# Identifying Knowledge Flow in Complex Sociotechnical Systems to Contribute to Resilient Capacity: An Empirical Study

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**Abstract**: Knowledge is a fundamental element to enable organizations in anticipating and responding to Operational Safety Events (OSE). The identification and analysis of knowledge flows emerge as strategies to strengthen the potential for organizational resilience, as they qualify the knowäedge necessary for risk mitigation and the strengthening of operational safety. This article presents the results of an empirical research conducted in a sanitation company, aiming to investigate critical knowledge and its flows in complex sociotechnical systems. The research involved interviews with professionals who faced OSEs in their daily activities. OSEs were defined as situations where professionals were able to prevent accidents and/or incidents, successfully dealing with potential threats. To achieve the research objectives, two sequential instruments were used. The first instrument was employed to identify critical knowledge related to OSEs, exploring those mainly related to situational awareness and the repertoire for implementing responses to an OSE. This process revealed a diversity of knowledge, much of which was tacitly present in the minds of professionals and was not formally documented in the company's standard operating procedures. The second instrument was developed to map knowledge flows associated with the identified OSEs. This mapping provided a deeper understanding of how these critical knowledge were shared and used within the organization. The research results evidenced various critical knowledge in the analyzed OSEs, going beyond the information available in tutorials, work plans, or organizations' standard operating procedures. Both instruments used in the interviews were validated and yielded positive results. As a result of this empirical research, the organization now has a valuable understanding of the critical knowledge evidenced, which has the potential to drive organizational learning and strengthen the resilient capabilities of the organization, considering that knowledge resources are a fundamental element for resilience. As a next step, it is aimed to investigate the visual representation of knowledge flows, assess their effectiveness, and provide specific guidelines to enhance knowledge management processes in organizations.

**Keywords**: Knowledge Flow, Resilient Capabilities, Complex Sociotechnical Systems, Knowledge Management, Resilience.

## 1. Introduction

In recent years, the work environment has faced a significant increase in complexity, driven by technological advancements, market digitization, and the data revolution. This increase in complexity is particularly notable in high-reliability organizations, where risks and uncertainties are paramount. To understand this evolution, the theory of complex systems has been increasingly utilized to attempt to explain why activities evolve with a high degree of uncertainty and unpredictability, as the combination of activity variability generates complex scenarios whose outcomes become difficult to predict (Oedewald & Gotcheva, 2015; Hirose & Sawaragi, 2020; Reiman et al., 2021).

The Cynefin framework, developed by Snowden and Boone (2007), offers an approach to understanding and making decisions in different operational contexts. Comprising four distinct domains - simple, complicated, complex, and chaotic - Cynefin helps categorize organizational environments and adjust strategies according to each context. Figure 1 presents the framework.

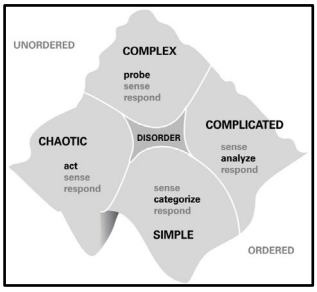


**Figure 1: Framework Cynefin. Source: Snowden e Boone (2007).**

Specifically in the complex quadrant of the Cynefin framework, situations and activities are characterized by high uncertainty and unpredictability. In this context, interactions between system elements are nonlinear and emergent, meaning that outcomes cannot be easily predicted based on simple cause-and-effect relationships. Instead, relationships are dynamic and may evolve in unexpected ways. As characteristics of this complex quadrant, Saurin and Sosa (2013) defined four main attributes: (i) a large number of elements that interact dynamically; (ii) a wide diversity of elements; (iii) anticipated variability; and (iv) resilience, with resilience being the primary attribute of these systems.

Given that resilience is the primary attribute of these systems, it becomes imperative for organizations to seek ways to enhance their capabilities for monitoring, anticipation, response, and learning in the face of unexpected events (Hollnagel, 2011). This article proposes the use of two guiding instruments - scripts for identifying applied knowledge in the face of OSEs, with questions - applied to professionals within an organization in the context of SSTC. The objective is to identify critical knowledge and knowledge flow in OSEs, seeking to qualify this knowledge in a way that makes it accessible and applicable within the organization. Additionally, the article also aims to verify and validate these instruments as part of its contribution to understanding and effectively managing organizational resilience in the face of the complexity of the current work environment.

The article is structured as follows: The first section contextualizes the problem in the introduction, establishing the foundation for the subsequent discussion. In the second section, theoretical foundations are provided, exploring the two main themes: knowledge flow and complex sociotechnical systems. Next, details of the knowledge flow identification process are presented, including the scenario, interview conduct, and results achieved. In the final section, concluding remarks are made, providing a conclusion on the study conducted.

## 2. Concepts

### 2.1 Knowledge Flow

The pioneering study on the construct of knowledge flow dates back to 1953, with the article titled "Planning Concepts and Regional Research," written by the American author Harvey S. Perloff. In this seminal work, Perloff investigated knowledge flow in the context of regional planning. However, until the late 1990s, publications on the topic were relatively scarce, and in several years, no publications related to knowledge flow were recorded. From 1991 onwards, a significant growth in works addressing the topic was observed, with the year 2020 standing out as the period with the highest number of publications (Miranda Junior et al., 2022b).

Despite the growing interest, there is still no consensus in the literature on a definitive definition for the concept of knowledge flow. However, the fundamental essence remains consistent, centered on the exchange, diffusion, or movement of ideas, knowledge, and concepts (An, Han & Park, 2017). In a comprehensive literature review, Bittarello (2014) identified several definitions for the term "knowledge flow," highlighting three levels of analysis: (i) team level, (ii) inter-team, and (iii) within the organization. Table 1 presents the definitions evidenced by the author, as well as others found throughout the research.

**Table 1: Definition of knowledge flow**

| Authors | Definition |
|---|---|
| Wu, David C. Yen (2012) | The process of knowledge transfer between individuals or knowledge processing mechanisms. |
| Rodríguez-Elias (2008) | Transfer of knowledge from where it is created or stored to where it needs to be applied. |
| Nissen (2002) | It considers the flow of knowledge in terms of dynamic knowledge, where the flow engages in activities such as knowledge conversion, transfer, sharing, integration, reuse, movement, and application of that knowledge over a period of time. |
| Zhuge (2002) | It is a process of passing knowledge between individuals or knowledge processing mechanisms. It possesses three crucial attributes: direction, content, and carrier, which respectively determine the sender and receiver, the content of shareable knowledge, and the medium that can transmit the content. |

**Source:** adapted of Bittarello (2014).

The definition of knowledge flow adopted in this work will be the one proposed by Zhuge (2002).

In studies on the topic of knowledge flow, three essential characteristics emerge to qualify this flow: (i) the study objective on knowledge flow; (ii) the representation of knowledge flow; and (iii) the level of analysis of knowledge flow. According to Miranda Junior, Potrich, and Todesco (2021), most research on knowledge flow is focused on three main objectives: (i) improving organizational processes, (ii) supporting senior organizational management, and (iii) stimulating organizational innovation. These objectives have been identified in various organizational contexts, from public and private organizations to research institutes, where the topic of innovation is particularly relevant.

The use of knowledge flow as a tool in knowledge engineering allows for its identification and qualification, aiming at the application of this knowledge in other related constructs, such as organizational learning and knowledge management.

In the next chapter, the second construct of this research will be presented, namely, complex sociotechnical systems.

## 2.2 Complex Sociotechnical Systems

Characterizing a complex sociotechnical system involves interrelations among diverse elements, including people, technology, physical environment, procedures, and regulations. In this context, activities performed are knowledge-intensive, with a strong technological presence and subject to residual risks and uncertainties. Moreover, such systems are constantly exposed to influences from the external environment (Saurin & Sosa, 2013; Schneider, 2019).

According to Saurin and Sosa (2013), four categories of characteristics define complex sociotechnical systems: a large number of elements interacting dynamically, a wide diversity of these elements, anticipated variability, and resilience.

Resilience, in particular, is a crucial attribute of these systems, denoting their ability to adjust their functioning before, during, or after changes to sustain unexpected conditions (Hollnagel, 2011; Saurin & Sosa, 2013). Woods (2015) emphasizes that resilience became a popular concept in the early 2000s due to pressure for more efficient and economical systems.

However, the popularization of resilience has also generated confusion, as the term is employed in various ways. Woods (2015) identifies four distinct approaches: resilience as recovery and return to equilibrium, as synonymous with robustness, as the opposite of fragility, and as network architectures capable of adapting to future surprises.

It is crucial to situate resilience within a specific research context. In this article, we adopt the perspective of recovery and adaptation, emphasizing the importance of a complex sociotechnical system's ability to overcome adversities and adjust to future changes, following the guidelines of Hollnagel (2011) as a central reference. Hollnagel highlights knowledge as an essential element for a system's resilience, being a fundamental component of resilient capabilities, as resilience only manifests in practice. Figure 2 presents the four capabilities described by the author.

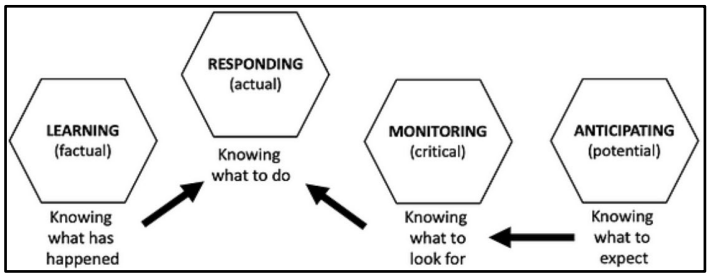


**Figure 2: The capabilities of a resilient system. Source: Hollnagel, 2011.**

As illustrated in Figure 2, knowledge plays a direct role in strengthening anticipation and monitoring capabilities, as well as significantly contributing to responsiveness. In this sense, knowledge is essential as a resource to guide effective action.

## 3. Knowledge Flow Identification Process

In this section, the process of identifying knowledge flow in a sanitation company in Brazil will be detailed. A description of the company where the research was conducted will be provided, along with details about the operational safety events that were addressed during the interviews.

### 3.1 Methods

The research was conducted in a public sanitation company. This organization is part of complex sociotechnical systems, characterized by dynamic interrelations among people, technology, physical environment, procedures, and regulations. In addition to its fundamental operations, the company also performs a series of other complex activities, such as water quality control and waste management. Its relevance in the context of basic sanitation and its representation as a large-scale organization make it a conducive setting for investigations into knowledge flow and resilient capabilities. The company has approximately 2.000 employees, serving around 2.7 million people across 195 municipalities within the Santa Catarina state in Brazil. For the research, two professionals from the technical department of the company were selected, who held different hierarchical levels and also had a minimum of 10 years of experience in the company. These professionals were intentionally selected due to their extensive knowledge about the operations that are the focus of this study.

Thus, the semi-structured interviews were encouraged to recall operational safety events (OSE) they witnessed during their experience in the company, events that, in some way, managed to prevent accidents and/or incidents based on their expertise. The two operational safety events (OSE) identified by the interviewees for the interviews were: (1) water reservoir rupture; (2) maintenance of pumped sewage network. To achieve the proposed objective and conduct the interviews effectively, two instruments were used. The first instrument was employed to identify the operational safety event and to highlight critical knowledge, as proposed by Miranda Junior et al. (2022a). The second instrument was sequentially used to identify the knowledge flow in the operational safety event in question, also proposed by Miranda Junior et al. (2023). Table 2 presents a synthesis of the field of study.

**Table 2: Summary of aspects of the field work carried out.**

| Item | Description |
|---|---|
| Population | Approximately 2.000 employees, serving approximately 2.7 million people in 195 municipalities in a state in Brazil |
| Method used to select interviewees | Should possess varying hierarchical levels within the organization, a minimum of 10 years of experience, and extensive knowledge about the company's operations. |
| Type of interviews carried out | Two semi-structured interviews were conducted using instruments developed by Miranda Junior et al. (2022a) and (2023). |
| Analysis method used | Conducted content analysis on the responses provided by the interviewees. |

**Source**: Authors (2024).

Tables 3 and 4 present a portion of the two instruments used to elucidate the interviews.

**Table 3: Critical knowledge identification instrument.**

| Activity | Description |
|---|---|
| Interviewee identification | What is your name, job title, and/or role? How many years of experience do you have in this field, both at your current organization and at other companies? Could you provide a brief overview of your daily activities? |
| OSE identification | Could you tell me an episode where your experience helped in solving a problem? |
| Diagnosis | How did you realize that the event would be unusual/difficult? What were the primary pieces of information or clues available when you first realized an accident was imminent? What knowledge did you employ to interpret this information? |

| Activity | Description |
|---|---|
| Intervention | Considering the perception of the event, what action plan was established? What information and critical knowledge were used to develop this plan? How were the necessary skills mobilized for the implementation of the action plan? |
| Difficult or facilitating factors | Were there any factors that impeded the design or implementation of the action plan? |

**Source**: Miranda Junior et. al. (2022a).

**Table 4: knowledge flow identification instrument.**

| Activity | Description |
|---|---|
| Reaffirm the critical knowledge identified | In the previous script, critical knowledge was highlighted, enabling the detection of clues and the conception of the action plan. Would it be possible to reaffirm this knowledge? Among those related, which are the two most relevant? |
| Origin of the knowledge | Would it be possible to share details about the source (origin) of the knowledge in question and provide additional insights about where this knowledge emerged? Could you provide a more detailed explanation of the process of obtaining this knowledge? |
| Destination of the knowledge | With regard to the recipient's receptiveness to this knowledge, was it easily assimilated? Was the content presented easily understood and absorbed by the recipient, without significant difficulties or barriers to understanding? |
| Channel of knowledge dissemination | In what specific way was this knowledge transmitted? Which medium, media, or channel was used to convey this knowledge to the recipients, allowing them access to it? |
| Context of the knowledge | Can you envision that this knowledge can be applied in other contexts (ESO) beyond the current one, or is it more specific and applicable only in this particular context? |
| Barriers and/or facilitators for the knowledge | During the dissemination of this knowledge, was it possible to identify any barriers or facilitating elements that may influence the movement of this knowledge? |

**Source:** Miranda Junior et. al. (2023).

Each interview was conducted with the consent of the interviewee and carried out online via the Zoom platform, with an average duration of one hour each. The interviews took place in early 2024. A summary of the research implementation is presented in Table 5.

**Table 5: CDM Roadmap application scenario**

| Activity | Description |
|---|---|
| Complex sociotechnical system | Water supply, collection and sewage treatment company |
| OSE within the operation performed | Maintenance of pumped sewage network<br>Bursting of water reservoir |

**Source:** authors, 2024.

In the next section, the research results will be presented.

## 3.2 Results and Discussions

The interviews were conducted using two instruments, as previously mentioned in Tables 3 and 4. The first instrument aimed to define the operational safety event and identify the critical knowledge involved in the event. Subsequently, using the second instrument, the qualification of this knowledge was further explored through the identification of information flow. The first interview addressed the Operational Safety Event (OSE) related to Pumped Sewage Network Maintenance, while the second discussed the water reservoir rupture. Tables 6 and 7 highlight the main evidence resulting from the analysis of the first OSE.

**Table 6: Main evidence of application of the critical knowledge identification instrument.**

| Block | Description |
|---|---|
| Interviewee identification | *The professional, referred to as interviewee 01, has thirteen years of experience in the organization, always working in the sewage operational system. He began working in a specific sewage system of a certain area, and soon after was invited to work at the central, where he oversees the sewage for the entire city.*<br><br>*"On a particular day, the team had scheduled and was executing maintenance on a pumped sewage network. When I arrived at the site to oversee the operation, I immediately noticed some signs that something could go wrong. This operation posed risks of both death and environmental hazards because there was a lift station shut down, which could cause overflows."* |
| ESO identification | *"Maintenance of pumped sewage network"* |
| Diagnosis | *"The sewage network operates by gravity, meaning it has sewage pipes 4 meters, 6 meters deep. So, when excavating for sewage maintenance, one must be careful with the soil because here, the soil is very sandy and has a high water table. During excavation, if precautions are not taken, it can collapse, burying anyone present."*<br><br>*"The team was conducting maintenance on a certain sewage network, and when I arrived at the site, I immediately noticed cracks in the asphalt, noticed sand around, and realized that everything was about to collapse. I halted the entire operation, asked everyone to come out of the trench, and within a minute, everything collapsed. It even caught the foot of an engineer, but thankfully it wasn't anything serious."*<br><br>*"We were supposed to shore up with iron plates and lower the water table around. To avoid influencing the soil. Because here, each region has a different type of soil. When I arrived and saw that none of this was done, I immediately realized that there could be an accident."* |
| Intervention | *"Knowledge of technical standards and regulations."*<br>*"Knowledge of the company's work plan and procedures."*<br>*"Knowledge acquired through fieldwork experience, alongside more experienced professionals."*<br>*"With this knowledge, I requested a redo of everything, including the trench that was going to be operationalized. I insisted on shoring up according to the service's depth, and only then could the work begin. Without these measures, I would not approve the start of maintenance."* |
| Difficult and/or facilitating factors (resources): | *"Time pressure for executing maintenance/service, as it heavily impacts city traffic."*<br>*"Emotional control, as everyone is experiencing adrenaline at that moment."*<br>*"Lack of knowledge among some employees regarding the proper use of PPEs for that operation."*<br>*"Established organizational culture with entrenched habits, making it difficult to change or correct."*<br>*"Cost can also be a barrier, as financial resources are always limited and can impact operations."* |

**Source**: authors, 2024

The focus of the second instrument is on identifying the knowledge flow, starting with the first question that reaffirms the critical knowledge identified in the previous instrument. Table 7 highlights the knowledge related to the work plan and company procedures.

**Table 7: Main evidence of application of the knowledge flow identification instrument.**

| Block | Description |
|---|---|
| Ratify the critical knowledge identified | 1. *"Knowledge of technical standards and regulations."*<br>2. *"Knowledge of the company's work plan and procedures."*<br>3. *"Knowledge acquired through fieldwork experience, alongside more experienced professionals."* |
| Knowledge origin | *"Knowledge of the company's work plan and procedures."*<br>*"Based on technical standards (NBR), Standard Operating Procedures (SOPs) are developed by the company's management and made available in a digital repository for all employees involved in those procedures. Knowledge of SOPs primarily comes from training sessions and safety management workshops. It's worth noting that accessing this knowledge is easy, as with a smartphone on-site, any SOP or other necessary information can be consulted instantly."* |
| Knowledge destination | *"Knowledge of the company's work plan and procedures."*<br>*"All employees involved in those procedures."* |
| Knowledge movement channel | *"Knowledge of the company's work plan and procedures."*<br>*"This knowledge moves from its source (digital repository of SOPs) to the involved employees, mainly through digital means, but also through informal conversations among workers. Evaluating this knowledge from the perspective of absorptive capacity, it can be said to have a moderate absorption rate."* |
| Knowledge context | *"Knowledge of the company's work plan and procedures."*<br>*"This knowledge can be utilized in various other sectors of the company, and it should be standardized across all operations of the organization to improve service quality."* |
| Barriers and/or facilitators to knowledge | *"Knowledge of the company's work plan and procedures."*<br>*The main barriers in the knowledge flow are indeed the "Time pressure for executing maintenance/service, as it heavily impacts city traffic," and the "Established organizational culture with entrenched habits, making it difficult to change or correct."* |

**Source**: authors, 2024

With the application of the instruments in this first interview, the importance of technical and regulatory knowledge for carrying out operations was evidenced. The interviewee emphasized the importance of possessing a deep understanding of technical standards and regulations relevant to working with sewage. This knowledge not only enabled them to identify potential risks during maintenance operations but also to take corrective actions to prevent serious accidents.

The interviewee also highlighted that knowledge flow in the company is essential to ensure the safety and effectiveness of operations. Access to Standard Operating Procedures (SOPs) through a digital repository facilitates knowledge dissemination among employees. However, it was mentioned that the absorption of this knowledge may only be at a moderate level, indicating the need for improvements in the effectiveness of knowledge transfer.

Several barriers hindering knowledge movement in the company were also identified, including time pressure, established organizational culture, and cost. Time pressure may lead employees to overlook proper procedures, while entrenched organizational culture may resist necessary changes and corrections. Additionally, financial constraints may limit the resources available to implement additional safety measures.

The second interview discussed the water reservoir rupture. Tables 8 and 9 highlight the main evidence resulting from it.

**Table 8: Main evidence of application of the critical knowledge identification instrument.**

| Block | Description |
|---|---|
| Interviewee identification | *The professional, referred to as interviewee 02, has nine years of experience in the organization and works as a leak detection technician, meaning he carries out operations to find hidden leaks in the water network, usually working at night when water pressure increases and consumption decreases. He is currently the head of the city's Water Operations Center.*<br><br>*"In the second semester of 2023, there was a rupture of a water reservoir in the city, and the force of the water caused significant damage to the neighboring community. As a result, the organization's management called all department heads to assist in support. This incident occurred in the early hours of the morning, and a few hours later, my team, consisting of about eight professionals, arrived to assist in the recovery efforts."* |
| ESO identification | *Rompimento do reservatório de água* |
| Diagnosis | *"The mission given by the organization's management to my team was to clean up the affected area. At first glance, it seemed like a war zone because there was debris, cars, swimming pools, fallen walls, and poles, all out of place and piled up. There was a lot of risk involved in this activity."*<br><br>*"Looking at the whole situation, I realized there was a lot of risk involved. So, I first conducted a reconnaissance of the entire area, entering houses, analyzing the terrain, and talking to residents to determine the action plan. Because I had to ensure the safety of my team."* |
| Intervention | *"The entire action plan for the team involved in this activity is not documented in company standards, manuals, or SOPs. It was defined through discussions and past experiences of both myself and my team."*<br><br>*"Knowledge gained through fieldwork experience."*<br><br>*"Leadership skills and empathy."*<br><br>*"From there, we organized the team and machinery to start the work. The focus was mainly on the position and path of the machinery because it had to remove the material and dispose of it."* |
| Difficult and/or facilitating factors (resources): | *"As factors that hindered the operation, we faced pressure from individuals seeking to take advantage of the situation, such as those who presented themselves as community leaders and exerted pressure."*<br><br>*"As facilitators, we had the support of senior management for the actions undertaken."* |

**Source**: authors, 2024

In Table 9, knowledge through fieldwork experience is highlighted.

**Table 9: Main evidence of application of the knowledge flow identification instrument.**

| Block | Description |
|---|---|
| Ratify the critical knowledge identified | *"Knowledge gained through fieldwork experience."*<br>*"Leadership skills and empathy."* |
| Knowledge origin | *"Knowledge gained through fieldwork experience."*<br>*"The knowledge within my team is acquired through knowledge transfer, meaning we gather every fifteen days for an informal discussion to exchange experiences from the past days."* |
| Knowledge destination | *"All employees of the organization."* |
| Knowledge movement channel | *"This knowledge moves from its source to the involved employees, primarily through in-person meetings every fifteen days.* |
| Knowledge context | *"This experiential knowledge can be applied in other contexts; for example, there was a 180mm reservoir rupture in another neighborhood, destroying the entire street and forming a false bottom. When the team arrived there to diagnose the situation, they already utilized the knowledge from the previous experience."* |
| Barriers and/or facilitators to knowledge | *"As factors that hindered the operation, we faced pressure from individuals seeking to take advantage of the situation, such as those who presented themselves as community leaders and exerted pressure."*<br><br>*"As facilitators, we had the support of senior management for the actions undertaken."* |

**Source**: authors, 2024

Considering the reports from Interviewee 02, whose experience focuses on incident management, the crucial role of knowledge acquired through fieldwork experience, as well as leadership skills and empathy in conducting emergency response operations, becomes evident. In a crisis situation such as the rupture of a water reservoir,

practical knowledge and the ability to make quick and effective decisions play a fundamental role in minimizing damage and ensuring the safety of the team involved.

Furthermore, the transfer of this knowledge among team members through regular experience-sharing meetings highlights the importance of internal communication and collaboration for disseminating best practices and strengthening the organization's capacity to respond to emergency situations.

Finally, reaffirming that knowledge is a fundamental element to support resilient capabilities, as defined by Hollnagel (2011), Table 10 synthesizes the evidence of knowledge identified in the interviews of this study, which are potential contributions to support and enhance resilient capabilities.

**Table 10: Identification of knowledge to strengthen resilient capabilities in both ESOs.**

| Identification of critical knowledge | Knowledge qualification through knowledge flow | nputs for organizational learning |
|---|---|---|
| Knowledge in technical standards and company regulations. | The knowledge is explicit, acquired through training, requiring a technical background as a prerequisite. It has been internally developed by the organization itself and presents a moderate level of difficulty for absorption. | Knowledge to review access to field work plans. |
| Knowledge of the work plan and company procedures. | The knowledge is explicit, acquired through safety training and seminars, requiring a technical background as a prerequisite. It has been internally developed by the organization itself and has a low level of difficulty for absorption. It is mainly accessed virtually and faces challenges in field accessibility. | Knowledge to review access to field work plans. |
| Knowledge gained through fieldwork experiences, alongside more experienced professionals. | The knowledge is tacit, acquired through interaction with experienced professionals within the organization, presenting a high level of difficulty for absorption. One of the main barriers is communication. | Formalization of this knowledge for sharing through training. |
| Knowledge acquired through fieldwork experiences. | The knowledge is tacit, acquired through interaction with experienced professionals within the organization, presenting a high level of difficulty for absorption. One of the main barriers is communication, while a facilitator is the support from senior management. | Formalization of this knowledge for sharing through training. |
| Leadership skills and empathy. | The knowledge is tacit and explicit, acquired through interaction with experienced professionals within the organization, presenting a moderate level of difficulty for absorption. | Formalization of this knowledge for sharing through training. |

**Source**: authors, 2024.

Following the presentation of potential contribution evidence, the conclusion of the research will be presented in the next section.

## 4. Conclusion

The main objective of the article was to investigate and identify critical knowledge and knowledge flows within complex sociotechnical systems, through interviews with professionals who witnessed risk situations and somehow managed to prevent a possible incident and/or accident, in order to contribute to resilient capacities.

The interviews yielded positive results, providing the organization with a valuable understanding of the critical knowledge identified, which has the potential to drive organizational learning and strengthen the resilience capabilities of the company. It is important to emphasize that knowledge is a fundamental resource for organizational resilience. According to the literature, as stated by Hollnagel (2011), knowledge is a determining factor for resilient capabilities, and through the interviews, this assumption was reaffirmed.

Based on these observations, it is possible to initiate a discussion on how the company can overcome the identified barriers and promote a culture of safety and efficiency through better transfer and utilization of available knowledge. This could involve investments in additional training, continuous review and updating of operational procedures, and a gradual change in organizational culture to prioritize safety as a fundamental priority.

The findings of this study corroborate the theories and concepts of renowned authors in the field of resilience and knowledge flow. Snowden and Boone (2007) identify the complexity of sociotechnical systems within the

complex domain of the Cynefin Framework, where resilience is essential, aligning with the operational safety events analyzed. Zhuge (2002) highlights crucial attributes of knowledge flow, reflected in the transfer of tacit and explicit knowledge observed in the study. Miranda et al. (2021) point out objectives of organizational improvement, management, and innovation, evidenced in the practical application of the critical knowledge identified. Woods (2015) discusses resilience as adaptation and recovery, exemplified by the effective crisis response documented in the study. Hollnagel (2011) emphasizes the importance of knowledge for monitoring, anticipation, response, and learning capabilities, confirming the central role of knowledge in organizational resilience found in the research.

As a next step, the aim is to investigate the visual representation of knowledge flows, evaluate its effectiveness, and provide specific guidelines to enhance knowledge management processes within organizations.

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## References

An, Y., Han, M., & Park, Y. 2017, "Identifying dynamic knowledge flow patterns of business method patents with a hidden Markov model', Scientometrics, vol. 113, no. 2, pp. 783-802. Available at: https://doi.org/10.1007/s11192-017-2514-8.

Bittarello, K. P. 2014, "Knowledge flow in the environment of technological-based business networks", Master's thesis in Engineering and Knowledge Management, Federal University of Santa Catarina, Florianópolis.

Hirose, T., & Sawaragi, T. 2020, "Extended FRAM model based on cellular automation to clarify complexity of socio-technical systems and improve their safety", Safety Science, vol. 123, p. 104556.

Hollnagel, E. 2011a, "RAG: the resilience analysis grid", in Hollnagel, E. et al. (Eds.), Resilience engineering in practice: a guidebook, Farnham, UK: Ashgate.

Miranda Junior, J., Potrich, L. N., & Todesco, J. L. 2021, "Classification of knowledge flow approaches by application domain: a literature analysis", in International Congress of Knowledge and Innovation – ciKi, 11th, 2021, Maringá, PR. Proceedings [...]. Maringá, PR: ciKi.

Miranda Junior, J., et al. 2022a, "Identifying critical knowledge to strengthen resilient response capability", in International Congress of Knowledge and Innovation – ciKi, 12th, 2022, Maringá, Brazil. Proceedings [...]. Maringá, Brazil: ciKi.

Miranda Junior, J., et al. 2022b, "Mapping the scientific production on knowledge flow", in International Congress of Knowledge and Innovation – ciKi, 12th, 2022, Maringá, Brazil. Proceedings [...]. Maringá, Brazil: ciKi.

Miranda Junior, J., et al. 2023, "Identifying knowledge flow in complex sociotechnical systems to contribute to resilient capacity", in International Congress of Knowledge and Innovation – ciKi, 13th, 2023, Florianópolis, Brazil. Proceedings [...]. Florianópolis, Brazil: ciKi.

Nissen, M. E. 2002, "An extended model of knowledge-flow dynamics", Communications of the Association for Information Systems, vol. 8, no. 18. DOI: 10.17705/1CAIS.00818.

Oedewald, P., & Gotcheva, N. 2015, "Safety culture and subcontractor network governance in a complex safety critical project", Reliability Engineering and System Safety, vol. 141, pp. 106-114. DOI: 10.1016/j.ress.2015.03.016.

Reiman, A., et al. 2021, "Human factors and ergonomics in manufacturing in the industry 4.0 context: a scoping review", Technology in Society, vol. 65, p. 101572. Available at: https://doi.org/10.1016/j.techsoc.2021.101572.

Rodríguez-Elias, O. M., et al. 2008, "Applying the KoFI methodology to improve knowledge flows in a manufacturing process", in International Conference on Software and Data Technologies, 3rd. Proceedings [...], p. 309-314.

Saurin, T. A., & Sosa, S. 2013, "Assessing the compatibility of the management of standardized procedures with the complexity of a sociotechnical system: a case study of a control room in an oil refinery", Applied Ergonomics, vol. 44, no. 5, pp. 811-823.

Schneider, V. 2019, The coherence of symbols that unite agents in sociotechnical coproduction contexts, PhD thesis in Engineering and Knowledge Management, Federal University of Santa Catarina, Florianópolis. Available at: http://btd.egc.ufsc.br/wp-content/uploads/2019/05/Viviane-Schneider-Tese.pdf. Accessed on: October 10, 2022.

Snowden, D. J., & Boone, M. E. 2007, "A leader's framework for decision making", Harvard Business Review, vol. 85, no. 11, pp. 69-76.

Woods, D. D. 2011, "Resilience and the ability to anticipate", in Hollnagel, E., Pariès, J., Woods, D. D., & Wreathall, J. (Eds.), Resilience Engineering in Practice: a guidebook, Farnham, UK: Ashgate.

Zhuge, H. 2002, "A knowledge flow model for peer-to-peer team knowledge sharing and management", Expert Systems with Applications, vol. 23, pp. 23-30.