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A temporal perspective for incident analysis: Extending Reason's Swiss Cheese Model to the post-incident analysis of the Costa Concordia disaster

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Abstract

According to error prevention literature, Reason's Swiss Cheese Model marked a paradigm shift by providing a psychosocial and systemic perspective on understanding workplace errors. Previous research has primarily adopted this model as a tool for analyzing errors and preventing incidents. The present paper aims to extend the application of the Swiss Cheese Model beyond the prevention phase to also include post-incident analysis by adopting a dual perspective that considers prevention and management as interconnected phases of a unitary flow. To illustrate this approach, the Costa Concordia incident is examined as an example case to apply the Swiss Cheese Model, examining psychosocial and technical factors across two temporal phases: before and after the incident. The analysis highlights the temporal interplay among factors and the significance of the intermediate phase –the period between the occurrence of the incident and its management– in determining the severity of the consequences of errors and the effectiveness of mitigation strategies. Overall, this research offers a more nuanced understanding of errors and incidents, advocating for a broader adoption of the Swiss Cheese Model, not only as a model for error prevention but also for incident management. The findings offer insights for both theory and practice.

Keywords: Swiss Cheese Model; Reason; incident; error management; error prevention

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Introduction

Within organizational learning literature, there is increasing interest in understanding how organizations can learn from errors (Rausch et al., 2022). One way to learn from errors is through post-hoc case analysis. The Swiss Cheese Model (hereafter, SCM), developed by Reason (1997), is a widely recognized framework for analyzing incidents. Reason, a leading scholar in the study of organizational error studies, conceptualized this model using slices of cheese as a metaphor for different procedural layers within an organization. Each layer contains potential weaknesses –referred to as “latent errors”– which only manifest when specific conditions align. An incident occurs when the “holes” in these slices of cheese line up, signaling a failure of the system’s tolerance and compensation mechanisms. The SCM primarily emphasizes the analysis and awareness of system vulnerabilities, the “holes”, with the goal of reducing their size and frequency, thereby minimizing the chances of an incident. In this way, the model serves as a preventive framework, consistent with traditional safety literature, that has long focused on error prevention through control of factors and processes (Helmreich et al., 1999; Bleetman et al., 2012; van Dyck, 2009). However, by addressing the prevention focus at the organizational level, SMC offers a valuable framework for uncovering root causes and understanding their interdependencies

More recent approaches argue that reducing the occurrence of errors is only one aspect of effective dealing with potential failures. The error management approach (Frese, 1991, 1995; Lei et al., 2016) posits the importance of fostering a cultural mindset that encourages early error detection, transparent reporting, thoughtful analysis, and swift recovery. This approach complements prevention strategies by helping organizations to cope with errors before they escalate into severe events, thereby mitigating the negative consequences of errors. It also supports continuous learning by encouraging critical reflection on incidents to inform future improvements (King et al., 2017).

One key factor for the enduring relevance of Reason’s model is its systemic perspective, which examines psychosocial –rather than purely individualistic– and technical factors and their interactions, thus reducing the tendency to assign blame to individuals and avoiding reflecting on the broader organizational process that over time led to failure. However, despite this integrated organizational perspective, the SCM does not fully encompass the entire process of error handling (van Dyck et al. 2005), particularly in bridging error prevention and post-incident management.

Building on an integrated perspective of error prevention and error management, this study aims to extend the interpretive framework proposed by Reason’s SCM by adopting a diachronic approach to analyze errors and their underlying factors across the entire flow of events. To illustrate how the SCM can be extended beyond prevention to include post-incident phases, we used an exemplary case, the Costa Concordia disaster, the most serious maritime shipwreck in Italian history.

Although extensively studied (Dankowski, Russell, & Krüger, 2014; Awal & Hasegawa, 2013), the Costa Concordia

incident has often been reduced to “a simple case of human error of the Captain, which constitutes the favorite plot narrated by the mainstream media” (Pellegrino, 2014, p.10) and framed according to sociotechnical model (Reason, 1997). These studies have primarily examined the factors leading to the incident from a prevention standpoint, while largely overlooking managing its consequences (Brazier, 2012; Di Lieto, 2012). The present study positions the Costa Concordia disaster as an exemplary case to demonstrate how the absence of an effective error management strategy contributed to the escalation of the event. The lack of an intermediate response phase –between the initial impact and subsequent rescue response– led to far more severe consequences than the collision alone would have caused.

This study aims to extend SCM as a comprehensive framework helpful to analyze the whole error-handling process. By integrating both error prevention and error management approaches, we emphasize the importance of mitigating error consequences (Helmreich, 2000) and making sense of critical events both before and after they occur (Weick, 1988). In doing so, this study contributes to the literature by complementing the traditional prevention-focused approach with a broader lens that incorporates error management as a crucial phase in handling organizational failures. It further builds on the SCM by assessing its effectiveness also in guiding also post-incident error management.

In the following sections, we review relevant literature on error management, and then present a qualitative analysis of the Costa Concordia case using SCM framework. Our findings categorize errors across technical and psychosocial domains (including organizational and cultural processes), and examine how these factors interact both within and across different time phases. Finally, we conclude by discussing the theoretical and practical implications of this integrated approach to error analysis.

Theoretical framework

SCM is a widely adopted framework for retrospectively analyzing risk factors and latent errors that lead to accidents, offering valuable insights into how incidents occur and how they can be prevented in the future. Drawing on Reason’s foundational work, many scholars (Shabani, Jerie & Shabani, 2023; Goodman et al., 2011; van Dyck, 2009) have underscored the importance of this model since it has become one of the most widely adopted models for detecting and analyzing organizational failures. Reason conceptualized the model around the idea that accidents result from a chain of events that bypass existing safety defenses, each represented metaphorically by a slice of cheese (Thonon et al. 2019; Toto & Limone 2019). Ideally, these defensive layers should be free of vulnerabilities, but effectively they are riddled with holes that can open, close, and shift position over time (Warner et al. 2019; Wiegmann et al. 2022). When these holes align across multiple slices, the likelihood of an accident significantly increases. One of the strengths of the SCM lies in its holistic perspective (Appicharla, 2022; Mendes et al., 2022; Raharjo et al., 2023) as it considers both active failures –errors or

violations made by individuals (Wu et al., 2023; Young et al., 2023)—and latent conditions, which reflect systemic weakened organizational defenses such as flawed managerial decisions, inadequate safety procedures, deficient organizational structure, and adverse cultural factors (Frese & Keith, 2015). Reason (1997) further identified the factors contributing to the emergence of these latent conditions, categorizing them into *organizational* and local workplace factors, which can collectively be defined as psychosocial factors.

Due to its ability to provide a clear and intuitive visual representation of complex systems (Adriaensen et al., 2019; Larouzee & Le Coze, 2020), the SCM has been widely adopted to retrospectively analyze incidents that are well-known for their severe and large-scale impact (e.g., Salge & Milling, 2006). It has been applied across various sectors (e.g., aviation, marine, healthcare, defense, nuclear, oil & gas, rails, roads, chemistry) and fields, including risk management (Larouzee & Le Coze, 2020; Maskari et al., 2023), human factor analysis (Cohen et al., 2018; Sarin et al., 2020), and safety systems (Seshia et al., 2018).

A more recent perspective suggests focusing on the management of errors as a process that helps to mitigate their negative consequences and learn from them (Frese & Keith, 2015; Frese, 1995; Nordstrom, Wendland, & Williams, 1998). Errors represent feedback for improving work processes and providing learning and innovation. Learning takes place when people are encouraged to learn from errors (Heimbeck, Frese, Sonnentag, & Keith, 2003; Weinzimmer & Esken, 2017; van Dyck, 2009). Therefore, organizations that embrace this culture view errors as valuable opportunities for restructuring organizational processes (Frese & Keith, 2015). Organizations within this approach “have to walk a fine line between taking errors seriously and emphasizing error tolerance and between using information on errors as examples of (lack of) performance and using errors as opportunities for learning” (van Dyck et al., 2005, p.1238). Conversely, organizations exhibit a cultural approach aversive to errors (Frese & Keith, 2015; Hofmann & Frese, 2011; van Dyck et al., 2005). These are culturally low tolerant toward errors and reluctant to support error management (Dimitrova & van Hooft, 2021). Nevertheless, some studies have shown that an error-averse culture has been linked to a higher number of incidents (Fruhen & Keith, 2014). Similarly, (2008) offers a synthesis in terms of IBL (Individual Blame Logic)—an accusatory approach focused on identifying the guilty—and OFL (Organizational Function Logic), adopting an organizational and functional perspective to deal with errors.

Given the rapid sequence of errors that can lead to an incident, scholars have referred to the aftermath as the “time lag” (Lei et al., 2016), the “error handling” phase (van Dyck, 2009), or the “error chain” (Lei et al., 2016). This critical period occurs just after an error has been made, when its negative consequences begin to emerge and may either be resolved or escalate rapidly. Therefore, timing plays a pivotal role not only for prevention, by intercepting errors early, but also in intervention, during the transition from one phase to another, to effectively mitigate its consequences. Effective responses hinge on the prompt recognition of these events as unexpected, yet this recognition often comes too late, usually

the consequences being seen only in hindsight as predictable outcomes of a failure to detect and act on the incident in time (March, 2010). These types of events, which disrupt organizational routines and create disorientation, often lead to the formation of impromptu teams, groups that “are not assigned by management, but rather by those who themselves become team members” (Jacobsson & Hällgren, 2016, p. 587). As the term “impromptu” implies, such teams rely heavily on improvisation and intuition to guide decision-making. Similarly, the literature on naturalistic decision-making emphasizes that, under time pressure and crisis conditions, effective decisions must be made in real time rather than delayed by attempts at exhaustive analysis (Klein, 2014; Klein, 2008).

Building on the existing literature on error prevention and error management, this paper examines the Costa Concordia disaster, exploring the multiple contributing factors. Specifically, we consider how SCM can enhance our understanding of the incident’s trigger point from a prevention perspective and the dynamics of error management as it unfolds. By adopting a temporal perspective that extends into the post-accident phase, we highlight these factors’ critical role in mitigating consequences and fostering organizational learning from errors.

Method

Research context

The Costa Concordia shipwreck was the most severe Italian maritime disaster, claiming 32 victims. At the time, the Costa Concordia was on a short overnight journey along the Italian coast, carrying more than 4,200 people. On January 13, 2012, the ship struck rocks near the island of Giglio, while performing a dangerous and unauthorized maneuver known as “bowing”, a close approach to the coastline intended to give passengers a better view of the island. The failure to promptly manage the resulting errors and crisis turned what might have been a containable incident into a full-scale disaster.

Although the commander was held largely responsible and convicted, the media and public opinion focused the blame solely on him. This scapegoating mechanism overlooks other actors’ roles and latent factors, limiting critical reflection and learning. To overcome this, we applied the SCM framework, to analyze the Costa Concordia case, adopting a systemic perspective.

Following established research process guidelines, this study analyzes how the events unfolded over time and why they evolved as they did (Van de Ven & Huber, 1990). In this case, the process data primarily consists of narratives about what occurred, events, actions, and decisions organized chronologically (Langley, 1999). Consistent with standard incident analysis approaches (Weick, 1993; Smith, 2002), the events were coded following a timeline based on their sequence. The accuracy of this timeline (*Tab. 1*) was further verified using the Technical Report (2012) and the study by Bartolucci and colleagues (2021).

Tab. 1. Timeline.

Time	Event
6:57 pm	Cruise sets sail from port of Civitavecchia (Italy)
9:04 pm	Starts 'salute' approach to Giglio Island
9:45 pm	Traveling at 15 knots, ship strikes the Scola Piccola rock off Giglio
9:45-9:55 pm	Ship decelerates to zero knots and turns more than 180 degrees
9:12 pm	Passengers advised to "return to their cabin"
9:14 pm	Officers begin contact with Port Authority of Livorno (Italian mainland)
9:25 pm	Captain admits to Port Authority that the situation is critical and requests the use of a tug
10:25-10:51 pm	Ad hoc unofficial evacuation begins
10:51 pm	Captain gives instruction to heed the abandon ship order
10:54 pm	Staff Captain orders the abandon ship
11:10 pm	The official evacuation starts
01:30 am	Captain communicates to Port Authority he left the ship
01:45 am	Harbor Master of Livorno 'orders' Captain to return to ship (he does not do so)
04:46 am	Evacuation officially ends
06:17 am	Search and Rescue teams leave the ship

Data collection and analysis

The study is based on secondary data, primarily collected from news reports published in the immediate aftermath of the Costa Concordia shipwreck. In reconstructing and analyzing the event, these reports serve as a valuable source, providing an objective and impartial representation of the facts (Möller, 2011; Wallace, 2011). Specifically, we relied on factual news articles, which offer accurate and unbiased accounts of the events. These sources include eyewitness testimonies and interviews, but exclude journalistic opinions, editorial commentary, or any evaluation with legal value of responsibilities or the actors' culpability. Their purpose is to report the facts as they unfolded, ensuring a neutral and fact-based representation of the incident.

We gathered news reports from major Italian newspapers, including "Corriere della Sera", "La Repubblica", "Ansa", and "Il Mattino". We also considered later articles and key documents, such as the harbormaster's report (June 2012) and the official Technical Report (September 2012). Our objective was to gather as much non-redundant and comprehensive information as possible to accurately reconstruct the events.

To examine the data, we adopted a thematic analysis methodology, identifying, recursively analyzing, and reporting patterns or themes within the dataset through an iterative process (Braun & Clarke, 2006). Specifically, we followed the steps outlined by Braun and Clarke (2006), beginning with data familiarization through repeated readings of both the news reports and the technical report. During this phase, we highlighted excerpts referencing potential factors that either contributed to the occurrence of the incident or exacerbated its consequences. We then generated initial codes, examples of which are presented in Tables 2 and 3 in the Findings section. These codes were then organized into potential themes, informed by the error management literature and their relevance to our research focus. We then refined these themes through an ongoing analytical process, focusing on both the details of each theme and the broader narrative emerging from the data. This stage involved substantial interpretation, making the analysis not merely descriptive but also theoretically grounded. The development of themes was guided by a theoretical approach rooted in Reason's (1997) SCM model, which helped identify

the latent conditions contributing to the incident. Although the model is typically used to analyze pre-impact factors, this study also applies it to the post-impact phase. This broader application enhances our understanding of error dynamics and underscores the importance of timely, effective responses.

Results

The analysis process involved iteratively comparing the theoretical categories from SCM with emerging content from the articles, leading to the identification of key factors relevant to the incident. These factors were coded according to Reason's (1997) two main dimensions: technical and psychosocial factors. Technical factors relate to errors of a technical-procedural nature, such as tool malfunctions or technological issues hindering task execution. Psychosocial factors pertain to the work environment, organizational culture, human interactions, and roles, which can significantly contribute to incidents. The process began by identifying text fragments (quotes) that referenced potential causal factors and categorizing them into the two phases. These factors were then classified within the technical and psychosocial dimensions and further grouped to identify underlying latent error conditions. Multiple quotes were assigned to each condition and grouped according to theoretical constructs commonly discussed in error and incident literature.

The analysis revealed that psychosocial factors could be further divided into organizational and cultural processes. Organizational processes involve coordination mechanisms like communication, role clarity, and leadership. Cultural processes refer to the organization's attitude toward errors, including unwritten norms that shape employees' perceptions and responses to errors. The final results of this analysis are presented in *Tab. 2* and *Tab. 3*.

Overall, in the pre-incident phase, the accident was primarily driven by technical issues such as system malfunctions, outdated navigation tools, and poor ergonomics. Thus, organizational process factors, including communication gaps, unclear roles, and inconsistent leadership, played a significant role. These

Tab. 2. Main factors of the phase before the incident.

Factor	Example original quote	Code	Theme
Technical Factors	“The radar echo ‘hit’ only the first rock, but there were actually two.” (From the Technical Report)	Inaccurate radar reading / malfunctioning radar	Technical failure
	“It was in fact established that the machinery had been malfunctioning since January 9, a full four days before the sinking.” (From news report)	Repeated malfunction of the black box	Technical failure
	“The officers on the bridge confirm that the fire doors were left open to facilitate movement during navigation: ‘this was a practice used during navigation to facilitate the flow of people who had to work.’” (Second deck officer and cartographer’s testimony, from news report)	Fire doors intentionally left open to ease crew movement	Ergonomics
	“We were sailing close to the coast, along a permitted tourist route, when the ship struck a rock on its side that was not marked on the nautical chart.” (Captain’s testimony, from news report)	Inadequate or outdated electronic chart system	Obsolescence
Organizational process factors	“Behaviors suggest that the skipper was expected to assume command after requesting a significant change of course.” (From the Technical Report)	Lack of communication about the risks of the maneuver and team doubts	Leadership
	“The captain did not consider increasing the lookout personnel after the helmsman left.” (From the Technical Report)	Delayed assignment of key safety roles	Leadership
	“It is the captain’s discretion to choose the sailing distance; this time, he took excessive risks.” (Crew member’s testimony, from news report)	Leader’s overconfidence	Leadership
	“Despite the ban, mobile phones were used in the command cabin, during watch duty.” (From the Technical Report)	Disregard for standard behavioral protocols by the Bridge Team	Leadership
	“Schettino addresses Ambrosio without clearly taking control of navigation.” (From the Technical Report)	Lack of authoritative command	Leadership
	“Evasive responses were given even when asked whether passengers were wearing life jackets.” (From news report)	Discordant communications, inaccurate or omitted information	Communication
	“Despite the bow maneuver, until 9:43 p.m., ‘No other Officers voiced concerns about the maneuver, none of them expressed doubts about it.’” (From the Technical Report)	Failure to express doubts regarding critical decisions	Communication
	“Although Italian was the designated language to be used on the bridge, the Captain spoke to the helmsman in English.” (From the Technical Report)	Miscommunication within the team due to linguistic inconsistency	Communication
Cultural process factors	“Mr. Tievoli, first maitre of a restaurant on Giglio Island, asked the Captain Schettino: ‘Since you have to disembark, I would appreciate it if you stop by the coast and say hello to the Giglio island’.” (From the Technical Report)	Compliance with personal requests unrelated to navigation	Cultural value
	“The team configuration adopted was that suitable for standard sailing, despite the high-risk context of night coastal sailing at high speed.” (From the Technical Report)	Superficial and complacent attitudes from Officers	Error Culture
	“The bowing maneuver had already been performed two weeks earlier and was common practice.” (From the Technical Report)	Routine tolerance of unsafe navigation practices	Error Culture
	“The helmsman confirms the order and abandoned lookout duties, leaving the ship without replacement, considering normal contravening the rule of maritime navigation that a lookout must always be secured.” (From the Technical Report)	Team normalization of violating the Commander’s Rules Procedures	Error Culture
	“During the bow maneuver, jokes are made about the dangerousness of the situation: ‘Otherwise we go on the rocks’ followed by laughter.” (From the Technical Report)	Trivialization and mockery of dangerous practices	Error Culture

Tab. 3. Main factors of the phase after the incident.

	Example original quote	Code	Theme
Organizational process factors	“Lacking internal communication of the presence of the leak, the roll call roles were not taken and all the officers went to the bridge to be informed of the situation, wasting even more time.” (From the Technical Report)	Ineffective coordination on board	Communication
	“The general emergency announcement was given at 22:33 while the external communication occurred at 22:36.” (From the Technical Report)	Misalignment between internal activation of the contingency plan and external communication	Communication
	“The captain assured us that it was only a machinery failure, which was not true: there was already a hundred-meter gash under the keel.” (Eyewitness account, from news report)	Withholding critical information	Communication
	“Three minutes after the impact, the Commander should have issued the DELTA-XRAY call to inform the crew and initiate their assigned emergency roles, but this was done significantly late.” (From the Technical Report)	Delayed activation of emergency roles	Team roles

	Example original quote	Code	Theme
Cultural process factors	"It is not true that there were no officers on the ship. Many were found in civilian clothes in the cabin or restaurant. They couldn't be identified, in the midst of the chaos. They didn't stand out in their uniforms but they were there." (<i>Health director's interview, from news report</i>)	Lack of visible identification for crew members	Team roles
	"At first, I searched for some officers, but saw no one. There was not much professionalism, of the crew. I mostly saw marshals. It was hard even to make myself understood. So, I spent the first 20 minutes, looking for. But there was a lack of leadership, people were left on their own." (<i>Mayor's interview, from news report</i>)	Absence of leadership role	Leadership
	"Captain Schettino ordered 'all tiller to port', but Ambrosio shouted 'Hard to Starboard', believing the Commander had confused port with starboard, and was steering ashore by mistake." (<i>From the Technical Report</i>)	Lack of trust in leadership decisions	Leadership
	"There was panic on board even among crew members. Many were foreigners, who didn't know exactly what to do either." (<i>Passenger account, from news report</i>)	Disorientation and confusion among the crew	Safety and security training
	"The crew probably imagined at first that they could handle the emergency," (<i>From news report</i>)	Misjudgment of the situation	Safety and security training
	"No one was telling us anything, and the foreign staff were shouting out of panic among themselves. We took life jackets ourselves by breaking windows in the corridors". (<i>Passenger account, from news report</i>)	Improvisation of rescue efforts	Safety and security training
	"Passengers independently headed to the Muster Stations and got life jackets without staff manning the situation." (<i>The first officer's testimony from news report</i>)	Lack of internal monitoring in passenger evacuation procedures	Safety and security training
	"There was a real assault on the lifeboats with totally untrained personnel, unfit for the situation, so much so that just as they were being lowered there were accidents. We had to replace the Commander of our lifeboat with an engineer officer from a different company." (<i>Bridge team member's testimony, from news report</i>)	Lack of quality control of emergency procedures by the organization	Error culture
	"The seriousness of the situation is not understood or valued until Schettino asked for the second time how many watertight compartments were flooded". (<i>From the Technical Report</i>)	Failure to appreciate the severity of the emergency situation	Error culture
	"Director Onorato defended Commander Schettino: 'He has been with us for 11 years. He was on the bridge at the time of the collision'. Nothing to object to the rescue operations: 'The safety procedures required in these cases were carried out in the correct timeframe' said Director Onorato again. And 'correct' was also 'the commander's decision to evacuate the Concordia ship when he felt that there were safe conditions'." (<i>Testimony of the CEO of the Company, from news report</i>)	Omertous attitude from the top level of the organization	Error culture

issues reflect an error aversion culture, where mistakes are hidden or ignored. In the post-impact phase, the emphasis shifts from technical factors to organizational and cultural processes. The organizational culture continues to covert or hide errors, a pattern that extends from top management down through the crew, and results in a lack of safety.

The analysis, based on concrete situations described in quotes, identified key factors and grouped them into broader macro-categories. Additionally, the findings were interpreted at a macro level.

The intertwining

This structured analysis highlighted how the identified factors are interwoven both vertically and horizontally within the organizational system. Cultural processes drive both technical and organizational process factors within each phase. For example, the organization's habitual compliance with non-navigational requests and the trivialization of dangerous practices led to navigation without the necessary equipment checks. Furthermore, there is a parallel between organizational processes and cultural processes. For example, a weak error culture could be related to poor communication management. Similarly, in the post-impact phase, cultural and process factors remain intertwined. For instance, widespread neglect of quality control of error-management procedures resulted in process errors, such as inefficient onboard coordination. These findings align

with error management literature, which highlights the role of leadership and culture in employee performance. Specifically, passive management-by-exception and laissez-faire leadership foster an avoidant attitude toward errors, ultimately reinforcing a covering-up approach (Farnese, Marzocchi, & Olivo, 2024).

Comparing the phases reveals a shift in the types of factors at play. In the pre-incident phase, technical factors dominate, alongside psychosocial factors. However, in the aftermath, psychosocial factors take precedence. This shift highlights the importance of team communication, role clarity, leadership, and organizational culture in mitigating or preventing further escalation. The analysis provides a deeper understanding of the systemic nature of errors and organizational failures, emphasizing the importance of addressing both technical and psychosocial dimensions in incident prevention and crisis response.

The flow between phases and factors

The analysis also reveals that many of the factors affecting the occurrence of the critical event during the pre-incident phase often continued to develop in the post-incident phase, amplifying the negative consequences of earlier errors or influencing other contributing factors in turn. For instance, the normalization of violating the Captain's orders by the Bridge Team in the pre-impact phase then worsens into widespread distrust in leadership. Similarly, the habitual disregard for navigation safety practices foreshadows the later

underestimation of the emergency situation. Additionally, the lack of clear role assignments before the incident led to the absence of coordination among the crew. These findings illustrate how the interplay among underlying organizational and cultural conditions creates a ripple effect, shaping responses and influencing crisis outcomes.

The absence of mitigation

Just as the pre-incident phase revealed significant latent errors indicating a failure in prevention, the post-incident phase also exposed ineffective behaviors in containing the consequences. Ineffective attitudes in handling the crisis not only failed to mitigate the consequences but, sometimes, actively contributed to further escalation. This pattern suggests the adoption of an overarching cultural approach underlying the whole error-handling process, failing both in error prevention and error management. In the pre-incident phase, unaddressed latent issues led to the impact, while in the post-incident phase, delays in addressing critical errors prolonged the crisis and hindered rescue efforts. Despite initial opportunities for effective intervention, the failure to act promptly forced the evacuation to take place under dire conditions.

Our analysis suggests that the absence of early mitigation transformed potential risks into actual failures. This connection between the phases reflects not only progression but also an interaction among factors, underscoring a deeper systemic issue in error culture.

Discussion

The analysis of the main factors that led to the Costa Concordia accident, while not exhaustive, provides valuable insights into the error-handling process when viewed through a socio-technical perspective. By adopting a dual approach that integrates both the pre- and post-accident phases as part of a continuous flow, this study highlights key dynamics that shaped the incident's development and its aftermath.

First, in line with the socio-technical perspective, the findings reveal that different types of factors within each phase of error handling are deeply interconnected. These interdependencies enact vicious cycles of mutual influence that exacerbate the negative consequences of the critical event (Amici & Farnese, 2024), suggesting that errors do not occur in isolation but rather emerge from systemic organizational vulnerabilities. Second, the findings underscore the crucial role of the immediate post-incident phase in mitigating the consequences of errors. However, in this illustrative case, persistent neglect and indifference to the initial conditions allowed the problem to escalate, leading to a manageable crisis in Italy's most significant maritime disasters. Third, our analysis shows the intertwining of factors across different time phases of the error-handling process. This finding supports the need for a comprehensive perspective to understand the process that unfolds from early errors to a serious accident. Fourth, the comparison between the phases highlights a

shift in the predominant types of contributing factors, with technical factors predominating in the antecedent phase, while psychosocial factors become prominent during the error management phase.

Overall, extending the SCM to the post-incident phase, allowed for a more comprehensive application of this framework, enabling the analysis of both the root causes of an incident and its unfolding consequences. This holistic perspective provided important insights into understanding how errors evolve over time, interact with one another, and contribute to the escalation or containment of a crisis. By adopting a temporal lens, this study sheds light on the dynamic nature of accidents, emphasizing the importance of addressing both prevention and management strategies to mitigate their impact effectively.

Practical implications

The intertwining of different factors demonstrates the need for a holistic approach to error management. This may involve organizational training programs that promote a culture of open communication, reporting without fear of blame, and mutual support in error recovery. Organizations should accompany the implementation of robust monitoring systems that regularly assess compliance with safety protocols and operational standards. Further, the different prevalence of factors across the phases underlines the importance of tailoring interventions to address the specific challenges present at each stage of the error-handling process.

Limits and further research

This study has several limitations. First, the dataset consists of a limited number of articles, which may not capture the full complexity of the incident. Additionally, the analysis relies solely on secondary data, which may restrict the depth of insights. Furthermore, while the case examined is highly illustrative, it remains a specific instance. To enhance the generalizability of the findings, future research should explore similar cases across different high-risk sectors to explore whether comparable error-handling patterns emerge.

Conclusion

The analysis of the Costa Concordia case provides evidence for the applicability of SCM as a valuable framework not only for incident prevention but also for error management. This dual perspective highlights the importance of the intermediate stage, a critical time window in which events can dramatically escalate. Moreover, the granular analysis of psychosocial factors, including both organizational processes and cultural processes, provides a comprehensive understanding of the incident, moving beyond a blame-oriented approach. Reason's model frames individual errors within the broader organizational context, emphasizing systemic and dynamic factors.

This study contributes to the development of a safety-oriented culture by recognizing the interconnected nature of

errors. By enhancing organizational communication, fostering a non-blaming approach to error reporting, and adapting response strategies, organizations can improve their resilience and ability to learn from errors. Ultimately, this leads to safer and more efficient operations, reinforcing the value of adopting systemic frameworks like Reason's model to guide both prevention and management efforts.

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Conflict of Interests

The authors declare that they do not have competing interests.

Author Contributions

M.L.F., conceptualization; E.C. developed the proposal; E.C. wrote the first draft with inputs and comments from M.L.F.; E.C. conducted the analysis; M.L.F., supervision. All authors contributed significantly and agree with the content of the manuscript. All authors have read and agreed to the published version of the manuscript.

Supplementary material

Not applicable

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