# Learning to anticipate the future: an analysis of organizational learning processes through weak signals in italian hospitals and interventions

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Note: Some of the results presented are still under analysis and further work is ongoing. Due to space constraints, the findings are reported here in a condensed format rather than in full detail. Other sections have also been streamlined compared to the original project plan.

Since the first year, the research project has undergone some adjustments, and content from the first year PhD project (focused on Anticipatory Thinking of frontline workers and managers) has been revised and incorporated into Study 2.a. These changes were primarily driven by:

- Time spent abroad, during which new methods and approaches were learned
- Limitations at San Martino Hospital regarding data collection, due to staff availability constraints caused by increased workload and staffing shortages

*The University Research Ethics Committee (CERA) of University of Genoa has issued favorable opinion no. 2025.39 for this project.*

**The project**

This PhD project focuses on organizational learning in the healthcare sector, specifically in the context of Occupational Health and Safety (OHS). Organizational learning is increasingly essential in complex organizations such as hospitals. According to Argyris and Schön (1996), it is the process through which organizations detect and correct errors by modifying behaviors based on experience and feedback. They distinguish between single-loop learning, which involves making adjustments without altering underlying assumptions or policies, and double-loop learning, which requires critically revising norms, policies, and fundamental objectives to better adapt to change. Both types of learning are crucial in hospital OHS contexts: for instance, when a healthcare worker is pricked by a contaminated needle due to a failure in safety device procurement, the organization may review its purchasing processes and supplier choices to prevent recurrence (double-loop learning). Conversely, if staff contract infections due to improper safety procedures, targeted training can correct the unsafe behavior (single-loop learning).

However, new safety paradigms, named Safety-II, emphasize proactive learning by anticipating risks rather than merely reacting to incidents (Hollnagel, 2014). Nowadays, hospitals face significant uncertainty about the future (Aarninkhof-Kamphuis et al., 2024; Staiger et al., 2017) due to social and economic changes (Dion et al., 2023; Milios, 2017; Ullah et al., 2021), ongoing technological innovations (Bhagat and Kanyal, 2024; Rajendran et al., 2021), and emerging risks (Gifford et al., 2022; Hawkins et al., 2025; Lindholm et al., 2020, 2024; Wagner, Schöne and Rieger, 2020). The COVID-19 pandemic showed how unexpected events can significantly affect biological risk management (Ketelaars et al., 2024).

Uncertainty about future performance is a common challenge in complex contexts like healthcare. While safety includes both patient and worker safety, the latter often receives less attention. Managing uncertainty in worker safety is increasingly important due to rising psychosocial risks such as stress, burnout, and workplace violence. Healthcare is among the most challenging environments for professional decision-making (van Kraaij et al., 2024; Zavala et al., 2017) due to time pressure, high workload, and emergencies. Decisions made by healthcare personnel carry serious consequences for both patients and staff. Healthcare professionals must constantly make trade-offs between patient safety and personal safety under organizational, peer, and external pressures, which can lead to deviations from established protocols to achieve immediate objectives.

These trade-offs and adaptive decisions occur in the daily work of healthcare staff – the routine, real-world practices and decisions that constitute work-as-done, i.e., how tasks are actually performed in practice, in contrast to work-as-imagined, which represents how procedures are designed and expected to be carried out according to protocols and organizational guidelines (Hollnagel, 2014). Daily work contains variability, improvisation, and adaptations that are critical to understand safety in hospitals because it is within these practices that weak signals often emerge.

Weak signals consist of seemingly irrelevant or unrelated information, details, or minor events that, if recognised in time, can help identify dangerous patterns that may lead to failures (Brizon and Wybo, 2009; Nicolaidou, 2021, 2022; Schoemaker and Day, 2009). They emerge during everyday operations and are typically detected by frontline workers, such as nurses, doctors, cleaning staff, and others (Carman, 2020; Tucker, 2008). An example of a weak signal within healthcare setting is a request for home care that omits the patient's history–potentially including psychiatric disorders or violent behaviour. This may reflect incomplete communication between the hospital and the community, a failure to consult patient records, and the absence of structured verification procedures, a pattern that can expose staff to the risk of aggression (Carman, 2020). The detection of weak signals can indeed offer organisations the opportunity to identify and address them before they escalate into accidents (Brizon and Wybo, 2009; Patriarca et al., 2022).

Safety-II emphasizes the importance of recognizing and learning from this daily work to detect weak signals and anticipate accidents, rather than relying solely on accident analysis. Traditional Safety-I approaches address uncertainty by analyzing past incidents and eliminating hazardous conditions. While effective in preventing recurrence, this reactive approach limits learning opportunities and does not prepare organizations for unexpected events. Accidents are relatively rare, and system conditions continuously evolve, meaning that interventions based solely on past events cannot guarantee future safety (Patriarca et al., 2022).

This project investigates whether hospitals can effectively leverage weak signals to anticipate and prevent future incidents. To do so, it examines processes and practices that support organizational learning in hospital OHS, focusing on two key domains: reporting systems and training. Near-miss – an event that could have led to harm or damage but did not by chance – and accident reporting systems are widely used tools to collect information from frontline staff, enabling organizations to improve practices and prevent recurrence (Li & Guldenmund, 2018; Lukic et al., 2010; Reason, 1997; Tucker et al., 2008). OHS training is recognized as crucial for workplace learning, injury reduction, and health promotion, particularly in high-risk environments (Carnazzo et al., 2024; Haj-Bolouri, Katende & Rossi, 2024; Harikkala-Laihinen, Fäldt & Bäckman, 2024; Robson et al., 2012; Freitas & Silva, 2017). Both processes – reporting and training – provide opportunities to detect weak signals and support proactive learning, yet they remain underexplored in the literature.

The overarching research questions of this PhD project are:

- Q1: In what ways do organizations learn from weak signals and apply this learning to anticipate future accidents?

- Q2: How can hospitals be supported in transforming weak signals into organizational learning to improve anticipation and prevent future accidents?

The first question focuses on the current ways in which hospitals learn from weak signals; the second question addresses interventions to enhance their ability to do so.

These questions are addressed through the two main processes: reporting (domain a) and training (domain b), with four sub-questions:

Reporting:

- Q1.a: How are hospital reporting systems used to learn from weak signals? (Study 1.a)
- Q2.a: How can an alternative structured method for collecting weak signals support organizations in transforming them into organizational learning to anticipate future accidents? (Study 2.a)

Training:

- Q1.b: How do OHS training practices in hospitals make use of weak signals to support organizational learning, and how do different training approaches influence this process? (Study 1.b)
- Q2.b: How can a training program developed using a weak signals approach support organizational learning? (Study 2.b)

The research is primarily conducted at the Policlinico San Martino Hospital in Genoa, the largest hospital in the region and an University hospital, providing a heterogeneous environment suitable for case study research. This hospital serves as the main site for Studies 1.a, 2.a (first part), and 2.b, while Study 1.b extends to other OHS professionals across hospitals.

Below, the reporting domain will be presented first, analyzing in Study 1.a how current reporting systems can generate organizational learning, and in Study 2.a an alternative method for collecting and transforming weak signals into organizational learning will be presented. In the second part, Study 2.b will show how training currently supports learning from weak signals, and Study 2.b will present a training program designed to promote the transformation of weak signals into organizational learning.

**Study a – reporting**

This study focuses on the process of organizational learning through structured tools and methods for the collection of weak signals from frontline workers. Traditionally, safety-critical data collection systems rely on worker reporting systems, which are primarily designed to capture near misses, overlooking the collection of weak signals and their potential contribution to organizational learning (Lukic et al., 2010; Reason, 1997). Moreover, innovative approaches are emerging that emphasize dialogue and face-to-face storytelling to maximize knowledge creation, thus differing from more “cold” or impersonal tools such as formal reporting systems (Patriarca et al., 2022).
The study is structured into two sub-studies aimed at addressing the following research questions:

> Q1.a: How are hospital reporting systems used to learn from weak signals?
> Q2.a: How can an alternative structured method for collecting weak signals support organizations in transforming them into organizational learning to anticipate future accidents?

The first sub-study examines if and how the hospital leverages weak signals within its reporting system to promote learning. The second sub-study focuses on the development of a structured method for collecting weak signals and transforming them into anticipatory learning and proactive actions, thereby illustrating alternative methods compared to traditional near-miss reporting systems.

**Study 1.a. – Q1.a How are hospital reporting systems used to learn from weak signals?**

## 1. Introduction

Near-miss and incident reporting systems are among the most widely used tools in hospitals to promote safety and prevent the recurrence of undesirable events (Lukic et al., 2010; Reason, 1997). They are an integral part of safety management systems (SMS), designed to collect, analyze, and utilize information about adverse events in order to improve processes and practices (Li & Guldenmund, 2018). Their strength lies in the ability to gather information directly from frontline staff, who have firsthand knowledge of system vulnerabilities (Tucker et al., 2008).

Traditionally, these systems are based on a Safety-I logic, focusing on what goes wrong: near misses, accidents, injuries (Hollnagel, 2014). However, this approach captures only part of the operational reality. It is by also observing the everyday work, with its adaptations and informal strategies employed by staff, that weak signals can be detected (Patriarca et al., 2022).

An important contribution in this direction comes from Leon, Hogan, and Jani (2024), who analyzed reports in patient safety reporting systems. They highlighted that many reports contained weak signals, such as difficulties in communicating with patients (e.g., providing too much information or using overly technical language when giving instructions about therapy). These elements did not describe errors that had already occurred but rather anticipated the risk of misunderstandings and, consequently, the possibility of inappropriate treatments. The study thus demonstrates that reporting systems, beyond recording adverse events, can also provide useful insights to anticipate future risks and support proactive learning. However, literature on this aspect remains scarce, particularly concerning occupational health and safety.

Specifically, there is a lack of systematic analysis of how weak signals emerge in reporting systems and how they can be translated into organizational learning, especially in the context of occupational heath and safety (OHS). This represents a significant gap for the healthcare sector, which must continuously adapt to change (Lintern & Kugler, 2017). Although hospitals collect enormous amounts of data through reporting, the challenge lies in transforming these data into proactive learning, capable of anticipating rather than merely reacting.

From this perspective, reporting systems, although conceived as reactive tools (Safety-I approach) can prove valuable in detecting weak signals and stimulating forward-looking learning processes. The present study aims to explore this potential by analyzing the reporting system of a large Italian hospital, the San Martino Hospital, situated in northern Italy.

To guide the analysis, the following research questions were formulated:

Q1: Are there weak signals in the hospital's reporting system?

Q2: How does the organization learn from these signals?

Q3: In what form do these signals appear?

Q4: What anticipations regarding the future emerge from signals reports?

This study will contribute to the literature on how hospitals can learn using traditional reporting systems, outlining gaps in order to maximize organizational learning oriented towards the future. The following sections will present the study's methodology, results, and discussion.

## 2. Method

A total of 149 reports collected over three years from the San Martino online reporting system were analyzed. This system allows all San Martino staff to voluntarily report near misses, including anonymously. The data were extracted by employees of the Prevention and Protection Service and provided to me in Excel format.

To address the research questions, a qualitative methodology was adopted, using a deductive approach for Q1 and Q2 and an inductive approach for Q3 and Q4. Specifically, Content Analysis was used for the deductive approach, while Reflexive Thematic Analysis was used for the inductive approach.

Content Analysis allows researchers to re-examine existing data and synthesize them into categories, verifying the presence of already known categories, in our case weak signals in addition to near misses and injuries, and the five levels of learning (see Tables 1.1 and 1.2). Reflexive Thematic Analysis, on the other hand, allows for organizing and thematizing qualitative data to identify relevant patterns and understand their content, starting from data that inductively contribute to theory development (Braun & Clarke, 2006).

### *2.1. Deductive Analysis – Content Analysis (Q1, Q2)*

For the deductive Content Analysis, unstructured categorization matrices were created, based on an extensive literature review. This allowed, for Q1, the coding of reports into predefined categories (near miss, weak signal, injury) and the addition of emerging categories, such as "Strong Signal", that we detected during the analysis. Reports not related to OHS were excluded.

For Q2, the analysis focused on the interventions implemented by the organization following the submission of a report. Specifically, it was examined whether procedures were modified, preventive actions were taken, or other measures were introduced to address the identified issues. The analysis considered the level and type of organizational learning triggered by the signals.

In particular, for Q2, the analysis matrix was based on the organizational learning levels proposed by Argyris and Schön (1996):

1. Single-loop learning: correcting symptoms without addressing underlying causes.
2. Double-loop learning: correcting actions while also addressing underlying causes.
3. Deutero learning: reflecting on how the organization itself learns.

And two additional levels inspired by Safety-II and resilience engineering (Hollnagel, 2014; Weick & Sutcliffe, 2001) were added:

4. Proactive risk-oriented learning: anticipating and addressing potential risks before they materialize.
5. Proactive resource-oriented learning: enhancing organizational resources and capabilities to better handle future challenges.

The final matrices with inclusion and exclusion criteria for the analysis are reported in Tables 1 and 2.

**Tab. 1 Matrix with inclusion and esclusion criteria – Q1**

| Label | Inclusion Criteria (CI) | Exclusion Criteria (CE) | Key References |
|---|---|---|---|
| **Weak Signal (WS)** | 1. Vague, ambiguous, fragmentary, unstructured information (CI_WS_01) | 1. Risk already manifested (injury) or narrowly avoided (near miss) (CE_WS_01) | Ansoff (1975); Brizon & Wybo (2009); Lesca (2001, 2003); Blanco & Lesca (2003); Coffman (1997); Hiltunen (2008, 2010); Mendonça et al. |

| Label | Inclusion Criteria (CI) | Exclusion Criteria (CE) | Key References |
|---|---|---|---|
| | 2. Latent risk/potential hazard not yet manifested (CI_WS_02)<br>3. Anomalous or out-of-standard condition generating uncertainty (CI_WS_03)<br>4. Difficult to evaluate in terms of concrete risk or probability of occurrence (CI_WS_04) 5. Based on intuition or suspicion rather than objective data (CI_WS_05) | 2. Clear, structured, unambiguous information (CE_WS_02)<br>3. Lack of potential for future evolution (CE_WS_03) 4. Purely descriptive facts with no anomalies or risks (CE_WS_04) | (2004); Ebadi et al. (2022); Patriarca et al. (2022); Schoemaker & Day (2009) |
| **Strong Signal (SS)** | 1. Clear, structured, unambiguous information (CI_SS_01)<br>2. High informational value, already consolidated (CI_SS_02)<br>3. Capable of anticipating an event with high probability (CI_SS_03) | 1. Isolated, vague information: remains weak signal (CE_SS_01)<br>2. Lack of concrete elements indicating high probability of an event (CE_SS_02)<br>3. Events already occurred (injury) or narrowly avoided (near miss) (CE_SS_03) | Hiltunen (2008); Ansoff (1975); Ebadi et al. (2022) |
| **Near Miss (NM)** | 1. Unplanned or unexpected event (CI_NM_01)<br>2. No actual harmful consequences such as injuries, illness, material damage (CI_NM_02)<br>3. Potential to cause severe outcomes: injuries, illness, material damage (CI_NM_03)<br>4. It did not result in an incident due to human intervention or fortuitous circumstances (CI_NM_04) | 1. Event causing actual harm (injury) (CE_NM_01)<br>2. Unsafe condition or act without a concrete event (CE_NM_02)<br>3. Lack of identifiable harmful potential (CE_NM_03)<br>4. Planned or intentional event by the person involved (CE_NM_04) | Bier & Mosleh (1990); Jones et al. (1999); NSC (2013); Shea et al. (2015) |
| **Injury (I)** | 1. Work-related event (CI_I_01)<br>2. Unplanned, unexpected, or accidental (CI_I_02)<br>3. Causes physical or mental harm, work-related illness, or death (CI_I_03)<br>4. Consequences include: days away from work, work restrictions, transfer, medical treatment beyond first aid, loss of consciousness, or death (CI_I_04) | 1. Events not work-related (CE_I_01)<br>2. Pre-existing conditions or damages (CE_I_02)<br>3. Planned or intentional events (CE_I_03)<br>4. Events without any physical, mental, illness, or death consequences (CE_I_04) | Probst et al. (2008); Aderaw et al. (2011); McGonagle & Kath (2010) |

## Tab. 2. Matrix with inclusion and esclusion criteria – Q2

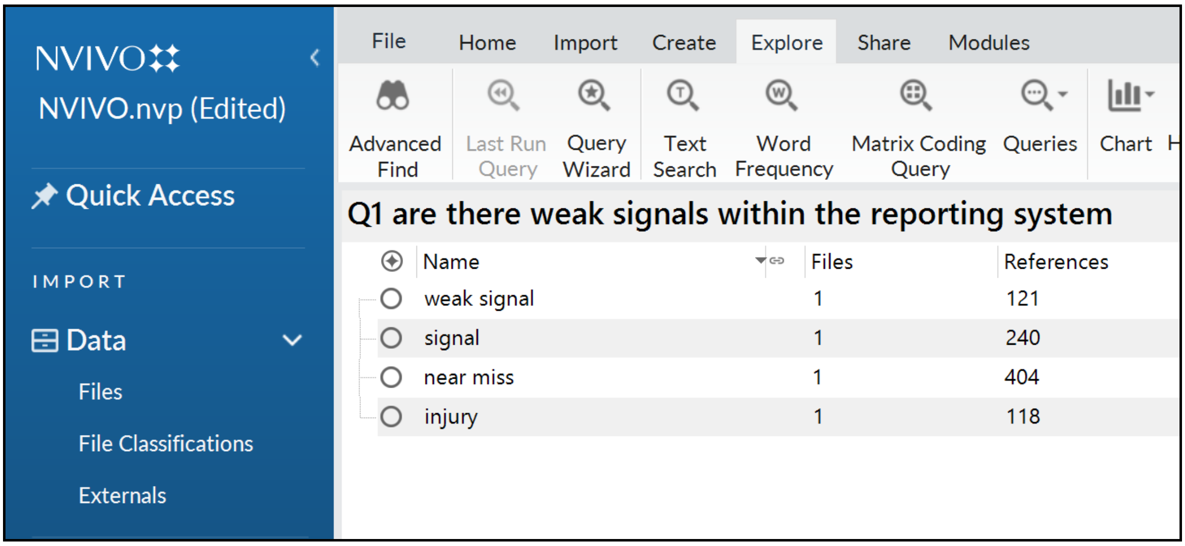
| Level | Description | Key Features / Criteria | References / Theoretical Basis |
|---|---|---|---|
| **Level 0: No Learning** | No documented intervention or other form of organizational learning. | – Absence of corrective actions or learning initiatives – No investigation of incidents or processes | Argyris & Schön (1996) |

| Level | Description | Key Features / Criteria | References / Theoretical Basis |
|---|---|---|---|
| **Level 1: Single-Loop Reactive Learning** | Corrective actions targeting the symptom, without investigating underlying causes or questioning organizational procedures. | – Corrective actions limited to visible issues – Repetition of correct procedures to operators (e.g., awareness campaigns) – Operator reminders to pay attention | Argyris & Schön (1996) |
| **Level 2: Double-Loop Reactive Learning** | Actions aimed at addressing the root causes of the manifested problem. | – Modification of organizational procedures – Interventions go beyond symptoms to address underlying causes | Argyris & Schön (1996) |
| **Level 3: Deutero Learning** | Learning based on reflection on how the organization learns. Focus on improving the organizational learning process itself. | – Meta-learning: improving learning methods – Reflection on processes, structures, and feedback loops – System-level learning and adaptation | Argyris & Schön (1996); Safety-II principles (Hollnagel, 2014) |
| **Level 4: Risk-Oriented Proactive Learning** | Actions that do not simply react, but use events as stimuli to investigate whether similar situations could occur elsewhere, with a prevention-oriented perspective. | – Preventive focus – Exploration of potential recurrence of risk in other contexts – Learning from weak signals to anticipate hazards | Argyris & Schön (1996); Safety-II principles (Hollnagel, 2014) |
| **Level 5: Resource-Oriented Proactive Learning** | Actions aimed at valuing practices and conditions that normally prevent incidents. Focus on what works well and promotion of this resources. | – Positive proactive focus – Reinforcement of safe practices – Leveraging strengths and resilient aspects of the system | Safety-II perspective (Hollnagel, 2014); Argyris & Schön (1996) |

To ensure the validity of the coding in the Content Analysis, it is necessary to assess inter-coder agreement, which quantifies the extent to which different coders assign the same ratings to the same data (Lombard et al., 2010). Among the most commonly used indices is Cohen's kappa (k), recognized as the reference standard in research involving coding. After defining the categories and their inclusion and exclusion criteria, the analysis was conducted by myself and an undergraduate psychology student, who had received extensive training on the topic and was writing a thesis on the subject. The inter-coder agreement, calculated using Cohen's kappa, was 0.97, indicating excellent concordance.

The data were then imported into NVivo, where, for Q1 and Q2, predetermined categories were applied by selecting the relevant portions of text (Fig.1).

**Fig.1 An example of predetermined coded on NVivo**




### *2.2. Inductive approach – Reflexive Thematic Analysis (Q3, Q4)*

After identifying the categories related to weak and strong signals, the thematic analysis to address Q3 and Q4 was conducted. For Q3, the content of reports categorized as signals and weak signals was analyzed, while for Q4, the reporter attempted to anticipate potential future accidents was examined.

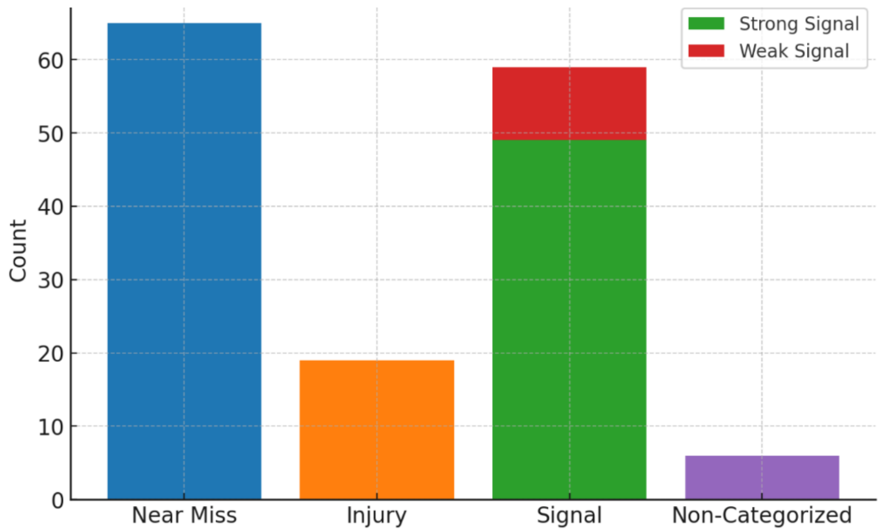
The thematic analysis followed the six phases described by Braun and Clarke (2006): familiarization with the data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. All these phases were carried using NVivo for coding and data organization.

## 3. Results

### *3.1. Q1*

In the reporting system, 59 signals were identified, of which 49 were strong signals and 10 were weak signals (Tab. 3).

**Tab.3. Frequencies of categories of reporting**




Below is the summary table (Tab.4).

**Tab.4. Summary table of categories of reports (Q1)**

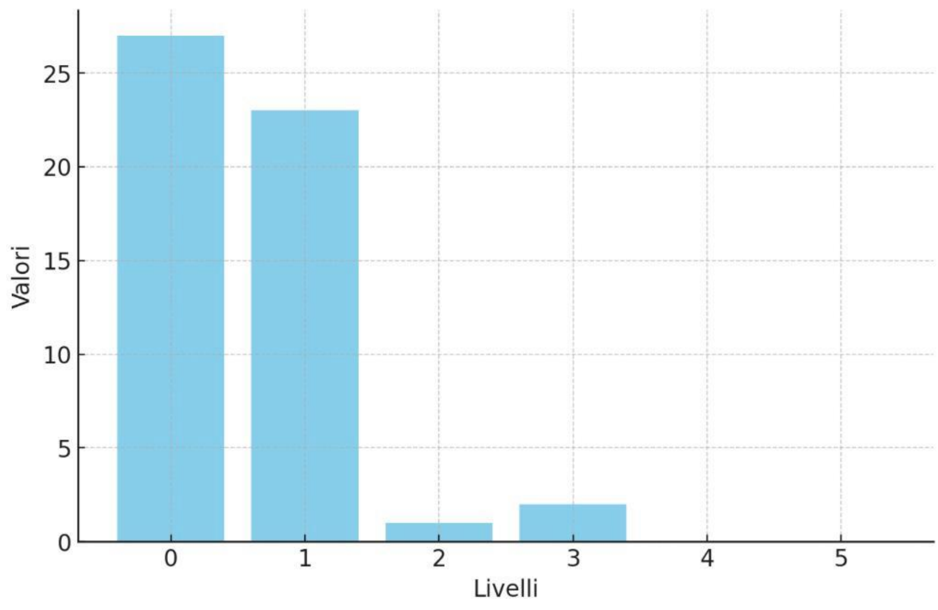
| Category | Count | Details |
|---|---|---|
| Near Miss | 65 | Unexpected events with potential harm that did not result in an incident |
| Injury | 19 | Events causing physical or mental harm, illness, or death |
| Strong Signal / Weak Signal | 59 | Total observed signals |
| – Strong Signal | 49 | Clear and structured information with predictive value |
| – Weak Signal | 10 | Vague, fragmented information with predictive value |
| Non-Categorized | 6 | Material damages already occurred or risks related to patient health, not the worker |

Signals account for 39.6% of the reports, slightly less than half but still substantial. The most frequent reports are near misses, as expected within a near-miss reporting system; however near misses number is relatively low, almost close to that of signals at 43.6%. The remaining reports consist of injuries to a lesser extent, as injury reporting usually follows other procedures and is mandatory to report.

### *3.2. Q2*

Regarding the second research question, conducted only on Strong and Weak Signals, the content analysis of reports showed that often no intervention is reported, although occasionally Level 1 interventions and, more rarely, Level 2 interventions are recorded. The following chart and summary table (Tab.5 and Tab.6) illustrate the results:

**Tab.5. Frequencies of categories of intervention only on the Signal category (including weak and strong signals)**




Below is the summary table.

**Tab.6. Summary table of categories of intervention (Q2)**

| Level | Description | Count |
|---|---|---|
| 0 | No learning | 27 |
| 1 | Single-loop reactive learning | 23 |

| Level | Description | Count |
|---|---|---|
| 2 | Double-loop reactive learning | 1 |
| 3 | Proactive risk-oriented learning | 2 |
| 4 | Proactive resource-oriented learning | 0 |
| 5 | Deutero learning | 0 |

Overall, there appears to be limited or only superficial learning in relation to the signals. Thus, according to Q1, signals account for slightly less than half of the reports but do not lead to substantial organizational learning.

### *3.3. Q3*

For Q3, reports classified as weak and strong signals were explored through thematic analysis. Six themes were identified, which are presented below.

*Theme 1.1. Issues in managing risk conditions*
These reports describe situations where identified risks or unsafe conditions are not properly addressed. Problems can persist for days or recur repeatedly despite being reported multiple times. For example, staff reported *"the gas alarm on the entire floor was inactive despite reporting it to the help desk 4 days earlier"*. Most reports concern physical or equipment issues, but some also hint at organizational problems, usually expressed as frustration about recurring unsafe situations.

*Theme 1.2. Patient control procedure failures*
Weak signals in this category highlight failures in procedures meant to prevent patients from bringing dangerous items or engaging in unsafe behavior. For example, one report noted *"a contaminated syringe was found on a patient during the disrobing procedure"*. These signals suggest gaps in existing patient safety checks and control procedures.

*Theme 1.3. Operator-related issues*
These reports focus on risks affecting directly staff safety, health, and work efficiency. Examples include minor injuries, understaffing, or environmental discomfort. For instance, one report stated *"unbreathable air due to dirty water rising from drains"*, highlighting that staff may face risks they cannot control.

*Theme 1.4. Violations*
Violations are deviations from established safety rules or standards. They include staff not following procedures and unsafe structural conditions. For example, a report mentioned *"emergency personnel without mask"*.

*Theme 1.5. Structural Problems*
This category includes physical problems in the hospital building or facilities: unsafe workspaces, damaged fixtures, broken windows, leaks, puddles, and tripping hazards. For example, one report stated *"puddles in the corridor caused by leaks or heavy rain"*, showing that safety concerns are often concrete and material-focused.

*Theme 1.6. Equipment problems*
Reports focus on malfunctioning equipment that could compromise safety, such as overheating machines, leaks, abnormal noises, or electrical faults. For instance, a report noted *"sparks and popping noises from the UPS despite a recent check"*, reflecting that equipment problems are a major source of weak signals.

### *3.4. Q4*

The anticipation reported by the worker in the report was analized.

*Theme 1.1. Personal harm*
Anticipatory thinking here is concrete and focused on immediate physical risks to staff. For example, reports mention *"risk of tripping over a piece of iron sticking out of the asphalt at the emergency exit"*, highlighting risks staff try to anticipate in their daily work.

*Theme 1.2. Organizational and operational safety vulnerabilities*
This thinking focuses on hidden or systemic risks that can affect staff safety indirectly. For example, one report noted *"risk for potential evacuation due to obstruction in the corridor"*, showing awareness of broader organizational factors that can influence safety, not just immediate hazards.

## 4. Discussion

From the analysis of the reporting system of the San Martino Hospital of Genoa, it emerges that signals are present, constituting just under half of the formal reports related to near misses, despite the system being formally designed exclusively to capture such events (Q1). This finding suggests that the reporting system, beyond its original function, has the potential to provide the organization with forms of learning oriented toward anticipation.

However, a marked imbalance is observed between reports classified as strong signals and those identified as weak signals: the latter represent only about one fifth of the total. This discrepancy may reflect a still limited reporting culture in hospitals, considering also the relatively low overall number of reports (147 in three years). The absence of specific initiatives to raise awareness or provide training on the importance of weak signals likely contributes to this scarcity, making it more difficult for workers to recognize and adequately describe them (Brizon & Wybo, 2009).

Another limitation concerns the ability to transform weak signals into organizational learning (Q2). The actions taken by organization tend to focus on symptoms (single loop learning) or no-intervention is taken. For example, recurring flooding events are managed through immediate cleaning interventions, without investigating the structural causes that would prevent recurrence. This behavior reflects a predominantly reactive approach, consistent with the Safety-I perspective (Reason, 1997; Hollnagel, 2014).

A further critical issue concerns the very nature of the weak signals collected, which emerge primarily as technical or physical problems, and they are not focused on "less evident and concrete" problems like communication issue, unclear procedures, etc. (Hollnagel, 2014) (Q3). Moreover, the reports are often extremely concise – limited to one or two lines – thus strongly constraining the possibility of deeper analysis.

Finally, only a few signal reports contained attempts by reporters to anticipate future accidents (Q4). This may reflect an organizational culture that pays little attention to anticipation as a form of learning.

## 5. Conclusion

The findings of this study show that although weak signals are present within the hospital's reporting system, their potential to generate organizational learning remains largely unused. The imbalance between strong signals and weak signals, the relatively low number of reports overall, and the lack of a consolidated reporting culture make it difficult to leverage this information for proactive purposes.

In addition, the predominantly technical and physical nature of the weak signals collected, combined with their poor descriptive articulation, limits the ability to capture their broader implications. To fully exploit the potential of weak signals, it is therefore necessary to adopt integrative approaches that go beyond the logic of formal reporting systems, including contextual analysis tools and direct exchange practices.

In the next study (Study 2.a), a structured method to collect weak signals from frontline workers and to transform them into organizational learning to anticipate and prevent future accidents will be presented.

**Study 2.a. – Q2.a How can an alternative structured method for collecting weak signals support organizations in transforming them into organizational learning to anticipate future accidents?**

*(In collaboration with the TU Delft [Netherlands] and Università La Sapienza di Roma, with Professor Arie Adriaensen and Professor Riccardo Patriarca)*

**1. Introduction**

This study introduces the Weak-Signal-Driven Anticipation Method (WS-DAM), a new approach to enhance hospitals' ability to anticipate future accidents by transforming weak signals into actionable foresight. Specifically, the framework integrates an existing method with an existing technique: Structured Exploration of Complex Adaptations (SECA) (Patriarca et al., 2022) and Backcasting (Geden et al., 2019). SECA is a method to detect weak signals and is particularly effective for its identification within complex socio-technical systems, but it does not directly support the development of anticipatory strategies. Backcasting, on the other hand, enables the construction of future-oriented scenarios and future interventions. WS-DAM is designed to bridge this gap: by applying backcasting to the weak signals identified through SECA, early signals are transformed into concrete anticipatory insights for healthcare.

Traditional reporting systems in healthcare are rarely designed to capture weak signals (Leon, Hogan & Jani, 2024). They typically follow a Safety-I approach, focusing only on near misses and injury reports (Hollnagel, 2014; Patriarca, 2022). However, Study 1.a shows that weak signals can be present within reporting systems, indicating that these signals are intrinsic to organizations and can, to some extent, be collected. Nevertheless, traditional reporting systems are often insensitive to the complexity of weak signals, as a formal written report may fail to capture systemic interactions in which these signals are embedded and the information they convey. This also makes it difficult to plan effective corrective actions aimed at anticipating future accidents before harm occurring to workers or to the organization (see Study 1.a). In this sense, there is a need for another structured method of collecting weak signals, grounded in operators' practices, that can grasp weak signals and their richness – going beyond the single cue to reveal the broader pattern they carry.

Currently, only a very limited number of structured methods exist to collect weak signals (Hollnagel, Laursen & Sørensen, 2022; Trancoso, Patriarca & Henriqson, 2024), and even fewer methods transform them into anticipation to prevent accidents. A recent Eurocontrol project, developed by Patriarca, Leonhardt, and Licu (2022), introduced a method to capture weak signals in daily operations. It analyzes daily work – the real work which includes trade-offs, deviations from procedures, and adaptations in daily operations, which is different from procedures, rules, and prescriptions – to understand variability and identify dangerous patterns that, if left unaddressed, could lead to future accidents. The method is based on examining how frontline professionals operate under pressure in several situations.

It is originally developed in the aviation field, and has never been applied to the healthcare context, yet it could offer significant benefits. SECA examines not only the decisions and actions of individual professionals but also the context in which these decisions occur and the organizational factors influencing them. Its ability to detect weak signals in complex socio-technical systems makes it a promising tool for improving anticipation and safety in hospitals.

However, while SECA's ambition is to enable safety professionals to design and implement interventions that support frontline decision-making and promote resilience, it only provides a snapshot of the system's current functioning, that is current weak signals and patterns within the organization. It does not offer a structured approach for anticipation and proactive action.

This study was therefore designed to bridge that gap and develop a method capable of transforming SECA outputs (dangerous patterns) into improvement actions to prevent future accidents. The aim is to create a method that supports and improves managerial decisions in operational contexts by leveraging knowledge of weak signals to prevent future accidents.

To achieve this, the psychological construct of Anticipatory Thinking (AT) and its associated technique, backcasting, were employed. AT is a cognitive skill based on the deliberate exploration and analysis of relevant alternative system states (Geden et al., 2019). It is not a simple prediction exercise but involves imagining different scenarios that could emerge from a specific set of available knowledge (Klein et al., 2011). Within this construct, backcasting is a technique that focuses on a desired future scenario and works backward in time to identify the conditions needed to achieve it (Geden et al., 2019).

Backcasting is mainly used in educational contexts, for example, to design long-term educational programs. Its application in safety, particularly in hospitals, remains very limited. In this study, backcasting is combined with SECA to create WS-DAM that transforms detected weak signals (from SECA) into actionable anticipation, helping safety professionals develop effective improvement strategies based on daily operational knowledge.

The final outcome of this study is the development of WS-DAM, rather than its practical implementation, due to the time constraints of the PhD. To assess the applicability of SECA within the healthcare context, SECA was first applied in two units of San Martino Hospital, where patterns were identified. Once its applicability to the healthcare context was verified, WS-DAM was developed. This document presents both the SECA findings and the initial draft of the method, which will require further refinement by experts. The process of expert involvement will be carried out at a later stage (in the coming months); in this phase, only the recruitment of experts and the organization of data collection and analysis are described.

## 2. The development of Weak-Signal-Driven Anticipation Method (WS-DAM)

The following sections first introduce the SECA method and backcasting theoretically, and then the conceptual framework on which the method will be developed, including several options for its implementation.

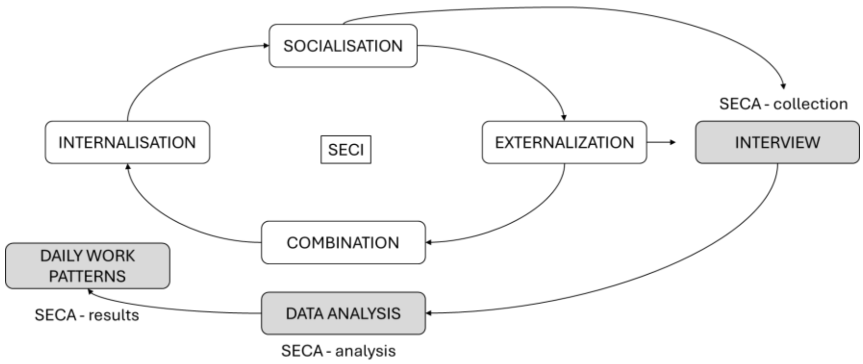
### *2.1. The Structured Exploration of Complex Adaptations (SECA)*

The Structured Exploration of Complex Adaptations (SECA) Method is grounded in the theory of resilience engineering. According to this approach, complex and variable systems require close attention to everyday work and the adaptations made by operators in order to be (re)designed to support resilient performance – that is, the ability of systems to effectively adapt to both expected and unexpected changes and perturbations without failure (Disconzi & Saurin, 2022; Hollnagel, 2017). The development of improvement actions must therefore be based on a thorough observation and understanding of daily work, with particular focus on where and how operators make decisions (Trancoso et al., 2024; West, 2018). Everyday work provides valuable insights into how people make decisions in real-world contexts, representing a form of tacit knowledge (Patriarca, Leonhardt and Licu, 2022).

Tacit knowledge refers to the implicit understanding of how work is performed in practice, including procedural violations, trade-offs, and adjustments. This knowledge resides in individuals' experiences, intuitions, and practical skills, acquired through direct experience and social interaction rather than formal learning. Tacit knowledge can be codified and made explicit through verbalization, when individuals reflect on the adjustments and trade-offs they make. Once made explicit, this knowledge can be combined with other explicit knowledge, resulting in more complex and informative forms of knowledge. This process is known as the SECI cycle, which represents the transformation of tacit into explicit knowledge and its subsequent internalization (Nonaka, Toyama & Konno, 2000).

The SECA method is based on a qualitative approach to data collection and analysis focused on this transformation from tacit to explicit knowledge. Data are collected through semi-structured interviews with frontline workers, exploring various aspects of daily experiences and responses to specific situations. These interviews are analyzed using a specific framework to identify recurring daily patterns. Both the SECI cycle and the SECA method are illustrated in Figure 2.

**Figure 2. The SECI cycle (Nonaka, Toyama and Konno, 2000) as integrated in the SECA method (Patriarca, Leonhardt and Licu, 2022).**




SECA is based on the definition of weak signal provided by Schoemaker and Day (2009), namely, a piece of information that can be recognized as part of a significant pattern. To identify such patterns, SECA extracts data embedded in work routines from interviews, transforming raw data into usable knowledge. Each interview describes the management of an event, carrying information stored within an individual mental model. For this information to go beyond a single perspective and reveal common ways of working within an operational context, it is necessary to extract, organize, and connect data from multiple interviews: this process allows the identification of patterns, which constitute knowledge.

This flow is represented by the DIKW pyramid (Data–Information–Knowledge–Wisdom, see Figure 3), where each step adds value to the previous one (Frické, 2019).

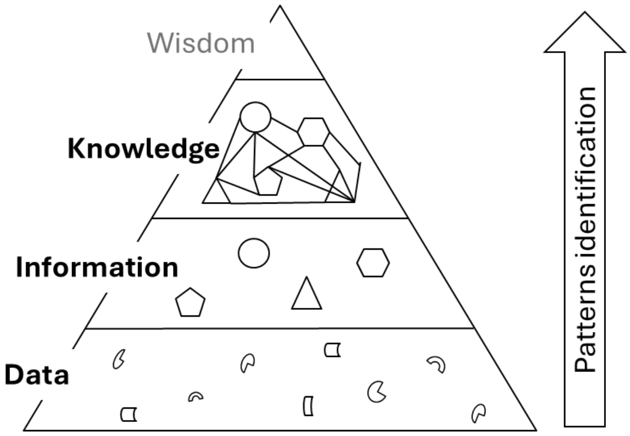



**Figure 3. The DIKW pyramid (Data-Information-Knowledge-Wisdom)**

Data alone are raw elements with little practical meaning; once organized, filtered, and contextualized, they become information, useful for understanding the “what”, “when”, and “where”. Connecting this information produces knowledge, which allows understanding of underlying relationships and their application to a purpose. SECA aspires to contribute to organizational wisdom, but in practice it only generates knowledge; the transformation of this knowledge into actionable foresight requires additional methods, such as backcasting.

SECA uses a qualitative research approach to analyze narratives and linguistic descriptions generated from interviews. Grounded Theory (Glaser & Strauss, 1967) is employed to interpret adaptive practices, which are context-dependent and embedded in socio-technical systems. The analysis is inductive and iterative, aiming to uncover detailed patterns and concepts from everyday operations. In addition, a deductive approach can also be applied, aimed at identifying archetypes, which are recurrent patterns of relationships among questionnaire items.

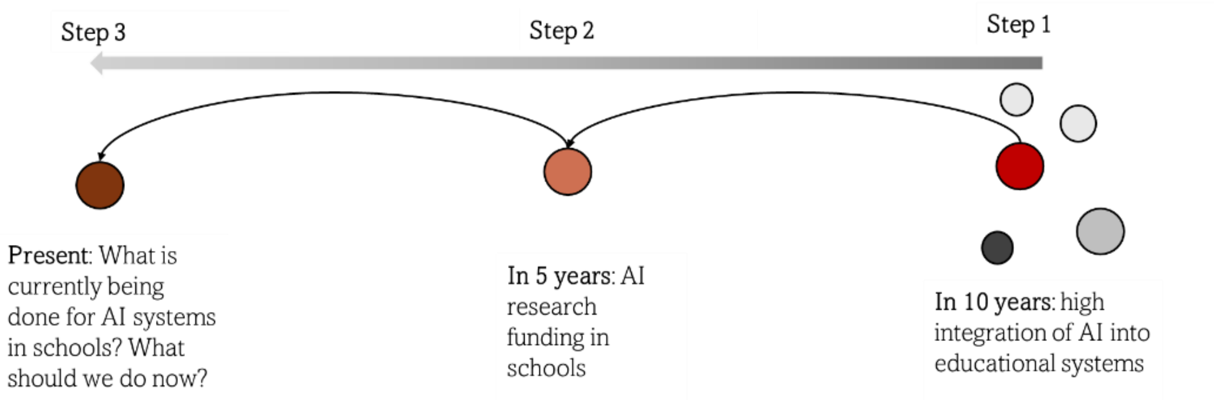
### *2.2. The backcasting*

A risk manager should possess the imagination necessary to anticipate key future possibilities. In a variable system, the ability to envision multiple future states ensures the system’s requisite variety – the capacity to provide diverse responses to the range of situations it may encounter (Hollnagel, 2024).

This requisite imagination is closely related to Anticipatory Thinking (AT), defined as the ability to envision multiple possible futures based on current knowledge (Klein, Snowden & Pin, 2011). AT enhances the capacity to foresee events and understand their potential consequences. The imagination of future scenarios should be grounded in how a system actually operates, drawing on present knowledge and past experience, rather than on idealized assumptions of how it is imagined to function (Klein et al., 2007).

Backcasting is a specific form of anticipatory thinking. It focuses on a desired future scenario – typically an ideal state to be achieved – and works backward in time to identify the conditions required to reach that scenario. Backcasting is commonly applied in the design of educational projects. For instance, educational planners might envision a scenario in which schools integrate AI tools into their programs within ten years. They then work backward to determine the conditions needed five years earlier, such as government investment in advanced AI systems for schools, and finally consider what actions can be taken in the present to enable this desired future (see figure 4).

**Figure 4. A visual example of backcasting within the educational field**




### *2.3. Framework for the development of the Weak-Signal-Driven Anticipation Method (WS-DAM)*

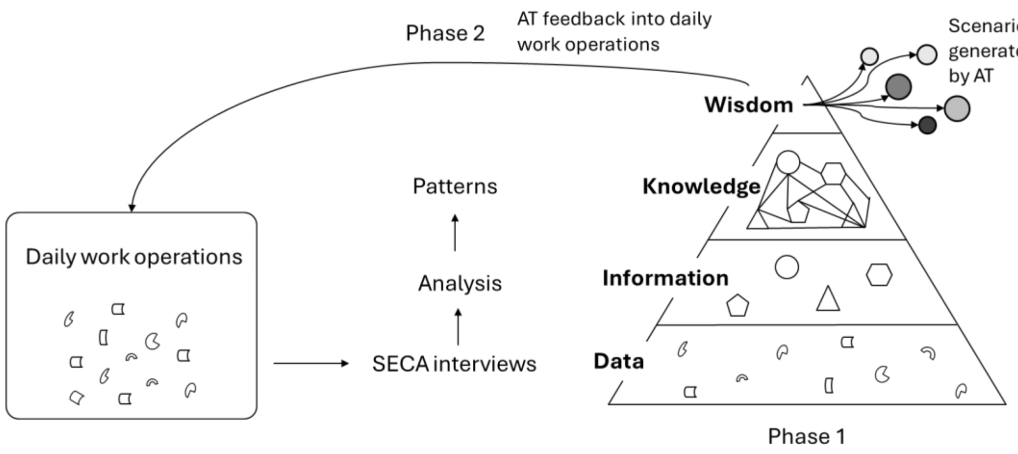
In this project, enhancing system safety means promoting organization's ability to convert knowledge about real work into wisdom through anticipation, allowing it to influence current operations and shape future outcomes. In this way, organizations adopt a proactive stance, implementing preventive measures before accidents or near misses occur (Hollnagel, 2014). The method presented in this study aims to transform knowledge about the daily functioning of a healthcare system into anticipatory insights – specifically, the creation of possible ideal alternative scenarios based on patterns observed in everyday operations through SECA. The goal is to support risk managers in developing strategies to improve the system, particularly in accident prevention.

This approach integrates SECA with backcasting. SECA uncovers knowledge embedded in everyday work by making explicit the tacit understanding within operators' routines. This tacit knowledge captures work-as-done, revealing the reality of daily operations beyond idealized or formal procedures. Backcasting transforms SECA findings into potential future scenarios and identifies effective strategies to achieve a desirable state (Geden et al., 2019).

Backcasting begins by envisioning different possible futures and then selecting the desired one. From there, the process works backward to identify the conditions required to achieve it. Unlike focusing solely on anticipating potential failures, backcasting explicitly incorporates the identification of desirable future scenarios. This distinction is crucial: while a weak signal approach might lead only to patching vulnerabilities, backcasting also emphasizes leveraging positive potential and enabling success. In this way, the method aligns closely with Safety-II principles, promoting proactive learning and improvement rather than merely avoiding incidents (Hollnagel, 2014). The method is carried out by risk managers in collaboration with frontline operators, ensuring an "ecological validity" of the decisions being planned. Ideally, these frontline operators are the same individuals who participated in the SECA interviews and therefore have a deep understanding of the context in which the interventions are intended to take place. The process helps identify strategies to effectively address pressures, conflicts, and trade-offs.

The method is thus organized in two phases. The first phase identifies patterns through SECA and the second phase transforms them into future scenarios that inform system improvements and actions to better manage the future. A visual summary is provided in Figure 5.

**Figure 5. The research structure into two phases (SECA + Anticipatory Thinking [AT])**




This process creates a circular workflow: daily operations are broken down into relevant data through SECA interviews and analyzed to identify current hazardous patterns. This knowledge is then transformed via scenario imagining, selection of an ideal scenario, and backcasting into actionable strategies for the present. In this way, improvement actions are operationalized, shaping present actions and restarting the cycle of learning and improvement.

In this way, SECA and backcasting are complementary: SECA provides the operational knowledge and patterns of weak signals necessary to ensure that the scenarios and interventions are grounded in the real-world context. This integration expands organizational knowledge by revealing connections and dynamics that would otherwise remain hidden, thereby enhancing the effectiveness of proactive learning and intervention design.

### *2.4. The first draft of WS-DAM*

In this section, the first draft of the method is presented, developed during the visiting period at TU Delft in the Netherlands. This draft will be further developed and refined with experts, and it may be redefined or even substantially modified.

The WS-DAM (Weak-Signal-Driven Anticipation Method) applies backcasting to shape future scenarios by identifying present actions. It allows safety experts to:

1. interpret patterns understanding future implications
2. transform them into ideal scenarios
3. select one ideal scenario, and
4. plan improvements to achieve it.

Leveraging SECA knowledge, managers and operators collaboratively develop multiple scenarios by sharing diverse perspectives, avoiding reliance on a single vision. The process begins by identifying patterns of weak signals and operational challenges revealed through the SECA analysis, which provides a detailed understanding of the actual day-to-day work practices and potential sources of risk. This empirical grounding ensures that the subsequent scenario-building phase captures the full complexity of the system. Once the optimal scenario is selected, the team applies backcasting to identify the key conditions and steps required to achieve it. Finally, participants define concrete, actionable steps that can be taken in the present to build these enabling conditions and, ultimately, realize the target scenario.

As noted in the previous section, backcasting is typically used in educational studies with temporal units, for example: *"What must happen five years before the chosen ideal scenario can be achieved?"* In this approach, however, system states in terms of fixed temporal units will not be explored. Instead, it is more relevant to think in terms of the conditions that enable an ideal future state, regardless of when they occur. In this sense, users "go back" by identifying the conditions that could make the desired future possible, without linking them to a specific timeline.

When identifying enabling conditions to achieve these scenarios, participants are explicitly asked to imagine them at three levels:

- Micro level: local/team level (tools, schedules, immediate leadership, training, etc.). For instance, readily available and fully functional patient lifting equipment (e.g., ceiling lifts) in every high-risk room, not just one shared across the ward.
- Meso level: organizational level (departmental coordination, HR policies, management systems, safety strategies, etc.). For example, the hospital's annual OHS budget explicitly includes a line item for upgrading and expanding the safe patient handling program.
- Macro level: broader systemic level (sectoral policies, regulatory context, funding, industry-wide norms). For instance, government OHS regulations that mandate minimum staff-to-patient ratios for units with a high number of non-ambulatory patients.

The method starts once SECA analysis has been completed and SECA patterns are available. It is then organized into four steps involving both risk managers, who conduct the analysis, and frontline operators.

a. Step 1: Preliminary phase
Workgroup formation**.** Risk managers assemble a group based on the relevance of their knowledge and their decision-making authority within the target unit. They also invite frontline workers to participate. When inviting workers, it is crucial to be transparent about the objectives and to build trust through a non-judgmental approach. SECA results may reveal procedural violations or adaptations, and the ultimate aim here is to support workers in their daily activities – not to control, punish, retrain, or reprimand them. This purpose must be clearly shared and agreed upon by all participants.
b. Step 2. Pattern recognition
Participants are presented with the SECA results. Through group discussion, they reflect on whether they recognize themselves in the identified patterns (especially for frontline workers who were involved in SECA interviews). This activates the recognition mechanism in anticipatory thinking, where personal experiences are confronted with collective ones. Such exchanges help stimulate the imagination of as many scenarios as possible (Klein, Snowden & Pin, 2011).
c. Step 3. Generation of ideal scenarios
Participants are asked to reflect on future situations where they would be better supported in managing trade-offs, pressures, and goal conflicts. The aim is to generate multiple positive scenarios – not to fix the past, but to envision desirable futures.
d. Step 4. Backcasting from the ideal scenario
Participants select one desirable future scenario and work backward to determine the changes required at the micro, meso, and macro levels to make it achievable. This step explicitly builds on the weak signals identified through the SECA analysis: by starting from these signals, the process ensures that the envisioned scenario reflects the actual operational patterns and potential vulnerabilities observed in daily work. The backcasting process then defines the enabling conditions and concrete actions needed to realize the target scenario, thereby addressing the patterns highlighted by the weak signals and translating them into proactive interventions.

## 3. Method

In this section method about this research will be presented, organised into two phases, the first one about the application of SECA into two units of the San Martino Hospital and the second about the plan for the development of WS-DAM through experts.

### *3.1. Phase 1: SECA application*

The first phase of this study involves collecting data on the daily work of three operating units across San Martino hospital using the SECA method (Patriarca et al., 2022). The purpose of this application is to assess whether SECA can be applied in the hospital context.

The Internal Medicine Unit and the Radiotherapy Unit were selected as the settings for data collection. Both units are under the responsibility of the same OHS Prevention and Protection Service (PPS) within the San Martino Hospital. They are not directly connected and follow separate processes, although links can exist, for instance when patients are transferred from one unit to the other.

The selection of these units was carried out in agreement with the San Martino PPS, which identified certain units as particularly problematic in relation to two specific risks that currently generate the highest injury rates in the hospital: biological risk and aggression risk. Biological risk refers to the potential exposure of healthcare workers to pathogens such as bacteria, viruses, or other microorganisms that can cause infection or disease, typically through contact with patients, biological fluids, or contaminated materials, and it also includes accidental needle sticks, cuts, and similar injuries (Descatha et al., 2023; Tejada-Pérez et al., 2022). Aggression risk refers to the possibility of healthcare workers being subjected to verbal or physical violence by patients or, in some cases, their relatives, a hazard that is increasingly recognized as a major occupational health and safety concern in hospitals (Civilotti, Berlanda & Iozzino, L. (2021).

From the units suggested by the Service, Internal Medicine and Radiotherapy were chosen because their level of complexity was suitable for SECA data collection. In particular, they met key criteria such as the number of workers (not too large, i.e., <50, and not too small, i.e., >10) and the type of activity (not as complex as the Emergency Department or urgent care units, where data collection would be difficult, and not too simple, where SECA might fail to capture meaningful patterns, such as purely office-based or administrative tasks).

**Participants**
The study participants were recruited through the PPS by contacting the unit coordinators. Access was granted by coordinator of nurses and healthcare assistants (HA) from the Internal Medicine Unit, and by a technical, nursing, and HAs coordinator from the Radiotherapy Unit, who acted as gatekeepers. A total of 21 interviews were conducted with nurses, technicians, and HAs. Specifically, the Internal Medicine Unit included 13 nurses and HAs, while the Radiotherapy Unit included 8 technicians, nurses, and HAs.

Data collection faced several challenges. Due to the high workload resulting from staff shortages, it was difficult to recruit a large number of participants, particularly for SECA interviews, which lasted approximately 40 minutes in the wards. Shift work, including night shifts, and a general reluctance to discuss incidents that might involve rule violations further limited participation. Consequently, not all staff agreed to participate, and several declined due to time constraints. Particularly, in Internal Medicine, 68% of the staff participated (13 out of 19 nurses and healthcare assistants). In Radiotherapy, 17% of the technicians participated (4 out of 24), and 67% of the nurses and healthcare assistants participated (4 out of 6).

Most participants had prior experience as nurses in other healthcare settings. Within Internal Medicine, recent hiring had occurred following a wave of retirements; thus many of the staff in this unit were relatively young. In contrast, personnel in the Radiotherapy Unit had greater experience within that specific setting.

A detailed description of the sample is provided in Table 7.

**Tab. 7. Sample characteristics**

| Department | Role | N | Average Years of Experience |
|---|---|---|---|
| Internal Medicine | Nurses | 10 | 3,4 |
| Internal Medicine | Healthcare assistant | 3 | 4 |
| Internal Medicine | Technicians | - | - |
| Radiotherapy | Nurses | 3 | 16,6 |
| Radiotherapy | Healthcare assistant | 1 | 2 |
| Radiotherapy | Technicians | 4 | 11,3 |

## Procedure

The project was presented to the units through PowerPoint presentations in multiple sessions with all personnel. Sessions were organized to accommodate staff work shifts and ensure maximum coverage. During these sessions, participants' willingness to take part was collected through personal contact. Interviews were then scheduled either online or face-to-face, according to participants' preferences.

Interviews had an average duration of approximately 30 minutes and followed the SECA interview protocol (see Tab. 8). They began by asking participants to describe an event that was neither an accident nor a near miss, but still related to safety, in line with a Safety-II approach. The interviews then explored different types of responses: those given by the interviewee, those typically provided by newly hired staff, and those by experienced professionals. They also addressed pressures from management, external sources, and colleagues, and finally examined whether conflicts between objectives and trade-offs had occurred. The interviews were semi-structured, allowing participants sufficient space to describe their experiences and perspectives. Each interview was recorded with the participant's consent, transcribed, and coded according to the grounded theory approach.

**Tab.8 SECA interview protocol**

| Code of Sector | Sector | Key Aspect Explored | Area Explored |
|---|---|---|---|
| 1 | Incident Description | Biological risk and aggression | 1 – Context |
| 1.a | Context | What happened, who was involved | 1 – Context |
| 2.a | Personal Response | How participant reacted | 2 – Responses |
| 2.b | Formal Procedure | Existence of procedures | 2 – Responses |
| 2.c | Colleague Response | Usual reactions in the unit | 2 – Responses |
| 2.d | Novice Behavior | How a new team member would act | 2 – Responses |
| 2.e | Experienced Behavior | How an experienced member would act | 2 – Responses |
| 3.a | Management Pressure | Pressures from management | 3 – Pressures |
| 3.b | External Pressure | Pressures from patients, families, other units | 3 – Pressures |

| Code of Sector | Sector | Key Aspect Explored | Area Explored |
|---|---|---|---|
| 3.c | Peer Pressure | Pressures from colleagues | 3 – Pressures |
| 4.a | Conflicting Objectives | Conflicts between personal, patient, and organizational goals | 4 – Conflicts |
| 4.b | Conflict Response | How conflicts were managed and which objective was prioritized | 4 – Conflicts |

## Analysis

Data analysis followed the grounded theory approach (Glaser & Strauss, 1967). Texts were segmented to identify specific actions, and initial codes were generated. These codes were subsequently grouped into categories and higher-level macro-categories to capture patterns and insights within the data.

In addition, a deductive approach was also applied, aimed at identifying archetypes, understood as recurrent patterns of relationships among questionnaire items. These archetypes were hypothesized during the design phase of the method, starting from the items of interest in the questionnaire, and were subsequently used as reference structures to guide the analysis.

## Results

The analysis is still ongoing to identify patterns; only preliminary results are presented here.

From Grounded Theory, several macro-categories were identified, as reported in Table 9. Some categories were observed in both units, while others were specific to a single unit.

**Tab.9 SECA results of the grounded theory**

| Macro Category | Description | Setting |
|---|---|---|
| Device and Material Issues | Difficulties with safety devices, needles, or materials such as test tubes. | Internal Medicine |
| Interference from Relatives During Therapy | Interruptions from relatives during therapy, inducing nurses to respond while handling risky tasks. | Internal Medicine |
| Informal Strategies to Reduce Distraction from Relatives | Informal coping strategies (e.g., pausing conversation, answering later) to avoid errors during therapy. | Internal Medicine |
| Operational Congestion Factors | Complex, unpredictable, or intensive clinical-organizational conditions slowing daily activities, generating task accumulation, overtime, or delays in critical diagnoses (e.g., infections). | Both |
| Patient, Relative, and Team Requests Managed by Expertise | Responses influenced by workload, type of task, risk perception, and level of expertise to preserve workflow and safety. | Internal Medicine |
| Communication Issues with Critical Safety Information | Absence of critical safety information (e.g., infectious diseases, patient aggressiveness), exposing staff to risks. | Both |
| Risky Behaviors Due to Organizational Issues | Exposure to biological or aggression risks due to missing procedures or absent safety information. | Both |
| Worker Conflicts | Tensions or misunderstandings between staff with different levels of experience, particularly seniors vs. new employees. | Both |
| Dependence of Less Experienced Staff on Experts | Inexperienced staff rely on experts in complex or critical cases, increasing experts' workload. | Internal Medicine |

| Macro Category | Description | Setting |
|---|---|---|
| Automation | Staff perform tasks automatically due to workload or contextual pressures such as interruptions by relatives. | Internal Medicine |
| Prioritizing Patient Over Safety and Protocols | Staff prioritize patient care or well-being over personal safety or procedural compliance. | Both |
| Staff Strategies in Response to Organizational Gaps | Staff voluntarily take on extra responsibilities or multitask to compensate for shortages or inefficiencies. | Both |
| Managing Inexperienced Staff | Organizational management of new hires, including training, onboarding, and integration. Inadequate support may compromise safety. | Internal Medicine |
| Organizational Failures in Identifying and Managing Infection Risk | Failure to identify and effectively manage infection risks in a timely manner. | Both |
| Increased Workload | Causes of increased workload, such as support for new staff, frequent exam requests, and other demands. | Both |
| Peer and Team Support | Collaboration, mutual help, and workload sharing among colleagues and teams. | Both |

The deductive analysis revealed recurring behavioral patterns, or archetypes, in how staff perceive and respond to their work environment. Archetypes combine individual experience, team competence, adherence to procedures, strategies for coping with organizational gaps, and responses to pressures and conflicts. They summarize how operators interpret and act within their professional context.

The predominant archetype is A13, the "experienced self in an experienced unit", typical of Radiotherapy, where staff perceive themselves as highly competent and operate within a cohesive, mature environment. Here, procedures are consistently followed, and decisions are guided by shared expertise and safety. In Internal Medicine, a more heterogeneous pattern emerges: less experienced operators work in a consolidated unit, carefully follow procedures, and rely on support from senior colleagues. Daily management requires balancing procedural adherence, high workload, and patient needs.

The most frequent thematic categories across both departments are increased workload, infection risk management, prioritizing patient care over personal safety or protocols, and strategies to compensate for organizational gaps. Internal Medicine emphasizes patient prioritization and workload, while Radiotherapy focuses on infection risk and workload. Adherence to procedures is generally high, especially in Radiotherapy, with deviations primarily occurring to address organizational gaps. Archetypes and categories also show procedure dependence: infection risk emerges when procedures are followed, while the inexperienced self in an experienced unit appears when they are not.

Pressures and conflicts between objectives are more frequent in Internal Medicine and more contained in Radiotherapy. Overall, Radiotherapy represents a mature and cohesive context, whereas Internal Medicine shows greater heterogeneity, strong ethical-professional orientation, and reliance on procedures. These insights provide a clear map of behavioral patterns and operational challenges, useful for training and organizational interventions.

## Discussion

This phase, through a case study in two hospital units, demonstrated that SECA, previously applied only in aviation, is applicable to healthcare, although with some limitations. Healthcare professionals often work under time pressure, making SECA data collection challenging, and PPS staff face constraints because the method requires many hours of interviews. Nevertheless, SECA revealed meaningful behavioral patterns. For example, in Internal Medicine, a nurse might face high workload and ethical dilemmas, such as deciding whether to prioritize patient care over strict procedural adherence while consulting more experienced colleagues. In Radiotherapy, a nurse may systematically follow procedures and coordinate complex treatments confidently, reflecting a mature, cohesive unit. These examples show how SECA can capture how staff respond to pressures, procedural demands, and organizational challenges in real clinical settings.

## *3.2.Phase 2: the WS-DAM development*

This section describes the method to develop the first draft of WS-DAM through experts.

**Method**

The WS-DAM method aims to integrate the SECA approach, which identifies weak signals in the form of patterns, with backcasting to support PPS in developing preventive actions for future accidents. A draft of the method was created to provide a framework and direction, showing a possible integration of SECA and backcasting, including elements such as worker involvement, scenario development, and collaborative approaches. For the actual development of the method, a qualitative variant of the Delphi method was chosen.

The Delphi method is a pragmatic research approach developed for policy-making, organizational decisions, and informing practice (Brady, 2015). It has been applied in organizational and safety contexts (Disconzi and Saurin, 2022). Traditionally, Delphi studies use questionnaires or mixed quantitative-qualitative methods. Fully qualitative Delphi studies are less common but have been applied, particularly in theory-building and community-engaged research.

Typically, Delphi studies begin with open or semi-open questions, which become more structured in subsequent rounds to verify consensus, test propositions, and finalize decision-making models. Standard Delphi studies usually involve three rounds: the first based on researcher-developed questions drawn from literature or existing knowledge, the second allowing participants to provide feedback on the first round's responses, and the third using prior rounds to reach final consensus. Additional rounds may follow if consensus is not achieved.

While qualitative Delphi studies vary, key features remain consistent, including purposive sampling, emergent design, anonymous and structured communication among participants, and thematic analysis. Participant expertise on the subject under investigation is one of the most critical requirements for Delphi studies.

**Participants (expert profile)**

The experts included in this study are selected for their extensive experience and recognized expertise in healthcare, covering both occupational safety and patient safety (quality). Experts have backgrounds in anesthesiology, healthcare quality, and organizational safety, offering a comprehensive perspective on safety challenges and strategies in healthcare contexts. Participants have substantial professional experience, often spanning multiple years in clinical and organizational settings. The sample is composed of international experts from different part of the world, such as Brazil, Australia, and the United Kingdom, ensuring diverse perspectives across different healthcare systems and practices. A list of experts to contact has been already created.

**Delphi method**

Each focus group includes a maximum of six participants to ensure in-depth discussion and interaction. Their engagement in research and practice within high-reliability and safety-critical healthcare systems contributes to the methodological rigor of the study.

The Delphi study aims to:

1. Explore how backcasting can be integrated with SECA results.

2. Understand how backcasting can be applied to real-world healthcare problems.
3. Collect suggestions and potential adaptations for the backcasting method based on SECA results.

The study involves at least three rounds with experts:

**Round 1 – Exploration Phase:**

- Establish a collaborative climate, allowing participants to introduce themselves and discuss their experiences.
- Present the initial version of backcasting applied to SECA results and collect feedback and suggestions.
- Provide preparatory materials and a brief training session on backcasting.
- Ask experts to propose potential solutions for integrating SECA with backcasting.

**Round 2 – Consolidation Phase:**

- Present an updated version of the method incorporating feedback from Round 1.
- Collect further suggestions and refinements from experts.

**Round 3 – Validation Phase:**

- Ask experts to assess and approve the final version of backcasting applied to SECA results.

## Conclusion and limitation

This phase, through a case study conducted in two units, showed that SECA – previously applied only in aviation – can also be applied in the healthcare context. However, SECA still presents limitations in hospitals, as it requires considerable time from participants for interviews, which are often a high demand in healthcare settings. Similar limitations can be observed for WS-DAM, which also requires significant time and engagement from PPS professionals.

Importantly, SECA allows going beyond traditional methods of collecting safety issues from frontline workers, using structured approaches that enable a deeper and more nuanced understanding of daily work and its challenges. This study contributes to building knowledge through SECA, not only by exploring current practices but also by fostering the imagination necessary for the system's required variety, enabling the use of knowledge from daily work to better prepare for future challenges (Hollnagel, 2024).

**Gantt for final data collection**

| | January | February | March | April | May | June |
|---|---|---|---|---|---|---|
| Round 1 | | | | | | |
| Round 2 | | | | | | |
| Round 3 | | | | | | |
| Data analysis | | | | | | |

**Study b – training**

This study focuses on training as a process of organizational learning. Training in Occupational Health and Safety (OHS) is widely recognized as a crucial tool for workplace learning, aimed at reducing injuries and promoting workers' health, particularly in high-risk organizations (Carnazzo et al., 2024; Haj-Bolouri, Katende & Rossi, 2024; Harikkala-Laihinen, Fäldt & Bäckman, 2024; Robson et al., 2012). It represents a key preventive measure and is commonly integrated into safety management systems (Freitas & Silva, 2017).

However, training has been little explored in the context of weak signals in OHS, leaving this area under-researched. This study therefore aims to understand whether training can foster organizational learning and whether it is possible to design specific training programs, based on weak signals, to promote training as a transformative tool for organizational learning. Specifically, the study is organized into two sub-studies addressing the following research questions:

- Q1.b: How do OHS training practices in hospitals make use of weak signals to support organizational learning, and how do different training approaches influence this process?
- Q2.b: How can a training program developed using a weak signals approach support organizational learning?

The first sub-study presents research on how training currently contributes to organizational learning. The second sub-study builds on this and focuses on designing training programs that will be implemented at San Martino Hospital between December 2025 and February 2026.

**Study 1.b – Q1.b: How do OHS training practices in hospitals make use of weak signals to support organizational learning, and how do different training approaches influence this process?**

**1. Introduction**

This study aims to explore how weak signals can be transformed into useful learning for Italian hospitals through training programs. Specifically, it seeks to examine the extent to which new safety approaches – particularly the Safety-II perspective, with its emphasis on weak signals and anticipation – are embedded in OHS training. Furthermore, it investigates how OHS training practices in hospitals engage with weak signals to foster organisational learning, and how internal versus external training approaches shape this process.

Traditionally, the content and objectives of international and organisational OHS training programs are largely focused on promoting safe behaviour in the workplace (Bęś and Strzałkowski, 2024; Liu & Li, 2022), preventing operator errors (Kabiesz, 2024), and ensuring compliance with safety procedures (Abaya & Ondieki, 2021; Walters et al., 2021); however, in recent years, such programs have increasingly been criticied by a growing number of scholars for their simplistic view of human behaviour as something that can be shaped and aligned with procedures, according to a Safety-I perspective (Laberge, MacEachen & Calvet, 2014; Liu & Li 2022; Peñaloza et al., 2019). In this sense, a training model focused solely on error prevention and behavioural control fails to equip workers with the skills needed to interpret weak signals, manage variability, and act resiliently (Peñaloza et al., 2019). Safety-II paradigm highlights a critical gap in traditional training approaches and calls for a shift towards models that support resilience performance (Hollnagel, 2014).

Safety-II paradigms open up new opportunities for training aimed at proactivity - emphasizing anticipation and preparation through weak signals - rather than focusing solely on compliance and error avoidance (Curcuruto et al., 2024; Mezentseva et al., 2023; Sorrentino & Stabile, 2024). Many organisations are introducing resilience and mindfulness programs to help workers manage stress and reduce the impact of future stressors (Parsakia & Tabar, 2024). However, as Ketelaars and colleagues (2024) observe, OHS training oriented toward resilience is still largely centered on the individual's reaction to stressors, rather than on anticipating unexpected critical events at an organisational level. OHS training remains far behind other safety training approaches – for example, the use of simulator-based training in the maritime industry to recreate variability in high-risk procedures (Wahl, Kongsvik & Antonsen, 2020), or the implementation of strategies to detect early signs of patient deterioration before escalation in pediatric hospitals, where staff are trained to momentarily pause and reflect on what is happening and what might happen next (Bartman et al., 2021).

Yet, equipping workers with the ability to detect weak signals is only part of the solution to make organisations capable of anticipating potential situations; it does not ensure that these signals are communicated to management or that timely preventive measures are triggered (Brizon & Wybo, 2009). The key challenge for organisations lies in transforming this information into actionable organisational learning. Organisational learning is the process of acquiring knowledge through social interactions at the group and organisational levels, leading to an increase in collective knowledge that can drive change within the organisation (Bratianu, 2015). Knowledge sharing is a form of active learning that occurs through interaction among people, who exchange experiences and connect new information to what they already know. When designed to value workers' real-life, training becomes fertile ground for sharing experience, revisiting and reshaping it through new perspectives and collective reflection (Goldstein, 1980; Lukic et al., 2010; Knowles, 1978; Kolb, 1984; Wahl et al., 2022). Reflection supports workplace learning by helping professionals make sense of daily experiences through a conscious cognitive process (Kolb, 1978). Knowles' (1978) theory of andragogy emphasizes the value of building on workers' experience and promoting self-directed learning, where individuals reinterpret knowledge to apply it in their work (Bratianu, 2015; Garvin et al., 2008; Jones et al., 2021; Cotton, 2021; Hetzner et al., 2015; Kolb, 1978). Since OHS training has this potential, we aim to observe it as a space for weak signals – a setting where these signals can be revisited and collective awareness fostered. In this study, the term "learning" refers not only to the acquisition of knowledge and skills predefined by the organisation and delivered through formal training, but also to an opportunity to share and reflect on operational practices, promoting collective understanding and organisational learning.

Thus, two important aspects within training programs should be taken into account to foster learning through weak signals in hospitals. On the one hand, it is necessary to examine how training is delivered: despite the growing attention to Safety-II in the literature, little is known about how OHS trainers actually embed its principles into hospital training practices. While weak signals are a key element of Safety-II, they are not the only one, and this study focuses specifically on them. On the other hand, the challenge lies in understanding how training practices support the transformation of weak signals into organisational learning, moving beyond individual recognition towards collective interpretation and preventive action (Andoh et al., 2022; Casey et al., 2021; Freitas & Silva, 2017).

A key role in promoting new safety approaches within training and organisational learning is held by OHS trainers. OHS trainers play a crucial role in promoting health and safety (Burke & Hutchins, 2008; Casey et al., 2021; Harikkala-Laihinen, Fäldt & Bäckman, 2024). Their role often ranges from transmitting skills necessary for performing critical operations in the field (Nielsen et al., 2024; Li & Pilz, 2023) to fostering attitude changes that support a more positive safety culture (Bęś & Strzałkowski, 2024; Jones et al., 2013). They are regarded as facilitators of active, self-directed adult learning, capable of creating a collaborative and stimulating environment, and guiding learners in exploring knowledge independently (Knowles, 1978). This is especially important when training programs aim to transform attitudes and mindsets (Jones, Gait & Tyson, 2024). Trainers are also essential in orienting the organisation, especially when they are internal since they can develop ongoing training programs and observe their long-term effects across the organisation (Freitas & Silva, 2017). They can contribute to create a collaborative and stimulating climate and guide learners in exploring knowledge autonomously, learning in turn from the exchange that occurs during training. By designing programs and influencing participant motivation, trainers can support organisational learning. Their effectiveness, however, may depend on their role within the organisation. Internal trainers, for instance, being familiar with organisational processes and culture, can align training with company needs and follow up more effectively (Freitas & Silva, 2017). External trainers, while typically less embedded within the hospital context, may offer a neutral perspective that encourages openness and critical reflection

(Bushardt, Fretwell, & Byrd Cumbest, 1994; Piyali Ghosh et al., 2012; Woźniak & Anczarska, 2018). Their external position can facilitate discussions that might be constrained in internal training sessions due to hierarchical dynamics or organisational culture, thereby supporting more effective knowledge sharing and learning (Freitas, Silva & Santos, 2017).

In this study we aim primarly to assess the extent to which Safety-II approaches are being adopted by Italian OHS trainers and secondly how safety-related weak signals can be transformed into organisational learning by OHS trainers within Italian hospitals.

The Italian hospital setting offers a useful case for examining how trainers can facilitate this transformation into organisational learning. In Italy, OHS training within hospitals is typically conducted by internal trainers, such as staff from the Prevention and Protection Service, who oversee risk analysis and propose corrective actions. A smaller portion of training addresses non-technical skills – like communication and situational awareness – usually provided by external consultants with limited knowledge of the organisation and no authority over safety decisions. Programs specifically targeting weak signals remain rare in both cases, leaving this area largely unexplored in hospital settings. In addition, in both cases, the formal training goals are concerning the transfer of knowledge and skills into workers, rather than an opportunity for sensemaking and knowledge elicitation. The coexistence of internal and external trainers, with distinct goals and approaches, offers a valuable opportunity to examine different organisational learning strategies and their relative effectiveness.

Specifically, this study is organised into these three sub-research questions:

Q1. To what extent are Italian OHS trainers aware of and reflective on Safety-II elements, particularly those related to anticipation and the recognition of weak signals?

Q2. How do OHS trainers in Italian hospitals transform weak signals into organizational learning?

Q3. How do different modes of training – led by OHS internal trainers versus external trainers – differ in their contribution to transforming weak signals into opportunities for effective organisational learning?

Accordingly, their reflexivity regarding such forward-looking safety dimensions has been explored. This allows for the evaluation of their sensitivity to evolving orientations in health and safety, including the recognition and interpretation of weak signals. Given that current health and safety paradigms emphasise the importance of adopting Safety-II principles and focusing on weak signals, engaging dialogue with trainers was conducted to explore the extent to which these concepts are embedded in their understanding of health and safety. This allowed for preliminary hypotheses for the development of future train-the-trainer programs. As a result, one of the main outcomes of this study is the definition of practical guidelines and recommendations for trainers involved in designing and delivering such programs.

Additionally, results advance an integrated model that positions training not merely as a site for individual skill acquisition but as a learning space where experiential knowledge becomes collective insight. In doing so, it provides new evidence on the organisational conditions and pedagogical strategies that facilitate learning from everyday work practices in high-risk settings.

## 2. Method

### Participants

The participants were internal and external OHS trainers from the Italian healthcare context. Internal trainers, in addition to their teaching role, also served as Occupational Health and Safety Officers (RSPP and ASPP). External trainers, on the other hand, are consultants who work across multiple contexts beyond healthcare. Most internal trainers had heard of weak signals and Safety-II before, but they were able to conceptualize these concepts through examples. External trainers possessed greater knowledge of weak signals, but this knowledge was largely self-acquired rather than gained through formal training, whereas internal trainers had less knowledge and experience with weak signals, reflecting a lower level of innovation in hospitals in this regard. None of the internal trainers had conducted training specifically on weak signals, whereas some external trainers had. A summary table below (Tab.10).

**Tab.10. Summary of participants features**

| Trainer Type | Avg Experience (years) | Main Organisation | Main Training Methods | Online (%) | WS Training (%) | Prior WS Knowledge (%) | WS Knowledge Source |
|---|---|---|---|---|---|---|---|
| Internal | 16 | Hospital / ASL | Lectures, some hands-on | 70% | 0% | 10% | Personal experience |
| External | 22 | Various | Role play, gamification, interactive exercises | 0% | 30% | 40% | Individual study / awareness sessions |

**Analysis**

The interviews were recorded and transcribed, and their content was subsequently analyzed using Braun and Clarke's (2006) Reflexive Thematic Analysis (RTA). Themes were generated regarding how trainers reflected on Safety-II elements in their training (Q1) and how they transformed weak signals into organisational learning (Q2). Themes were derived inductively from the entire dataset, without distinguishing between internal and external trainers. For Q2, the themes were then organized into a framework and enriched with relevant literature, and a framework analysis was conducted to examine differences in how internal and external trainers transform weak signals into organisational learning (Q3). The results for Q1 and Q2, as well as the preliminary findings for Q3, will be presented.

## 3. Results

### *3.1. Q1*

**Theme 1.1. Situated capacity to recognize weak signals**

Trainers highlight that the ability to recognize weak signals varies according to role, experience, and the perspective from which the system is observed. The position held within the hospital influences sensitivity to signals: doctors, due to their responsibilities and central clinical role, perceive them less, as they have fewer opportunities to be in direct contact with operations. Health Assistants have difficulty noticing them because of their mindset, while nurses, immersed in daily management, detect them more easily, also thanks to their professional education more focused on identifying critical issues.

"*So, I'd say that… doctors, partly because of a sense of superiority (cannot see weak signals) […] and the Health Assistants because of a low level of schooling do things very automatically and therefore with little ability to reflect on what they do […] The nurse being in direct contact with all the risks, notices them more… I'd add especially the younger ones… they are more trained when they start and they find themselves in a work context that leads them to notice these things.*" (Internal trainer, medium experience)

Individual experience can be ambivalent: it allows subtle anomalies to be recognized, but habit can normalize them, making people "numb" to the context and thus no longer able to see weak signals:

"*Good question. In my opinion it's a mix of both (a lot of experience and little experience) […] the moment you think about it, you start to see them all, it's a bit like the monkey (the Inattentional Blindness experiment, if you've seen the experiment, the next time you'll see the monkey, like the workers who gain experience in a context), right?*" (Internal trainer, medium experience)

*“[…] a couple of fresh eyes that have never seen anything of that process are maybe more used to noticing… in a company… those who worked there instead by now took these things for granted.*” (External trainer, high experience)

The detection of weak signals requires a systemic and collaborative perspective, integrating interactions among operators, procedures, the environment, and patients’ lived experiences, in line with the Safety-II approach (Hollnagel, 2014; Curcuruto et al., 2024).

“*If you just stick to the 81 regulation (the regulation in force in Italy on OHS), do your own part, but then you’re missing a piece […] if the surrounding conditions go wrong, then it affects the patient, creating tension for my operator who if they are under tension […] it’s a problem.*” (Internal trainer, medium experience)

**Theme 1.2. Training as a space for experience and reflection**

*“People have models, that is, theories of how their own context works, and they bring them into the classroom. Their models, their worldviews are different from theory because they are operational, true, real.” (External trainer, expert)*

The trainers agree that hospital training is not merely the transmission of abstract knowledge, but a space connected to the concrete experience of workers. In the classroom, participants bring operational models derived from managing everyday complexities, often different from theoretical ones. Training thus becomes a place where models are tested and enriched:

*“Every model I have tested with people, and people create better models every day, people already have a model.” (External trainer, expert)*

Collective discussion is fundamental for addressing ambiguous weak signals, testing intuitions, and validating perceptions:

*“There is something, but since I am limited (referring to human beings and cognitive limits), we are all limited. I (the learner) perceive that something is wrong and I verify it in training.” (External trainer, expert)*

This approach goes beyond traditional technical-bureaucratic training focused on compliance, instead enhancing the value of learners’ experience. The trainer acts as a facilitator, encouraging dialogue and shared reflection:

*“Trainers must be competent facilitators, authoritative but not intrusive.” (External trainer, expert)*

**Theme 1.3. Training as a laboratory for operational skills for weak signals**

*“It is natural to perceive, then you cannot understand the meaning of what is needed to search for everything and everything […] so in the classroom we refine our ability, it is like cleaning the lenses well.” (External trainer, expert)*

Training does not only transfer theoretical knowledge but also allows the refinement of operational skills and the development of new ones, rooted in real experience. Operational skills include the ability to detect weak signals, which must be continuously tested and verified.

Some interviewees emphasize how training is still often driven by regulatory compliance:

*“Very often training activities are carried out to achieve legislative compliance […] it is never taken for granted that training actually works.”* (External trainer, expert)

Instead, training should support workers in recognizing and interpreting weak signals, strengthening critical awareness and anticipatory capacity:

*"A weak signal should allow individuals to intervene […]"* (External trainer, expert)

The process integrates both technical and transversal knowledge (communication, risk perception, self-awareness), transforming individual experience into collective knowledge and fostering organizational learning:

*"We read the data together and compare it with what could have happened […] we can avoid repeating the same mistakes."* (External trainer, expert)

**Theme 1.4. Training as support within a context that rarely listens**
*"It is not just training, it is a moment of sharing." (Internal trainer, medium experience)*

In organizational contexts where weak signals often go unheard, training becomes the primary space for expressing them. Workers bring their own perceptions into the classroom, finding a protected environment where they can test them without fear of being discredited:

*"In a simple context, communication is enough; in a context of isolation or hostility, instead, it becomes necessary to build bonds and relationships."* (External trainer, expert)

*"The problem is not that the worker does not perceive weak signals, it's that they do not know who to talk to. [...] They perceive all of them, but sometimes they overestimate them, sometimes they use them strategically for other things; the key is being able to discuss them with someone who can help."* (External trainer, expert)

Training not only fosters sharing but also stimulates concrete proposals for intervention:

*"Training becomes a place where weak signals are transformed into constructive dialogue and concrete proposals for improving organizational safety."* (External trainer, expert)

In the absence of organizational tools, it becomes essential to support the transition toward a Safety-II perspective, transforming individual intuitions into collective actions.

### *3.2. Q2*

Q1 points toward rethinking training not merely as a space for knowledge transmission, but as a context for dialogue, reflection, and the shared construction of meaning.

In particular, Theme 1.4 raises the issue that training should support organizational contexts that tend to pay little attention to weak signals, thus assuming the role of a privileged channel for bringing them to light and transforming them into actionable resources. In this sense, training becomes not only a moment of individual learning but also a collective device capable of generating organizational learning.

In the following themes, it will be shown how organizational learning is concretely created from weak signals, which, once shared and discussed, are transformed into collective knowledge and improved practices.

**Theme 2.1 Training as a collector of weak signals**
*"If we go back to training, yes, it is definitely a tool that can have its function in terms of spreading weak signals. [...] Just as with near misses, where participants report them and then action is taken, the same can be done with weak signals, collecting them in the classroom and transforming them into concrete actions."*
(Internal trainer, medium experience)
Training functions as a system for collecting weak signals, allowing them to be identified, shared, and transformed into actionable items, just as with near misses. In the classroom, participants bring signals of varying intensity, from the most obvious to the most subtle, and the trainer's role is to record, filter, and transform them into shared knowledge, creating an operational context in which weak signals become tools for improvement.

*“[During training] they report everything, from very strong signals to very weak ones.”* (Internal trainer, expert)

*“Absolutely, absolutely, since there was a lot of interactivity, people had to express their own difficulties and challenging situations [...] for example, the nephrology department theoretically had five doctors, but in practice there was only one in service, because the others had retired or there had been no turnover [...] across three hospital sites.”* (External trainer, expert)

As highlighted in the last theme of Q1 (Theme 1.4), training collects weak signals when the organization does not listen, creating a protected environment where workers can share their perceptions and develop social bonds. In this space, signals that are perceived but not reported emerge and can be transformed into concrete operational practices.

The trainer plays a multifunctional role: collector, direct detector, filter, and transformer of weak signals. They bring out weak signals that workers perceive but might not report, stimulating discussion and reporting. In this way, they contribute to the creation of organizational learning, transforming collected signals into shared knowledge and improved practices.

This role goes beyond traditional training functions and connects to other safety roles (RSPP, ASPP), showing how the trainer operates both as a receiver and a facilitator of weak signals within the system.

**Theme 2.2. Training as a link between reporting and intervention**

*“When I see that there is something (reported by learners during training) that I cannot address at that moment for many reasons, whether due to time constraints, classroom dynamics, or other factors, I don’t write it down, and at the first opportunity I go see them, I check it. That is my technique. Just to also convey the message that if you tell me something, it doesn’t remain in the air.”* (Internal trainer, medium experience)

This statement highlights a critical function of training: it is not only a space for identifying and discussing weak signals, but also creates a direct connection between reporting and concrete intervention. The trainer plays an active role as a link between what is perceived and what can be managed operationally. Signals raised in the classroom are not left unresolved but are collected, monitored, and followed up in the workplace. In this way, training becomes a dynamic process that ensures insights do not remain theoretical or confined to discussion, but translate into real organizational action.

Training thus functions as a safe environment where participants can report weak signals without fear of judgment or inaction (Theme 2.1). Even when immediate intervention is not possible due to practical constraints, the trainer’s follow-up ensures these signals are eventually addressed, reinforcing trust in the reporting system. This mechanism also encourages active participation from learners, who understand that their observations are meaningful and can lead to tangible changes.

By acting as a bridge between reporting and intervention, the trainer also fosters organizational learning: repeated cycles of signal collection and feedback allow the organization to recognize patterns, identify risk areas, and implement preventive measures. The classroom thus becomes a living interface between operational reality and the organizational response system.

**Theme 2.3. Training as a catalyst for social learning and empowerment**

*“People [in training] challenge themselves a little, and this has to happen in a group discussion where participants, seeing that others are also questioning their own points of view, become more willing to do the same. In my opinion, this is psychosocial training: the major difference between purely informative training and real training. The group plays a fundamental role in helping the individual change and question themselves, and if the discussion is productive, the group itself may even restructure a concept or principle.*

*[...] If reflected upon and properly discussed, it can become an opportunity to make a report, to provide proactive signals, and so on. The main function of the group is this."* (External trainer, expert)

Training can become a moment of genuine learning from weak signals, but this happens primarily when participants are actively involved and engage in group discussion. Psychosocial training differs from purely informative training because it challenges participants, making them reflect on their own points of view while observing others do the same. This create reflexive skills, useful for recognizing weak signals outside the training setting.

In this context, the group plays a crucial role: it not only helps each individual restructure their ideas and concepts, but it also transforms potential problems or weak signals into concrete opportunities for frontline action, promoting learners' empowerment. When classroom discussion is productive, it encourages participants to generate proactivity, surfacing solutions or signals that can be applied in the operational context.

However, this process works best in groups of colleagues who share the same work environment. In the case of inter-company training, participants do not have pre-existing social ties, so the ability to transfer weak signals identified in the classroom to the real context is more limited.

*"It is different depending on whether we are talking about inter-company training or training conducted within a company [...] In inter-company training, there is still the added value of engaging with other companies, practices, and cultures, but then you have to translate everything into your own individual experience. You can be an agent of change, it depends a lot on your leadership, etc., but there is an additional difficulty. Conversely, if the group that has discussed a topic, a weak signal, or a risk is composed of colleagues, it opens the door so that when people return to work, after hours or days, they can use social ties to reflect on the weak signal and create empowerment."* (External trainer, expert)

Inter-company training provides value through comparison with other practices, cultures, and companies, but the practical application of the signals collected depends heavily on individual experience and leadership capacity. Conversely, when the group consists of colleagues, discussion helps create social bonds that facilitate the use of weak signals outside the classroom, transforming them into operational learning and genuine empowerment.

*"Yes, of course, especially in the basic fire course. We explain it immediately because it is a weak signal that can evolve into something negative or otherwise, and how it could be, the prevention and protection measure, call it that, or the way to manage it better. Also, because that is a course, but it also touches the home sphere, so many weak signals come from home; people are therefore much more attentive, managers, supervisors"* (Internal trainer, medium experience)

Training is therefore not merely the transmission of knowledge; it creates individual and organizational learning, encourages participation, fosters proactivity, and strengthens the social bonds necessary to apply what has been learned in the operational context.

### *3.3. Q3*

These are the preliminary results of the framework analysis, which is still in progress.

**Internal trainers – collecting and acting on weak signals**

*"The trainer must know how to listen and decide; if they know how to listen, they also hear the weak signals. Then, if they are an internal trainer, they have the possibility to act. I imagine that an external trainer uses it*

*as experiential knowledge for future training sessions, but there is little they can do."* (Internal trainer, medium experience)

Internal trainers build organizational learning by acting directly on weak signals when these fall within their responsibilities as Safety Officers (RSPP or ASPP), or by referring them to the appropriate services. In this way, each signal becomes an opportunity for organizational learning.

*"Yes, absolutely. So, the prevention and protection service, when it receives reports in training, if it can address them directly, it does; if it cannot, it must report them to someone else who can intervene, because it depends on the issue, there are different structures handling various areas. But every time we act directly, the worker always thanks us. Unfortunately, when we cannot act directly and have to pass it on to someone else, this responsibility is often not picked up."* (Internal trainer, high experience)

The dual role of internal trainers as both RSPP or ASPP and as trainers ensures that training becomes a container for weak signals, functioning similarly to a reporting system, which is otherwise absent in hospitals that primarily rely on near misses. Internal trainers stimulate organizational learning by collecting weak signals during training and bringing them back to the operational context through direct interventions or by reporting them to the relevant services.

**External trainers**

**External trainers – using weak signals as learning material**

*"At that moment, when the worker tells me and reports it, the first thing I do is ask everyone else present in the classroom what they think; I'm not alone in this anyway, but it's an opportunity for everyone to reflect on these aspects."* (External trainer, expert)

For external trainers, the role regarding weak signals is different from that of internal trainers. They have less power to intervene directly on the signal, as they are not internal safety figures within the hospital. Consequently, the signal is not taken outside the training classroom but remains within it, becoming content and learning material for the participants.

*"I am not the person who perceived the weak signal and can act on it, because the signal itself remains there; it is the person who detected it who can then contextualize the signal, creating situations where the signal is highlighted or valued."* (External trainer, expert)

In this context, the weak signal becomes a learning tool: it allows participants to revisit it, develop reflective skills, and better understand the signals surrounding them in their operational context. Moreover, it contributes to building empowerment, fostering the participants' ability to act concretely on the signals they observe.

## 4. Discussion

Results show that, when the organization does not actively listen, training becomes the space where weak signals find a voice and, consequently, a concrete tool for organizational learning. These signals emerge directly from workers' daily experience and are brought into the classroom, where they can be shared, discussed, and collectively interpreted. This process allows situated knowledge, often divergent from the work-as-imagined described in formal procedures, to be transformed into an understanding more aligned with the work-as-done, that is, what actually occurs in everyday operational practices (Hollnagel, 2014).

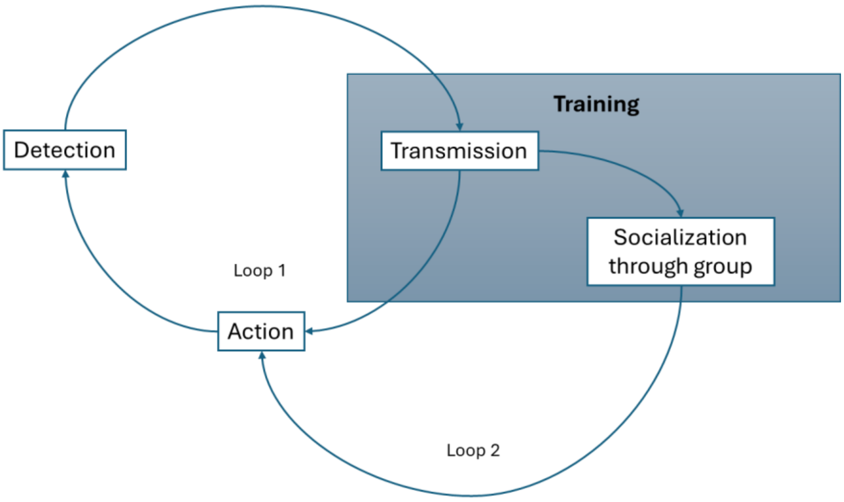
Training thus acts as a container for weak signals, similar to a reporting system but with distinctive characteristics. However, as highlighted by trainers, the value of training does not lie solely in the transmission of information but in the ability to stimulate participants' critical reflection in a group context. In this context, the group plays a central role: it fosters the restructuring of participants' ideas and transforms problems or weak signals into concrete opportunities for intervention, stimulating proactivity and solutions applicable at work.

This process is particularly effective in groups of learners who are also colleagues, as social ties facilitate the transfer of weak signals from the classroom to daily practice. In inter-organizational training, where participants do not have pre-existing connections, the transfer to the real context is more limited.

In the absence of formal reporting channels, such as those used for near misses, training becomes a safe space where workers can share, clarify, and report weak signals. Internal trainers support a virtuous loop similar to the one sustained by formal reporting systems: “detection → transmission → action.” The operator detects the signal, the trainer collects and transmits it, and the organization intervenes, generating operational learning. In hospital contexts, where formal systems for weak signals are lacking, training itself functions as a reporting system, ensuring that the cycle is completed and the signal is valued.

External trainers, on the other hand, stimulate a different loop: they socialize weak signals within the group, fostering empowerment and collective action. In this case, action arises from the bottom up, through sharing and group reflection, contributing to the development of a reporting culture and strengthening organizational learning through participation and critical thinking. An integration of the two loops should be done (see Fig. 6).

**Fig.6. The integration of the internal trainer loop with the external trainer loop**




Training emerges as a powerful tool to stimulate organizational learning from weak signals, but its effectiveness depends on the integration of multiple levels. The internal trainers collect signals and intervene on them directly, while the external trainer stimulates sharing and critical thinking, ensuring that information is not lost. In this way, training is not just knowledge transmission but becomes a community of practice and a space for empowerment, generating individual and organizational learning simultaneously. This means that an integration of the two loop is needed.

In this sense, it is crucial to develop train-the-trainer programs that can support these loops, also introducing training on weak signals within hospitals. The training objectives inevitably shift from the mere transmission of knowledge and skills to aspects such as the emergence of critical data from operators, the development of empowerment, and so on, with much less direct intervention from the trainer, who primarily acts as a guide for the material brought by the learners.

In this regard, it is essential both to train the trainers – equipping them with key competencies such as group facilitation, the ability to notice weak signals themselves, understanding the meaning of signals, and communication skills to provide effective feedback – and to train learners in capacities such as critical and systemic thinking to detect and understand weak signals. This implies developing non-technical skills that go beyond the classic classification by Flin and O'Connor (2017) (situation awareness, decision making, communication, teamwork, leadership, assertiveness, adaptability, stress management), extending into areas such as critical and anticipatory thinking, reflexivity, mindfulness, and similar.

Table 10 below presents a summary of a possible train-the-trainer program, which will be refined and implemented in Study 2.b.

**Tab.10. A summary of a train-the-trainer program**

| Training Objectives | Training Methods | Trainer Competencies | Learner Competencies (Non-Technical) | Loop Integration |
|---|---|---|---|---|
| Detect and interpret weak signals in hospital contexts | Role-plays based on real cases, operational simulations, systemic observation exercises | Observation and detection of weak signals, systemic thinking, understanding organizational dynamics | Situational awareness, critical thinking, anticipatory thinking, attention to context | Internal loop: trainer collects and interprets weak signals; External loop: trainer facilitates group reflection and discussion of signals |
| Transform weak signals into collective knowledge and actionable organizational learning | Guided discussions, reflection groups, post-simulation debriefs | Facilitation of group reflection, linking signals to organizational action, active listening | Knowledge sharing, collaborative problem-solving, reflection on everyday practices | Internal loop: trainer channels signals into actionable recommendations; External loop: learners collectively discuss and validate insights |
| Promote empowerment and proactive behaviors | Collaborative brainstorming, role-plays, analysis of near misses | Leadership in action, ability to intervene on signals, stimulate active participation | Decision-making autonomy, initiative, proposing interventions, proactive mindset | Internal loop: trainer acts on weak signals directly when possible; External loop: trainer stimulates group reflection to generate new ideas and solutions |
| Foster reflexivity and anticipatory thinking | Case analysis, scenario simulations, group reflection exercises | Guiding reflective exercises, prompting anticipation of potential issues | Reflexivity, systemic thinking, anticipation, mindfulness | Internal loop: trainer models and reinforces anticipatory thinking; External loop: group develops shared awareness and foresight |
| Strengthen social learning and collective sensemaking | Peer discussion, collaborative problem-solving, experiential exercises | Creating psychologically safe spaces, facilitating dialogue, encouraging knowledge sharing | Communication, teamwork, perspective-taking, empowerment | Internal loop: trainer ensures signals are noted and followed up; External loop: group interprets and applies signals collectively |

## 5. Conclusion

In conclusion, this train-the-trainer program emphasizes the dual role of trainers in hospital OHS contexts: not only as active agents who collect and act on weak signals (internal loop), but also as facilitators who foster group reflection, social learning, and empowerment (external loop). By focusing on non-technical skills such as critical thinking, anticipatory awareness, reflexivity, and communication, trainers can transform everyday operational observations into collective organizational knowledge. This integrated approach ensures that training becomes both a space for immediate action and a catalyst for long-term organizational learning, promoting a proactive and resilient Safety-II culture within hospitals.

## Study 2.b. – Q2.b How can a training program developed using a weak signals approach support organizational learning?

Study 2.b aims to present the design of a train-the-trainer program based on a weak signals approach and to evaluate its potential, although the training has not yet been delivered (see Gantt below). Study 1.b highlighted the crucial role of training in fostering learning from weak signals, revealing the existence of two distinct loops that support organizational learning: the internal loop, in which the trainer collects and acts directly on signals, and the external loop, in which the trainer facilitates collective reflection and participant empowerment. Integrating these two loops is essential, as it allows signals to be translated into concrete actions while also developing workers' ability to actively participate in safety, increasing their agency and collective awareness. However, currently the two loops remain separate and are generally associated with either internal or external trainers, making it necessary to develop train-the-trainer programs capable of integrating them effectively.

**1. Introduction**

Transformations in work driven by technological innovation, automation, and social changes accelerated by the COVID-19 pandemic have created an urgent need for large-scale reskilling and upskilling (Li, 2024; Mishiba, 2024). According to the World Economic Forum's Future of Jobs Report 2020, half of the global workforce would require skills updating by 2025 (Schwab & Zahidi, 2020). This situation calls for a rethinking of learning contexts to provide everyone with the opportunity to develop the skills necessary to fully participate in contemporary work (Li, 2024).

Even within occupational health and safety, traditional hazards (chemical, physical, biological, ergonomic) coexist today with more complex risks arising from organizational changes, stress, overload, and irregular schedules (Schulte et al., 2022). The traditional biomedical model, although effective in the past, proves reductive in high-risk, interconnected contexts, as it addresses hazards individually without considering interactions between organizational, social, and psychological factors. This complexity requires systemic and holistic approaches, as well as a reorientation of professional education in OHS (Schulte et al., 2022).

In the healthcare context, these pressures are compounded by socioeconomic factors, budget cuts, and challenges amplified by the COVID-19 pandemic, which exposed workers to high levels of stress, anxiety, burnout, and post-traumatic disorders (Ashari, 2022; Sethi, Chaturvedi & Kataria, 2023). Ensuring both patient and worker safety increasingly requires investing in workers' capacities to develop and leverage their knowledge, skills, and critical judgment to navigate adversity and seize opportunities in highly complex and dynamic environments (Sethi, Chaturvedi, and Kataria, 2023; Staiger & MD).

Traditionally, training is conceived as a transmissive process, in which participants play a passive role and receive predefined knowledge and skills. However, evidence from Study 1.a suggests that new approaches to safety training should make people active participants in their learning process, transforming training into a space for organizational learning, where the collection of weak signals and collective reflection generate shared knowledge and empowerment. In contexts where formal reporting systems are lacking or ineffective, training becomes an essential opportunity to give workers a voice, foster participation, and stimulate the generation of proactive behaviors.

Thus, it is crucial to understand how a training program developed using a weak signals approach can effectively support organizational learning. The following research question is thus formulated:

Q2.b: How can a training program developed using a weak signals approach support organizational learning?

Accordingly, this study will present a draft of the intervention and describe the planned approach for evaluating its effectiveness, including the methods, participants, and intended outcomes. A Gantt chart will also be provided to illustrate the planned timeline and the schedule for the delivery and assessment of the training program.

## 2. Method

### Design

The design of this study follows the findings from Study 1.b and focuses on developing a train-the-trainer program that integrates the two loops identified: the internal loop (collecting and acting on weak signals) and the external loop (facilitating reflection, empowerment, and social learning). The program will be developed by the research team and presented at the San Martino Hospital at the beginning of December 2025. The training date has already been set, and participants have been informed.

### Participants

Participants are internal trainers (RSPP and ASPP) at San Martino Hospital, responsible for delivering the majority of in-house OHS training. The group consists of 7 ASPP and 1 RSPP, all professionally qualified as safety trainers and possessing medium to high experience in the field of occupational health and safety. In addition to their training role, they perform safety-related tasks within the hospital, such as risk assessment. Although hospital employees, the Prevention and Protection Service functions as a consulting office with limited authority and budget, requiring collaboration with other departments (e.g., technical, administrative, HR) to implement interventions.

### Training Design and Contents

During the training, participants will acquire the skills necessary to sustain both loops:

- **Internal loop competencies:**
  - Elicit weak signals from workers
  - Create a relaxed and safe climate
  - Protect participants while encouraging discussion of their daily operational context
  - Collect comprehensive information to enable organizational action
- **External loop competencies:**
  - Facilitate empowerment and reflective skills
  - Mediate group discussions and stimulate collective reflection

The training will cover:

1. Presentation of the loops, including guidance on micro-design of activities (e.g., setting objectives, aligning examples to weak signals).
2. Focus on the skills required for both loops.
3. Examples of exercises and activities to activate participants, such as role plays, group brainstorming, and analysis of safety issues, which trainers can adapt to their own training sessions.

### Methods

- Explanation of concepts and demonstration of exercises
- Simulations and practical exercises for participants to practice the application of both loops

### Post-training application

In January and February, two training sessions with hospital workers and safety supervisors are already scheduled. Participants from the December train-the-trainer session will co-facilitate these sessions, applying the skills learned to activate both loops. This will allow researchers to observe the application of the training objectives and assess their effectiveness in real operational settings.

**Evaluation**

The study will adopt Kirkpatrick's evaluation model (Kirkpatrick & Craig, 1970):

1. **Reaction evaluation (L1):**
   Focus groups immediately after the training will assess participants' perceptions of:
   - Level of engagement
   - Clarity of training objectives
   - Trainer's presentation and explanation
   - Alignment between reflective stimulation and content
2. **Learning evaluation (L2):**
   Focus groups around mid-December will explore whether the concepts were acquired and how participants have processed and internalized them.
3. **Behavior evaluation (L3):**
   Trainers' application of skills will be observed during sessions with hospital workers and safety supervisors, evaluating their capacity to activate both the internal and external loops effectively.
4. **Organizational impact evaluation (L4):**
   Due to the duration of the PhD, assessment of organizational-level impact will not be conducted, as it would require an extended data collection period.

**Gantt**

| | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|
| Training development | | | | | | | | |
| Train-the- trainer application | | | | | | | | |
| Focus group (L2 evaluation) | | | | | | | | |
| First training application (L3 evaluation) | | | | | | | | |
| Second training application (L3 evaluation) | | | | | | | | |
| Data analysis | | | | | | | | |
| Results | | | | | | | | |

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