss management by generating cascading improvement actions at the local level. This might be considered a crucial process for the survival of the entire near-miss management system because it proves its value to end-users. Common activities might include the sharing of sectoral statistical data, evidence-based good practices for specific sectors, proposals for corrective actions, and financial incentives.

3.1.2. Scenarios

The discussion among the focus group participants led to the identification of two operative scenarios for the processes of the *Operational Management* area, which were deemed valuable alternatives for encouraging more companies, particularly SMEs, to adopt this near-miss management system. The scenarios differ in the first two processes, namely *detection and information gathering* (Phase 1) and *data analysis at the local level* (Phase 2). The *first scenario* involved a company's in-house near-miss detection, data gathering, and analysis processes. Data

collection within the company can be either *direct*, performed by the protagonist or eyewitness of the event, or *indirect*, performed by the other workers in charge. It is worth noting that the detection of an event is always direct because it is done by witnesses, while information gathering can be both direct and indirect. In the *second scenario*, companies can outsource Phases 1 and 2 to external entities such as external assistance figures. This guarantees that companies report and share near-miss events without the burden of tracking and analyzing them. The choice of a scenario depends on the company and may depend on several factors, such as company size, sector, and OSH awareness.

In sum, Phases 1 and 2 occur at the local level, within or outside the company, while Phases 3, 4, and 5 develop externally at the territorial and national levels. This implies that in Section 3.2, when the actors involved in each process are discussed, they will vary according to the selected scenario, just in Phases 1 and 2.

Finally, the *Control* area acts as a detached supervisory division that monitors the correct development of the other two areas—*Design & Maintenance* and *Operational Management*—by ensuring the correct operation of the entire near-miss management system. This area monitors two main parameters:

- the level of use of the system, that is, the number of users, sectors, and geographical areas in which the system is used to possibly increase the audience of potential users;
- the impact of its continuous use in companies (end users) can be evaluated through Key Performance Indicators (KPIs), such as the number of near-miss events, preventive and corrective actions, training programs, and awareness campaigns.

Evidently from the previous discussion, the use of the arrows between the strategic areas in Fig. 1 has been clarified. Continuously monitoring the front-end and back-end processes enables the assessment of their work to achieve their objectives. The *Design & Maintenance* and *Operational Management* areas are interrelated because back-end processes support front-end processes and vice versa; daily operational processes feed the system with new data by fostering continuous improvement through back-end processes. Therefore, the backflow of information from the front-to-back-end processes is essential. Indeed, providing evidence of the positive impact of the system to end users will induce more users to participate, hence increasing the number of users over time, that is, the level of system use.

3.2. Network of actors

The last session of the focus group laid the foundation for the development of the workshop series by identifying potential actors involved in the processes of the three strategic areas.

The actors involved in the back-end processes would be primarily, at least initially, the promoter, INAIL, who is the funding institution for the intervention. Later, it may be considered an option to collaborate with other entities, such as *education & training* processes, and even completely outsource others, such as software tool management (*model upgrade*).

The discussion of the steps following the focus group (i.e., the workshop series and refinement events) focused on the *Operational Management* area because of its high complexity in terms of the number of processes and people involved at different levels. Table 2 presents the results at the end of the three design steps, with the key players selected for the internal and external scenarios of the *Operational Management* (front-end) area. During the focus groups, the participants discussed the necessary roles for each process, ultimately identifying three types of actors:

- the process owner, who acts as the point of contact and decision-maker;
- the person responsible for operatively developing the process;
- the person responsible for monitoring the process's correct execution.

For each process in the *Operational Management* area, the distinction of figures—*the owner*, *operational referent*, and *supervisor*—ensures that the planned activities are correctly executed and maintained over time. For any given process, it is essential to have someone who can actively execute and monitor its progress. The owner can delegate these activities; hence, depending on the context and process in question, these three roles can overlap in a single person.

The final list of actors for the five front-end processes is presented in Table 2. Discussions on the actors in Phases 1 and 2 differed according to the scenario considered. One or two actors were selected in almost all cases, except for a few roles in which more options were retained to account for context specificities. Appendix C provides a detailed description of the actors selected for each phase of the Italian near-miss management system.

The next section discusses how these findings can be generalized to other OSH interventions by identifying the distinguishing factors that would be effective and safeguard their sustainability.

4. Discussion

Companies and public institutions are increasingly interested in OSH management performance; particularly, public institutions are investing significant funds in interventions to enhance OSH conditions in the workplace, which require their actual effectiveness (i.e., how the intervention is developed) and efficacy (i.e., outcomes) to be verified. The success of every OSH intervention begins with a controlled design that lays a solid foundation for its sustainability and long-term effectiveness. Through the definition of the methodological steps and the subsequent application of the Italian national intervention for near-miss management, it was possible to derive suggestions for establishing successful OSH interventions in a variety of sectoral areas and contexts. The theoretical and practical implications are discussed in Sections 4.1 and 4.2, respectively.

4.1. Theoretical implications: Methods generalizability

Hence, the design process for the CONDIVIDO intervention is critically examined by distinguishing the discriminant factors that would ensure its effectiveness.

4.1.1. Deepening on who, how, and when for sustainability of the intervention

A multistep design process was built to identify a productive environment (system) that ensures durability and sustainability of the intervention by defining the processes that need to be implemented and actively involving responsible actors. An **accurate design** is the first step in enhancing the effectiveness of an intervention. Although dependent on the Italian national intervention context, the methodological steps presented by this work show compelling logic that might be generalizable to OSH interventions developed in other contexts.

4.1.2. Collaboration should be a 'must'

The CONDIVIDO intervention, in line with the PMP 5.0 intervention (both in research projects funded by INAIL), followed an **iterative process** of designing the near-miss management system by collaborating with several experts and integrating different points of view.

Similar to Chambers et al. (2013), the optimization of any phase of the intervention should be tested in real settings following an iterative process of development, evaluation, and refinement in diverse contexts. The definition of scenarios and actors for the near-miss management system followed this logic precisely, which was first defined in the initial focus group among the CONDIVIDO partners, but was then questioned during the two following steps of workshops and events by several interested people who were later involved in the actual implementation of the intervention.

4.1.3. Participatory approach: Open or closed interaction

The iterative design approach is consistent with **participatory research logic** (Nielsen, 2013). The design of the near-miss management system included the opinions of a wide range of stakeholders, ensuring that the intervention was properly implemented in the environment. However, engaging several actors in the design process might **generate complexity** with the risk of being grounded.

Convergence is often considered a primary goal during the design phase; however, by increasing the number of people involved, **the convergence rate diminishes**. Project leaders often experience a predicament and seek convergence that does not exist. At this point, people's ability to make decisions can make a difference. Not all choices have a single direction, and the people involved in the decision-making process should be able to discern when an issue cannot be fixed a priori. During the two workshops, it was highlighted that the participants did not share common views of certain roles, as differences in territorial areas affected their perspectives. In Phase 3 'data analysis at the territorial level', three different actors were retained as potential options, particularly regional coordination committees, who were overlooked in the first workshop, instead gained a large consensus in the second workshop where other actors who were deemed valuable previously were disregarded. Hence, more possibilities for that role were retained, thus renouncing full convergence. Another option to reduce the chaos that a participatory approach may generate is to **limit the 'participation' and the decisional power of participants**. Although this may seem counterintuitive, not all choices should be provided through a fully participatory approach and some should be made in small groups with less heterogeneity between participants. The final event organized at Thiene for the refinement of the built near-miss management system followed this logic, in which processes and actors were not questioned again and participants provided suggestions on how the second scenario could have been valorized. Consequently, knowing *who* the participants are is not sufficient; distinguishing *how* and *when* to involve them is essential for a proper design.

4.2. Practical implications: Results generalizability

The entire design process led to the definition of the near-miss management system, and provides some generalizable insights applicable to other OSH intervention contexts, although it is context-specific in its outcomes.

Given that reporting and monitoring near misses within companies is an activity that is typically less structured and regulated than other processes involving worker injuries, developing a system to identify the relevant processes and actors involved is crucial for the sustainability of the intervention. However, in contexts where regulations are less prescriptive, the process affords greater flexibility, generating both opportunities for improvement and the potential for regression. Therefore, a meticulous design is essential in avoiding negative implications. The initial review of the literature served as support for the design process and established a baseline for comparison of the developed system with existing models.

4.2.1. The Control strategic area for efficacy and effectiveness

From literature, a continuous **evaluation of the process** in the built system offers ways of evaluating pre- and post-intervention implementation (Biron and Karanika-Murray, 2014; Olsen et al., 2012). A proper evaluation, which is not a simple assessment of the execution of planned activities, requires a deep understanding of the intervention and its effects with the aim of monitoring its evolution and potentially improving it (Olsen et al., 2012). Moreover, during the focus group in the first design stage, the control and evaluation of the processes were extensively discussed. The participants considered them critical for the long-term success of the CONDIVIDO intervention and the sustainability of the near-miss system. Therefore, a *Control* strategic area was proposed for the near-miss management system. Monitoring takes place in both *Design & Maintenance* and *Operational Management* areas by assessing the effectiveness and efficacy of the system.

In addition, a detached *Control* area monitoring *Design & Maintenance* and *Operational Management* provides **stability to the entire system** and shows how to adapt and improve the system by enhancing both strategic areas and leveraging potential synergies between the two. By improving both the level of use (i.e., the overall number of users) and local impact (i.e., higher safety levels for adopters), the system, striving for a stable equilibrium, would become increasingly efficient and **sustainable over time**.

4.2.2. The two-way flow between front-end and back-end

The **double information flow** between the *Design & Maintenance* and *Operational Management* areas, as defined after a critical debate among the participants during the focus group (Step 1), provides sustainability to the entire system by **enhancing its robustness and enabling continuous improvement**. Back-end processes (*Design & Maintenance* areas) support front-end (user) processes, and vice versa. Daily operational processes in the *Operational Management* area provide the system with new data, which foster continuous improvement through back-end processes. Indeed, the goal of the front-end area is to provide evidence of the positive impact of the system on end users, simultaneously encouraging more users to join and increasing the level of system use, the goal of the back-end area. From this perspective, the last phase, 'dissemination and feedback to local areas and companies' in the *Operational Management* area is crucial for the survival of the entire near-miss management system. Through this phase, companies can perceive the value of documenting near misses and benefit from the knowledge acquired from all participating companies, leading to cascading improvement actions at the local level. Even companies that do not report near misses in the system will have access to the aggregate data. Therefore, new companies may decide to become involved, thereby expanding the audience of users who feed data into the system and creating a virtuous cycle.

4.2.3. Scenarios for flexibility

Finally, the system was conceived to **adapt to situations** by creating various scenarios for the daily management of near misses within companies. Selecting the scenarios was not an easy task, and their definition required extensive discussion with practitioners in the field, which is evidence of the crucial role that scenarios play in ensuring the proper functioning and **high flexibility of the entire system**.

Specifically, **two scenarios** for internal and external near-miss reporting were identified to extensively include companies' specificities. Given their intrinsic characteristics, such as size and sector and considering the surrounding environment, companies can freely choose between internal and external scenarios. Hence, they have flexibility to select the best options. Companies that do not want to collect and analyze near misses internally for a variety of reasons can outsource these activities to external entities, such as external assistance figures.

Moreover, the first phase, 'detection and information gathering,' of the internal scenario offers flexibility as companies can choose between **direct or indirect data collection**. This allows companies to enable or disable a general worker from reporting a near-miss event using a tool provided by the company. Training workers in near-miss reporting may be challenging for certain companies. Furthermore, with **indirect reporting**, the number of recorded events may decrease, but **the process would be much more in control** than with direct reporting because a **trained responsible worker** will perform this task. As companies may start reporting any type of event as a near miss, which corrupts the system with false near misses, properly training people in near-miss reporting is crucial, even more than in accident reporting.

In conclusion, this discussion provides an overview of the benefit of the proposed design process and the results achieved.

5. Conclusions

This study proposes a method of establishing sustainable, effective, and efficient interventions for near-miss management based on the knowledge gained from the CONDIVIDO intervention. It outlines how a near-miss management system should work and offers insights on how to encourage individuals to participate.

A participatory design approach prevented the intervention from failing early. While CONDIVIDO partners are responsible for introducing a national supportive near-miss management system, other practitioners have also been involved in the design process from the beginning. These practitioners contributed to the definition of processes, scenarios, and actors, thus reflecting the opinions of individuals who were actively involved in the daily management of such a system once implemented. The active participation of stakeholders in the introduction of the intervention limits the gap between the intended and actual outcomes (Micheli et al., 2018).

A robust system was built to make the CONDIVIDO intervention self-sustainable, even after its conclusion, by pursuing two primary goals. The first evaluates the impact of the system on companies that implement it, and the second focuses on the number of end users in the system with the intent to increase the potential user base.

The near-miss management system will be tested in different territorial contexts to determine whether it performs as expected. The flexibility of the system allows for the choice of various scenarios and responsible actors based on different processes. Diverse testing environments should be selected to identify potential issues with the system and enhance it iteratively.

Nevertheless, it must be acknowledged that the design approach used in this study had a few inherent biases. The system design considered only three local areas in Italy, which means that once implemented, it may perform better in some cases than in others. Additionally, the individuals who participated in the organized events were interested in the intervention and willing to manage near misses, which means that the feedback obtained may be biased because it comes from a small group of potential users while ignoring the opinions of others. Thus, it is crucial to test the system in a real-world environment and improve it iteratively. As mentioned before, the ongoing intervention PMP 5.0, funded by INAIL as an additional deployment of the ongoing intervention CONDIVIDO, is developing technical and organizational tools to support and monitor prevention interventions across the territory using a participatory approach that actively engages territorial joint bodies and intra-company actors.

Furthermore, this work offers two generalizable takeaways for future developments.

First, the methodological approach used to develop the initial stages of the intervention may be applicable to other cases. Although interventions are often viewed as unique and their findings are not transferable owing to their context-dependency, practitioners should not refrain from studying ways to improve them. Rather than treating the interventions as black boxes, it is worth considering the various factors that affect them (Micheli et al., 2018). The methodological participatory approach employed in this study follows the same logic: a realist perspective, meaning what works, in what circumstances, for whom, and how (Pawson, 2006), and which would be a good option for the initial developmental stages of interventions. Future work may propose implementation procedures according to this logic, suggesting ways of introducing interventions in specific environments.

The second takeaway from this study is that the near-miss management system, originally designed for near misses, has potential applicability in other contexts for different types of events, such as accidents. While certain underlying principles such as flexibility and robustness may remain consistent across systems, the specific processes and actors involved are likely to vary owing to contextual factors. Therefore, the system and all processes that adopt its definition could serve as a reference model for other countries willing to start similar interventions. Further applications of the system in different contexts could involve identifying stable and changing conditions, thereby generalizing and expanding its use.

In summary, this work provides great opportunities for future development, and authors hope that further research will pursue the proposed directions that, from different perspectives, will improve how interventions are developed (effectiveness) and their impact at the local level (efficacy), which are both particularly important in dynamic and unpredictable environments.

CRediT authorship contribution statement

Gaia Vitrano: Writing – original draft, Writing – review & editing, Visualization, Validation, Supervision, Methodology, Project administration, Investigation, Conceptualization. **Guido J.L. Micheli:** Validation, Project administration, Investigation, Conceptualization. **Armando Guglielmi:** Validation, Investigation. **Diego De Merich:** Validation, Investigation. **Mauro Pellicci:** Validation, Investigation. **Davide Urso:** Validation, Writing – original draft. **Christine Ipsen:** Validation, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. The initial framework for step 1: The focus group

Fig. A1

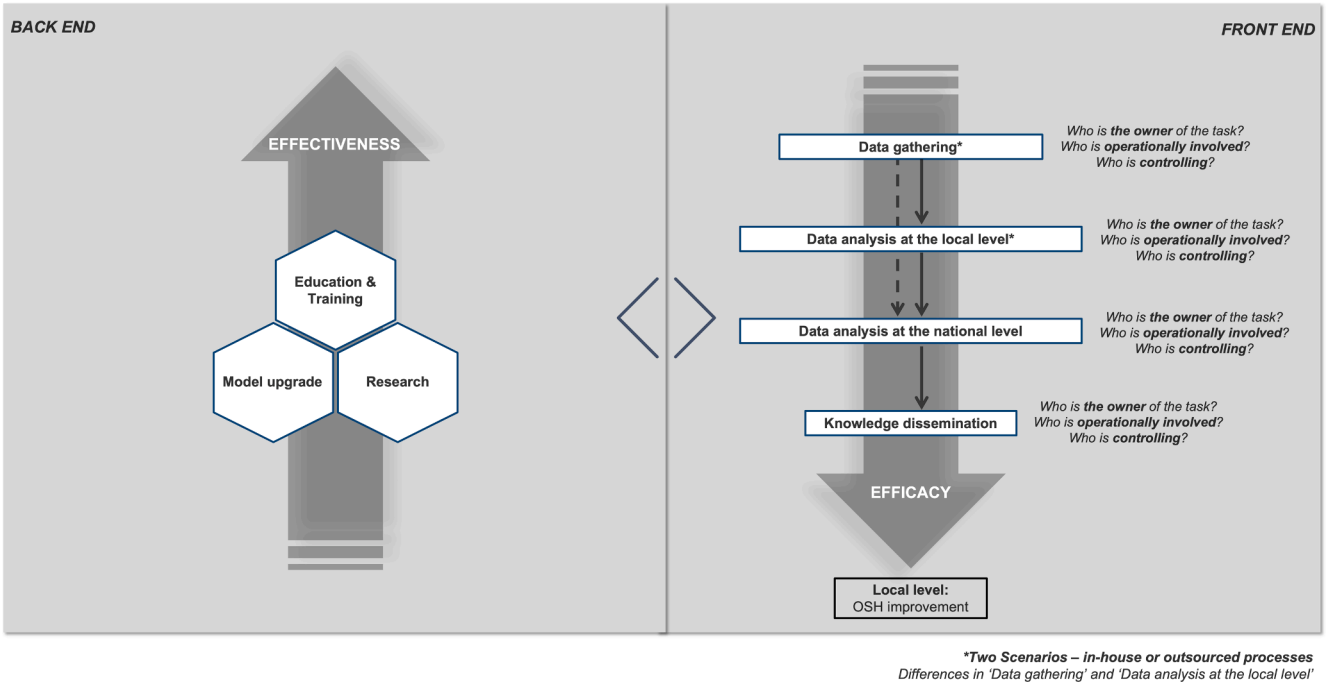

Fig. A1. Processes and scenarios initially proposed to the focus group participants (Step 1).

Appendix B. Questionnaire protocol

B.1. Scenario 1 Internal near-miss detection - Phase 1 Detection and information gathering

Who is the owner of the task? *[Please tick just one option]*.

- Employer
- Internal and external OSH service (SPP)
- Worker in charge
- Delegate
- *Other*, indicating another suggested figure

Who is operationally involved? *[Please tick just one option]*.

- Internal and external employees (direct reporting and data collection processes by a witness to the event)
- Workers' representative for OSH (RLS)
- worker in charge
- Internal and external OSH service (SPP)
- External assistance figure
- *Other*, indicating another suggested figure

Who is controlling? *[Please tick just one option]*.

- Internal and external OSH service (SPP)
- Delegate
- External assistance figure
- *Other*, indicating another suggested figure

B.2. Scenario 1 Internal near-miss detection - Phase 2 Data analysis at the local level

Who is the owner of the task? *[Please tick just one option]*.

- Employer
- Internal and external OSH service (SPP)
- Delegate
- Territorial workers' representative for OSH (RLST)
- *Other*, indicating another suggested figure

Who is operationally involved? *[Please tick just one option]*.

- Delegate
- Internal and external OSH service (SPP)
- Territorial workers' representative for OSH (RLST)
- External assistance figure
- *Other*, indicating another suggested figure

Who is controlling? *[Please tick just one option]*.

- Employer
- Internal and external OSH service (SPP)
- Delegate
- Territorial workers' representative for OSH (RLST)
- *Other*, indicating another suggested figure

B.3. Scenario 2 external near-miss detection - Phase 1 Detection and information gathering & Phase 2 Data analysis at the local level

7–8. Who is the owner of the task?

7. How do you rate (from 1 *poor* to 5 *very good*) external support figures (e.g., consultants and heads of trade associations) as being responsible for the collection of reports and analysis of near-miss data?

[8. If a score of 1 or 2 is given, please include in the next question *Other* suggestions on other potential figures].

9–10. Who is operationally involved?

9. How do you rate (from 1 *poor* to 5 *very good*) the external assistance figures (e.g., consultants and technicians of trade associations) to materially perform the collection of reports and analysis of near-miss data?

[10. If a score of 1 or 2 is given, please include in the next question *Other* suggestions on other potential figures].

11–12. Who is controlling?

11. How do you rate (from 1 *poor* to 5 *very good*) the external assistance figures (e.g., consultants and technicians of trade associations) to

monitor whether the activity of collecting reports and analyzing near-miss data is performed correctly and continuously?

[12. If a score of 1 or 2 is given, please include in the next question *Other* suggestions on other potential figures].

B.4. Scenario 1–2 Internal or External near-miss detection - Phase 3 Data analysis at the territorial level

13–14. Who is the owner of the task?

13. How do you rate (from 1 *poor* to 5 *very good*) the representatives of the associations (in joint, bilateral, or participative bodies) responsible for the territory-wide analysis of near-miss data?

[14. If a score of 1 or 2 is given, please include in the next question *Other* suggestions on other potential figures].

15–16. Who is operationally involved?

15. How do you rate (from 1 *poor* to 5 *very good*) the external assistance figures (e.g., consultants and technicians of professional associations) in materially performing the territory-wide analysis of near-miss data?

[16. If a score of 1 or 2 is given, please include in the next question *Other* suggestions on other potential figures].

Who is controlling? *[Please tick just one option]*.

- Assistance association
- Surveillance body (with assistance functions)
- Regional coordination committee
- *Other*, indicating another suggested figure

B.5. Scenario 1–2 Internal or External near-miss detection - Phase 4 Data analysis at the national level

Who is the owner of the task? *[Please tick just one option]*.

- Assistance association
- The national institute for insurance against accidents at work (INAIL) – INAIL Research
- *Other*, indicating another suggested figure

Who is operationally involved? *[Please tick just one option]*.

- Assistance association
- The national institute for insurance against accidents at work (INAIL) – INAIL Research
- *Other*, indicating another suggested figure

Who is controlling? *[Please tick just one option]*.

- Assistance association
- The national institute for insurance against accidents at work (INAIL) – INAIL Research
- *Other*, indicating another suggested figure

B.6. Scenario 1–2 Internal or External near-miss detection - Phase 5 Dissemination and feedback to local areas and companies

Who is the owner of the task? *[Please tick just one option]*.

- Assistance association
- Regional coordination committee
- *Other*, indicating another suggested figure

Who is operationally involved? *[Please tick just one option]*.

- Assistance association
- Regional coordination committee
- *Other*, indicating another suggested figure

Who is controlling? *[Please tick just one option]*.

- Assistance association
- Regional coordination committee
- The national institute for insurance against accidents at work (INAIL) – INAIL Research
- *Other*, indicating another suggested figure

Appendix C. Actors' detail for each phase of the Operational Management area

The descriptions in Table 2 detail the actors selected for each phase and scenario of the *Operational Management* area.

C.1. Phase 1. Detection and information gathering (Scenario 1)

In the first scenario, the same figures are indicated for the owner and supervisor, the internal and external OSH service (SPP), and the delegate as a second option. In micro realities, the delegate corresponds with the employer. Workshop participants stated the importance of having separate figures for the owner and the supervisor whenever possible. If the delegate is responsible, it is advisable to have the SPP for monitoring and vice versa.

Operationally involved actors should observe the daily operations of the company, such as internal and external workers operating at the production site. Otherwise, the worker in charge may gather information once the eyewitness reports an event (indirect process). The SPP, initially considered a potential body, was disregarded after the workshops because the activity would be too time-consuming to be regularly performed by this service.

C.2. Phase 2. Data analysis at the local level (Scenario 1)

For the owner and supervisor roles, the figures eligible for the first phase were also confirmed for the second phase. As before, the participants in the workshops stated the importance of having separate figures for the owner and supervisor whenever possible. In addition to the SPP and delegates, unlike in Phase 1, the employer might oversee this process as an important activity to manage internally. The size of the company counts first and foremost. In micro-enterprises, employers can also perform SPP activities.

The SPP is the most appropriate figure for data analysis within companies. The information that at this phase may have already been partially processed, which further confirms the previously entered data through analysis. However, the SPP is ultimately responsible for this activity. All the selected figures for these roles are already involved in collecting, aggregating, and analyzing data for other similar activities within companies.

C.3. Phase 1 & 2. Detection and information gathering & data analysis at the local level (scenario 2)

In the second scenario, having an internal process owner is not advisable. The figure in charge of the activity should be an external consultant or person (technician) from the assistance association. This case was the most discussed scenario during both the workshops and the two final fine-tuning events.

At the end of the workshops, the participants were skeptical about the second scenario because they believed that the first two phases could not be externalized to assistance associations and external assistance figures. Nonetheless, different figures for the second scenario were not proposed by the participants who questioned the feasibility of the scenario and not the relevance of the figures proposed. Therefore, the internal refinement session discussed whether this scenario should be maintained or eliminated. It was retained mainly because it was an existing option, already tested in some Italian realities and worked well

when implemented. Hence, the final event in Thiene (Veneto, Italy) was structured to investigate how to overcome the potential criticalities of the second scenario by leveraging its strengths.

Assistance associations were recognized as valuable assets capable of providing significant benefits and operational support, as they can organize events to encourage companies to report near misses and support them with free training sessions conducted by qualified professionals from the association. These associations may enhance companies' awareness by sharing previous experiences with member companies that have already dealt with near misses. Furthermore, associations can assist company operators in the reporting and data analysis phases.

Participants at the event held in Thiene discussed the potential advantages of companies in selecting this scenario, implicitly suggesting when it should be preferred. Companies, particularly SMEs, would have several advantages in sharing data through assistance associations. First, they would receive an easy-to-use tool for near-miss management and continuous external assistance to use it. Second, they would have access to aggregate data on near-misses reported by other companies and previous solutions that might be replicated in their workplace. Companies should receive or download analyzed reports of the occurred events. Third, financial incentives should be established for companies that decide to implement near-miss tools and share data with their reference associations. Finally, to ensure that the near-miss management system is widely used, assistance associations should guarantee the anonymity of companies and workers reporting events.

C.4. Phase 3. Data analysis at the territorial level

The two scenarios merge for phases 3, 4, and 5, as activities are developed externally by the company and do not depend on the type of data collection (internal or external).

The owner and operator figures selected in Phase 3 are already involved in aggregating and monitoring data of plurality of companies, such as associations (i.e., joint, bilateral, or participative bodies), which have been confirmed by the workshops as suitable for data analysis at the territorial level.

Three types of supervisory figures are identified to account for the differences across territorial areas. These include assistance associations such as the Italian Formedil and Confindustria, supervisory bodies such as ASL with assistance functions, and regional coordination committees, all of which are considered viable options.

C.5. Phase 4. Data analysis at the national level

This phase is almost exclusively delegated to INAIL research, specifically the Department of Medicine, Epidemiology, Occupational Hygiene, and Environment (DiMEILA), which plays an important role in data analysis for reconstructing the dynamics and causes of work-related injuries at the national level, as previously implemented for a national intervention called Infor.Mo (Campo et al., 2020; De Merich et al., 2022). Therefore, it is difficult to think of any other Italian figure who can gather national cross-sectoral data on near misses.

Process supervision, as emerged from the workshops, might be left to regional coordination committees, thus separating the monitoring process from the other two figures entrusted with INAIL research.

C.6. Phase 5. Dissemination and feedback to local areas and companies

Assistance associations, such as the Italian Formedil and Confindustria, are tasked with the responsibilities of both owner and operator roles, as they currently disseminate knowledge throughout the territory for other OSH activities. However, the clear preference for assistance associations as process owners lessened after the second workshop, where the value of regional coordination committees was recognized. These committees were excluded from the operational process because of their limited operational power.

INAIL research plays a supervisory role by monitoring whether evidence gathered through data analysis has been effectively returned to local areas and companies. Therefore, at the end of the workshops, to preserve territorial specificities, two figures—the assistance association and the regional coordination committee— were identified as possible owners of the process, and one figure—the assistance association—was considered appropriate for operational involvement. However, after the internal design refinement, INAIL research was also considered responsible and operationally involved because it is currently developing these activities.

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