FROM CRISIS RESPONSE TO ADAPTIVE GOVERNANCE: ORGANIZATIONAL LEARNING AND RESILIENCE AT BUCHAREST AIRPORTS

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Abstract. *The COVID-19 pandemic highlighted the fragility of airport systems that had been designed for stability instead of long-term disruption. Airport resilience is often measured through traffic, financial, and operational indicators. However, little attention has been given to the organizational mechanisms that facilitate the development of resilience in critical infrastructure organizations. This paper seeks to explore the Bucharest Airports National Company as a qualitative case for adaptive governance in the face of long-term uncertainty. Using document analysis of various Bucharest Airports National company reports, public communications, and various policy documents from the national and European government, this study shows that the resilience that was developed within the organization was a result of three different mechanisms: adaptive coordination across units, feedback loops that connected local operational signals to organizational adjustment, and cumulative learning that gradually reshaped routines, communication, and governance practices. Rather than presenting resilience as a fixed attribute or a matter of redundancy alone, the case shows it to be an emergent organizational capability produced through distributed adaptation and institutional learning. This paper will thus contribute to the existing literature on adaptive governance and organizational resilience by providing insights into the evolution of the organizational responses to crises into more sustainable forms of coordination and governance reform in the airport systems.*

Keywords: *adaptive governance; organizational resilience; airports; organizational learning; complex adaptive systems; crisis management*

JEL codes: L93, D83, H12, M10

Introduction

The COVID-19 pandemic placed extraordinary pressure on the global aviation industry, transforming it into a real-time experiment in crisis management and adaptation. Within weeks, international passenger traffic across Europe dropped by more than eighty-five percent, while airport operations and logistical networks struggled with severe disruptions and uncertainty. These abrupt, large-scale shifts exposed the fragility of aviation systems, as designers had built them for stability and efficiency rather than for sustained turbulence.

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Airport leaders faced a challenge that extended far beyond maintaining operations. They needed to protect passenger safety, preserve financial balance, and coordinate staff in an environment where predictability had nearly vanished. In this context, the Bucharest Airports National Company (CNAB) illustrates how a vital public infrastructure organization can reorganize its internal processes and sustain performance during a global systemic shock.

The pandemic prompted both researchers and practitioners to reassess how large socio-technical systems respond to high stress. It revealed the limits of traditional hierarchical management and underscored the growing importance of adaptability, collaboration, and distributed intelligence in maintaining coherence. Complexity science and organizational learning theory describe such institutions as Complex Adaptive Systems (CAS)—networks of interdependent agents that adjust and learn through feedback loops. In these systems, resilience arises not from control but from the capacity to reorganize relationships, absorb shocks, and create new modes of functioning.

At the same time, much of the existing literature on airport resilience has emphasized the overall results of the system in terms of the decrease in traffic, financial disruption, and recovery. While these factors are relevant, they do not provide a comprehensive understanding of the generation of resilience within organizations that deal with high degrees of uncertainty. In the existing literature on the subject of airport resilience, there is limited emphasis on the overall governance structures and learning processes through which organizations adapt under stress. It is therefore necessary to understand the behavioral mechanisms that help generate the concept of resilience within the overall framework of critical infrastructure systems.

This study analyzes how CNAB responded to the pandemic's disruption and identifies the adaptive mechanisms that supported its recovery and sustained performance. It focuses on how operational and organizational subsystems interacted, and how adaptive governance contributed to institutional resilience. Two research questions guide the analysis: (RQ1) how did the adaptive capacity of teams operating under stress shape air-traffic normalization at CNAB beyond the effects of external regulations? and (RQ2) how did inter-team coordination and feedback loops influence the effectiveness of CNAB's recovery measures by enabling rapid decision adjustments?

Instead of treating resilience as a fixed attribute or an issue of redundancy, this paper seeks to explore resilience as an emergent organizational capability produced through feedback, distributed adaptation, and institutional learning.

Ultimately, the case of CNAB illustrates how airport resilience depends on not only infrastructure or regulatory frameworks, but also on human, technological, and institutional systems' capacity to adapt in the face of uncertainty. The adaptive trajectory of the CNAB case illustrates that systemic resilience in critical infrastructure is dependent not only on the structural resources that are available, but also on the capacity of the system to learn from disruption. This paper makes an original contribution to the transport policy literature in that it illustrates the role that adaptive governance mechanisms play in the development of systemic resilience within air transport systems in the face of prolonged disruption.

Literature Review

The concept of adaptability has regained central importance in management and organizational research, particularly following the COVID-19 pandemic, which exposed the fragility of traditional planning systems. Earlier theories, shaped by Argyris and Schön (1974) and later by Senge (1990), understood learning mainly as an individual cognitive process. More recent research, however, interprets adaptability as a collective and systemic capacity that emerges from continuous interactions among people, technologies, and institutions. Within this framework, organizations operate as Complex Adaptive Systems (CAS) - dynamic networks capable of self-organization, feedback-driven learning, and nonlinear adjustment to external shocks. The pandemic

accelerated this transition by revealing the limitations of linear management models and highlighting the need for agility, experimentation, and ongoing learning.

Current studies on adaptive management in high-stress contexts emphasize the importance of modular flexibility and distributed coordination as key drivers of organizational resilience. Schulze & Pinkow (2020) argue that effective leadership in adaptive systems depends less on direct control and more on enabling conditions that foster emergence and sensemaking. Aghion et al. (2021) demonstrate that decentralized organizations perform better during crises, as distributed intelligence facilitates faster information flow and encourages innovation. In public management, Horton et al. (2022) describe resilience as the outcome of reflexive learning - the capacity to transform failure into a mechanism for redesign and renewal. These insights are particularly relevant to aviation, where operational interdependence, strict safety standards, and cross-border coordination continuously test the balance between control and adaptability.

In the context of airports, the CAS approach is particularly relevant because of how it frames resilience: not as a static reserve of resources, but rather as an emergent property resulting from interactions across operational, organizational, and human subsystems (Patriarca et al., 2021; Vert et al., 2021). Airports represent more than technical infrastructures; they are socio-technical systems that involve the co-evolution of procedures, technologies, and regulations in the face of adversity (Berard et al., 2022; Apolinário et al., 2020). This approach allows for the move from linear recovery thinking toward the mechanisms of feedback that allow for organizational self-coherence in the face of disruption.

Hanif & Pierotti (2025) define resilience as an ongoing process through which organizations absorb shocks, sustain performance, and reconfigure underlying structures. Institutional frameworks developed by the OECD (2023) and the EU-NATO Task Force on Resilience of Critical Infrastructure Report (2023) extend this perspective to critical infrastructures, viewing resilience as both a governance principle and an organizational practice that links technology, human cognition, and policy. In aviation, Eurocontrol (2022) and ICAO (2022) identify digital transformation, interoperable data systems, and Airport Collaborative Decision-Making (A-CDM) as central enablers of adaptive governance. Collectively, these studies suggest that resilience in aviation represents more than a technical capability—it is a social and institutional process grounded in trust, coordination, and feedback across multiple layers of governance.

Recent empirical research reinforces these theoretical insights. Khare (2024) examined India's aviation network and found that digital coordination platforms reduced recovery time by nearly thirty percent. Horton et al. (2022) observed that transparent communication and inter-agency collaboration strengthen adaptive capacity in Latin American airports. In Europe, Barbera et al. (2023) and Senivongse (2023) demonstrated that financial resilience improves when governance frameworks allow rapid reallocation of resources and flexibility in decision-making. Similarly, Christianson & Barton (2021) highlighted that post-pandemic recovery depends on technological innovation combined with cultural adaptability - particularly the ability of teams to align mental models and engage in collective sensemaking.

Another line of research explores the governance of global coordination systems. Within transport research, adaptive governance has increasingly been discussed as a policy response to systemic uncertainty, rather than as a purely organizational or managerial construct. The pandemic highlighted persistent fragmentation between national regulations and regional aviation policies, resulting in inefficiencies in traffic recovery. Cosens et al. (2021) argue that governance under uncertainty requires adaptive architectures connected through feedback loops rather than hierarchical command. This approach aligns with the emerging field of adaptive governance, which conceptualizes institutions as co-evolving systems capable of reflexive learning and self-adjustment. In aviation, adaptive governance is manifested through digital coordination hubs, standardized data protocols, and crisis-response platforms that integrate public and private stakeholders into shared decision-making environments.

A foundational contribution to this theoretical landscape comes from panarchy theory (Holling & Gunderson, 2002), which models adaptive cycles as nested, non-linear processes of growth, collapse, and reorganization. Rather than treating crises as purely destructive events, this framework conceptualizes systemic disruptions as windows of reorganization that enable structural renewal. Recent scholarship confirms the continuing relevance of this perspective: Mirzabeiki & Aitken (2023) apply panarchy theory empirically to demonstrate how organizations navigate adaptive cycles of resource release and reorganization in response to major environmental disruptions. Similarly, Guo et al. (2023) apply network resilience theory directly to airport systems during the pandemic, demonstrating that post-crisis reorganization depends strongly on the responsiveness of governance arrangements rather than infrastructure size alone.

A complementary theoretical perspective is provided by Ostrom's (1990) polycentric governance model, which posits that resilient systems benefit from overlapping, self-organizing decision centers rather than centralized hierarchical control. Recent scholarship has extended this argument to contemporary governance challenges: Behnke (2024) demonstrates that polycentric governance functions as a structural resilience resource, whereby coordinated decentrality and flexible adaptation enable systems to absorb prolonged turbulence more effectively than centralized command structures. Gatto (2022) further extends Ostrom's framework to infrastructure and resource systems, showing that resilience is enhanced when overlapping governance jurisdictions enable distributed, adaptive, and self-organizing responses.

Together, panarchy theory and polycentric governance offer a structural complement to the Complex Adaptive Systems (CAS) perspective adopted in this study. Where CAS theory explains how organizations self-organize and learn through feedback, panarchy illuminates why collapse phases are necessary preconditions for adaptive renewal, and polycentric governance explains which institutional configurations best sustain adaptive capacity under stress.

Despite notable theoretical and empirical progress, significant research gaps remain. Most studies still focus on technological and infrastructural mechanisms of recovery while overlooking the behavioral and cognitive dimensions that explain how organizations learn under stress. In the airport literature, resilience is still too often assessed through traffic restoration, infrastructure continuity, or financial stabilization, while the internal governance and learning mechanisms that make adaptation possible remain underexamined. This study addresses that gap by examining the Bucharest Airports National Company (CNAB) as a complex learning system in which coordination, feedback, and decision flexibility interact to sustain systemic performance. By focusing on adaptive governance, organizational learning, and team-level coordination, the paper explains how resilience emerged within a critical infrastructure organization during prolonged disruption.

Research Design and Methodology

Empirical context and case selection

The COVID-19 pandemic provided an exceptional empirical setting for observing how complex socio-technical systems adapt to prolonged disruption. Among global industries, aviation was particularly exposed, as its interdependence between technology, regulation, and human coordination left little room for error (Suk & Kim, 2021; Sun et al., 2022).

CNAB, managing Romania’s two main airports - Henri Coandă International (Otopeni) and Aurel Vlaicu International (Băneasa) - represents a hybrid organization operating between public governance and market-driven performance. Before the pandemic, CNAB served over 14.7 million passengers annually (CNAB, 2020–2022). In 2020, traffic declined by nearly 80%, and revenues contracted significantly (Romanian Ministry of Transport and Infrastructure, 2021). Despite these shocks, CNAB maintained essential operations such as humanitarian and cargo flights, illustrating

the adaptive behaviors and institutional flexibility that underpin resilience in Complex Adaptive Systems (CAS).

This study follows an explanatory single case design with CNAB as a critical infrastructure organization amid prolonged uncertainty. The case was chosen not only for the critical role CNAB plays in Romanian and regional aviation, but also for the opportunity to explore the dynamics of adaptation in a hybrid public-market organization in the midst of prolonged disruption. Rather than treating CNAB simply as an example of sectoral recovery, the paper uses the case to investigate how governance structures, coordination routines, and learning processes were reconfigured during crisis. The analysis is structured around three sub-units of observation: the operational subsystem, in terms of flight management, logistics, and infrastructure; the organizational subsystem, in terms of governance processes, communication flows, and coordination mechanisms; and the human subsystem, in terms of team resilience, leadership dynamics, and learning processes.

Research objectives and conceptual orientation

The research aims to investigate how the Bucharest Airports National Company (CNAB) modified its operational, decision-making, and governance frameworks in response to the systemic disruptions caused by the COVID-19 pandemic. It primarily seeks to identify the adaptive strategies that enabled CNAB to sustain operational stability during crisis. Additionally, the study evaluates the internal processes that facilitated learning and organizational resilience. A key aspect focuses on understanding how feedback loops - dynamic exchanges of information and adjustments within the system - helped preserve coherence amid uncertainty.

The study is rooted in the CAS framework, which conceptualizes resilience as an emergent, nonlinear process rather than a fixed state. In this view, resilience develops through ongoing cycles of learning, coordination, and structural change that help systems withstand shocks while maintaining their functions. This perspective supports a governance-centered reading of the case, in which resilience is treated as an emergent organizational capability generated through feedback, distributed adaptation, and institutional learning. Accordingly, this section is less focused on measurement and more on interpretation. The goal is to provide an explanation of how adaptive governance developed in CNAB as a function of its operational, organizational, and human subsystems, as well as how crisis management was transformed into more sustainable types of coordination and learning.

Qualitative research design

A qualitative case study design based on document analysis stands at the core of this paper. The methodological objective is not to estimate resilience through composite metrics, but to identify the organizational processes by which resilience was developed within the context of CNAB during the pandemic. This design focuses on the evidence of adaptive events, coordination processes, governance changes, and learning processes that can be identified in institutional documentation.

As a secondary methodological technique, a comparative qualitative benchmark analysis has been employed, to conceptualize CNAB's adaptive approach in comparison to regional peers, but only where it strengthens the governance argument rather than shifting the paper toward regional performance comparison.

Table 1 summarizes the qualitative research design used in this study.

Table 1. Qualitative methods

Component	*Purpose*	*Sources*	*Analysis*	*Output*
Document analysis	Identify organizational strategies, team coordination, and	CNAB reports, EU and national policy documents,	document selection; thematic coding; category	explains how resilience emerged through feedback, coordination, and

	adaptive governance practices	press releases.	clustering; interpretive analysis	institutional learning
Comparative contextualization	Contextualize CNAB's adaptive practices relative to regional peers	Reports from BUD, PRG, SOF airports, Eurocontrol briefs.	selective comparison; pattern matching	supports transferability of the case

Source: Authors' contribution

Given that this study focuses on formalized and publicly visible forms of organizational adaptation, institutional documents provide an appropriate empirical basis for analysis. For instance, annual reports, policy documents, communications, and other publicly available materials allow us to track how coordination mechanisms, governance adjustments, and organizational responses were developed, justified, and solidified. The goal is not to access private cognition or non-documented informal interactions but to understand these publicly visible organizational mechanisms of adaptation. The credibility of this study is ensured by triangulating different types of institutional and policy documents, enabling the recognition of patterns across different documentary contexts.

Data sources and analytical procedures

All data were sourced from verified, publicly accessible institutional sources, presented in the Annex. The qualitative aspect of the research was based on a thorough review of CNAB's internal communications and public reports that detail operational measures, crisis responses, and structural adjustments. These sources were analyzed in the context of Romanian and European Union regulations related to airport governance, crisis management, and institutional learning.

Data collection followed a systematic and multi-layered approach. Qualitative materials, such as policy notes, reports, and press releases, were collected chronologically to trace the evolution of adaptive decisions over time. These documents were coded to identify recurring patterns, themes, and feedback loops reflecting organizational learning and resilience mechanisms.

The process of qualitative research included four structured stages to ensure thorough analysis and clarity. Initially, the document selection phase involved finding and reviewing publicly available institutional and policy reports covering the pandemic period and the immediate recovery phase that focused on adaptive airport management. Then, in the thematic coding stage, recurring patterns related to governance, learning loops, coordination, and communication were identified and systematically coded with NVivo. During the third phase, clustering techniques grouped the coded data into broader categories that represent adaptive mechanisms and team coordination processes. Lastly, the interpretation stage connected these themes to the study's theoretical framework, allowing the analysis to explain how organizational learning, coordination, and adaptive governance contributed to resilience in practice.

This approach has limitations. Because the analysis relies on publicly available documents, it captures formalized and institutionally visible adaptation more effectively than informal decision-making dynamics or undocumented internal tensions. To reduce this limitation, CNAB documents were interpreted alongside external sectoral and policy sources, allowing for contextual triangulation and a more balanced reading of the case.

Results and Discussion

Crisis shock and recovery context

This case study aims to understand how resilience develops within a complex public organization during significant disruption. CNAB was selected not only for its strategic significance

in the Central and Eastern European air transport network but also because it illustrates the challenges faced by large, state-owned entities dealing with market volatility and regulatory hurdles. This organization offers a valuable context to examine how public infrastructure systems can act as living systems—able to sense change, adapt their behavior, and evolve their structure.

The development of air traffic at Bucharest Airports National Company (CNAB) should be understood within the wider context of the significant changes that transformed the global aviation industry from 2019 to 2022. The COVID-19 pandemic caused a sharp decline in passenger numbers to record lows and exposed the structural weaknesses and resilience of airport systems globally. In this context, CNAB's progress mirrors the typical phases of decline, stabilization, and adaptive recovery seen in European aviation.

Before 2020, CNAB recorded consistent growth, handling over 14.7 million passengers in 2019, mainly driven by European low-cost carriers and increasing non-aeronautical revenue. The COVID-19 pandemic, however, caused a sudden systemic shock. Passenger counts plummeted by 79.7 percent in 2020, revealing financial vulnerabilities and unprecedented coordination challenges for the organization. Despite these shocks, CNAB maintained essential operations such as humanitarian and cargo flights, illustrating the adaptive behaviors and institutional flexibility that underpin resilience in CAS. This crisis underscored the interconnectedness of CNAB's operational subsystems with the wider European air-transport network, illustrating the limitations of centralized control amid volatility and uncertainty.

Taken together, these developments establish the empirical context for the case: CNAB did not face a temporary interruption, but a prolonged systemic disruption that tested the organization's capacity to coordinate operations, preserve coherence, and adapt its governance practices over time.

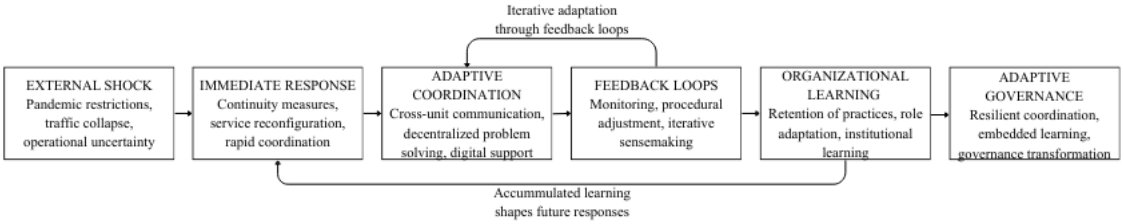

Figure 1. From external shock to adaptive governance: a conceptual sequence of CNAB's adaptive response during the pandemic.

Figure 1 provides a schematic representation of the adaptive sequence identified in the case study. It represents the way in which external disruption generated immediate operational responses, which in turn are transformed through feedback loops, organizational learning, and increasingly coordinated governance practices. The figure serves as a visual synthesis of the mechanisms discussed in the following subsection.

Qualitative analysis and triangulation

The qualitative aspect of the research complemented the broader recovery context through a systematic thematic document analysis focused on institutional learning and adaptive governance within CNAB. This process consisted of four interconnected stages designed to maintain methodological consistency and deepen interpretation. The empirical material consists of publicly available institutional, sectoral, and policy documents published between 2020 and 2024, with a primary focus on CNAB annual reports and financial statements (2020–2022), complemented by aviation-sector assessments from ACI, EUROCONTROL, IATA, and ICAO, as well as relevant European and Romanian policy documents. Next, each document was coded to identify adaptive events, coordination mechanisms, and innovation practices indicating CNAB's adaptive response. These coded elements were then grouped thematically into three key analytical dimensions—operational, organizational, and human, providing a structured view of how adaptability appears across different system levels. Finally, the identified patterns were interpreted through the lens of

adaptive governance and organizational learning, strengthening the interpretation of how systemic resilience develops in practice.

The analysis identified three recurring findings. Firstly, the documents demonstrate the presence of repeated patterns of adaptive coordination in the operational units, particularly in relation to the application of the continuity measures, adjustments for safety, and the handling of rapidly changing constraints. Secondly, the documents demonstrate the presence of feedback loops as a mechanism of governance adjustment, where the operational information is used for organizational responses. Thirdly, the documents demonstrate the presence of cumulative learning, where the responses to the disruptions gradually changed the routines, communication, and coordination mechanisms.

The results indicate that CNAB's ability to adapt stemmed from its skill in converting disruptions into information, a hallmark of CAS behavior. Each disturbance—such as the sudden drop in flight volume, new safety regulations, or supply chain issues—acted as a prompt for local adaptation and adjustment.

A key insight from the case study relates to the feedback structure that supports organizational adaptation. CNAB's learning loops act like an internal nervous system, constantly converting local data into organizational knowledge. This ongoing process aligns with the Safety-II framework introduced by Jurado, Lopez, and Li (2021), which views safety and resilience as proactive rather than reactive. In this context, learning loops helped identify risks and adjust procedures before issues developed into system failures. The capacity to collect, interpret, and share learning demonstrates how high-pressure environments can foster systemic innovation when feedback mechanisms are embedded.

Adapted governance, team resilience, and distributed coordination

The data from Bucharest Airports National Company (CNAB) indicates how resilience and performance develop within organizations seen as complex adaptive systems (CAS). The pandemic disturbed the stable structure of global aviation, turning airports from steady logistic centers into flexible systems of testing and adaptation. In this changed environment, CNAB demonstrated the relationship between structure and agency fundamental to complexity science. Its capacity to maintain operations, reorganize activities, and steadily regain performance indicates that effective crisis management during high-pressure situations relies more on ongoing coordination among dispersed agents—through feedback, learning, and shared understanding—than on strict procedural control.

This corresponds with Cosens et al. (2021), who argue that effective governance of complex systems requires bottom-up self-organization, polycentric authority, and multi-actor networks that enable change to spread through interconnected feedback processes rather than through top-down hierarchical structures. CNAB's approach confirms this: leadership functioned more as a facilitator of multiple feedback loops rather than a strict authority, allowing coherence to develop through decentralized coordination.

The CNAB case highlights the evolution from reactive resilience to adaptive governance. Traditional resilience models concentrate on a system's capacity to withstand shocks and revert to stability (Cosens et al., 2021). In contrast, adaptive governance prioritizes ongoing learning and transformation amid uncertainty. The findings suggest that CNAB's response was not limited to preserving continuity; it also involved modifying the way decisions were coordinated across the organization. CNAB's approach (delegating authority, improving interdepartmental communication, and speeding up digital transformation) embodies these principles in practice. In this respect, resilience emerged through adaptive coordination rather than rigid hierarchy.

This case also highlights the multifaceted nature of team performance in high-pressure environments. The aviation crisis kept personnel under ongoing cognitive and emotional strain, requiring quick decisions with limited information. Ceken (2025) emphasize that such situations

demand cognitive flexibility — the capacity to adjust perspectives and strategies based on changing circumstances. CNAB's cross-functional teams illustrate this trait: operational staff, maintenance engineers, and managers quickly shared feedback, improvised, and built trust through collaboration. These actions reflect what Junça-Silva & Caetano (2023) call adaptive team performance - a mutual regulation process that supports coordinated efforts amid unpredictability.

The psychosocial aspect of adaptive capacity is equally crucial. In complex systems, success relies not just on structure but also on shared narratives that unify individuals around common goals. The stable morale among CNAB teams during the crisis reflects what Duchek (2020) terms "relational resilience": the trust, empathy, and communication that keep teams cohesive under pressure. This relational layer served as a buffer against cognitive overload and emotional exhaustion, helping personnel maintain focus and initiative even when procedural clarity was temporarily lost.

From crisis response to adaptive governance

When viewed through the lens of network resilience, CNAB's recovery trajectory also aligns with complex network theory (Sun & Wandelt, 2021; Sampaio, Costa, & Guterres, 2022). The organization's connectivity with regional and European partners served as a stabilizing factor, enabling access to real-time data and regulatory synchronization. Khare's (2024) Global Resilience in Transport-and-Logistics (GRIT) Framework bolsters this interpretation by highlighting the importance of cross-sectoral coordination to maintain flow integrity during disruptions. CNAB's place within Eurocontrol's network allowed adaptive coupling: its internal learning processes were guided by external signals, helping the organization to adjust recovery efforts in line with broader system dynamics.

More generally, the case indicates that operational stabilization, digital coordination, and regulatory synchronization tended to mutually support one another. Instead of representing isolated responses, these mechanisms formed an adaptive pattern in which local adjustments, coordination within departments, and external alignment contributed in a joined manner to recovery.

Table 2 synthesizes these results by linking the human, organizational, and system-integration levels of analysis to their broader theoretical implications.

Table 2. Theoretical synthesis of adaptive governance and resilience at CNAB

Level of analysis	*Empirical focus*	*Main finding*	*Theoretical interpretation*
Micro (teams / human subsystem)	Team coordination, feedback sharing, improvisation, trust	Adaptive team performance and learning loops supported rapid adjustment under uncertainty	Supports team resilience, relational resilience, and complexity leadership
Meso (organization / governance subsystem)	Interdepartmental coordination, delegated authority, communication routines, digital coordination	Resilience emerged through adaptive coordination rather than rigid hierarchy	Supports adaptive governance, distributed cognition, and decentralized coordination
System integration (operational–organizational link)	Interaction between operational continuity, governance adaptation, and feedback processes	Crisis response evolved into institutional learning and governance reform	Supports CAS theory and resilience as an emergent organizational capability

Source: Authors' contribution

Three findings stand out in particular: resilience emerged through adaptive coordination rather than rigid hierarchy; feedback loops linked operational and governance subsystems; and crisis response evolved into institutional learning and governance reform.

Conclusion

The findings of this study show that CNAB's adaptive trajectory during COVID-19 can be understood through the core dynamics of the Complex Adaptive Systems (CAS) framework: distributed decision-making, feedback-driven reorganization, and institutional learning under pressure. Rather than treating resilience as a fixed attribute of infrastructure, the case demonstrates that in aviation, resilience is actually a product of the interaction between operational continuity, organizational adaptation, and human coordination. In this sense, adaptive governance, and not static preparedness alone, emerges as a central driver in the development of systematic resilience in critical infrastructure.

The study conceptually shifts from traditional risk management to adaptive governance in aviation. Instead of focusing on control and standardization, adaptive governance highlights flexibility, quick learning, and cross-sector teamwork as key for handling systemic crises. The CNAB case illustrates that resilience develops through three interconnected layers: (1) Operational agility, driven by digital tools and flexible resources; (2) Organizational learning, fostered by team resilience, ongoing feedback, and decentralized decision-making; (3) Institutional adaptability, enabled by collaboration among national authorities, European agencies, and private entities. This framework provides a transferable governance lesson for other critical infrastructure sectors in the face of uncertainty, including transport, emergency management, and infrastructure protection. The broader applicability of this work is not in the specific metrics, but in illustrating how organizational coherence can be maintained through the integration of feedback, coordination, and learning into everyday governance processes.

Several implications arise from these findings. First, there is a need to move beyond crisis contingency planning in airport governance frameworks, with greater emphasis being placed on adaptive coordination capacities that operate during times of disruption. Second, digital coordination tools should be seen not only as efficiency tools, but also as governance tools that facilitate communication, synchronization, as well as adaptation among units. Third, there is a need to move beyond redundancy as well as control in approaches to resilience, with greater emphasis being placed on learning, communication, as well as feedback.

In summary, the present study shows that that the resilience of complex organizations such as the CNAB is based on dynamic learning, coordination, and flexibility in governance rather than static preparedness. Through the implementation of distributed coordination and learning mechanisms within airport organizations, the disruption that airports face can become an opportunity for organizational renewal. The present study contributes to the development of the adaptive governance and organizational resilience theories, while at the same time providing important implications for the design of responsive and sustainable airport organizations.

Future research could further extend this perspective by examining if similar adaptive governance processes exist in other critical infrastructure sectors and during different types of prolonged disruption. A comparative qualitative study design would be particularly beneficial in understanding the cross-organization portability of institutional learning, team adaptation, and coordination.

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