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ABSTRACT

In an increasingly volatile world, organisations must be prepared to navigate high-impact crises such as pandemics, geopolitical tensions, and disasters. As a result, resilience has become a strategic priority. Operationalising resilience, however, remains challenging due to three key barriers. First, the complex, interconnected nature of organisations makes it difficult to understand interdependencies and implement effective resilience interventions. Second, many crises are considered unimaginable, so-called Black Swans, hampering proactive resilience-building. Third, resilience is highly contextual and conceptually ambiguous, leading to uncertainty about its practical application. To address these barriers, this study investigates what decision-makers within complex systems can learn from wargaming (i.e. the practice of simulating decision-making in environments of conflict or competition) Black Swans to support the operationalisation of resilience. Based on four wargames with 57 decision-makers from aviation, defence and other sectors, we conducted a thematic analysis to interpret their outcomes. Our findings suggest that wargaming helps decision-makers (1) develop a shared understanding of their organisation within its complex system; (2) imagine the impact of type-B (unknown knowns) and type-C (ignored knowns) Black Swans on their organisation; and (3) operationalise resilience-as-an-outcome while deepening their theoretical understanding of it. Finally, conducting wargames may enhance resilience capabilities, namely shared situational awareness, the management of keystone fragilities, anticipating future developments, and sensemaking. Our findings suggest that wargaming can be a valuable tool for organisations to operationalise resilience.

1. Introduction

From the 2020s onwards, our society has had to deal with many high-impact crises. Events such as the COVID-19 pandemic, the Suez Canal obstruction, the Russo-Ukrainian war, and multiple disasters have exposed fragilities within our respective healthcare systems, supply chains, national security, and climate policy. In response, the concept of organisational resilience, widely regarded as a desirable organisational characteristic for dealing with adversity [1] and hereafter referred to simply as resilience, has gained traction across various sectors. For instance, in healthcare, resilience initiatives are focusing on strengthening health system to better deal with

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public health challenges [2]; in defence, on deterring and responding to geopolitical threats [3]; and in the field of critical infrastructure, on protecting essential services (e.g. energy, transportation and financial sector) against natural and man-made risks [4]. However, academic knowledge on operationalising resilience, by which we mean translating resilience aspirations into actionable interventions (e.g. training, products or strategies) by decision-makers (e.g. strategic managers, crisis managers or policy-makers), remains scarce [1,5,6]. Based on prior research [7,8], the difficulty in operationalising resilience can be attributed to three key barriers: the complexity of modern organisations, the unimaginability of the so-called Black Swans, and the conceptual ambiguity of resilience.

The first barrier lies in the labyrinthine behaviour of modern organisations, which, more than simply being complex systems themselves, are embedded within overarching ones. Following Snowden and Boone [9], complex systems are characterised as dynamic, emergent, unpredictable and having many non-linear interacting elements and sub-systems. Consequently, for decision-makers to fully grasp these complex systems and determine where resilience should be operationalised is a significant challenge requiring continuous engagement with them [10], and a considerable investment in time and effort [11]. Furthermore, as operationalising resilience for individual organisations (e.g. an airport operator) could lead to different interventions than those for an entire industry (e.g. aviation) or even for society as a whole, defining a complex system's borders, while crucial, can be both highly ambiguous and dependent on the perspective taken.

The second barrier emphasises the difficulty of operationalising resilience in the face of crises that cannot be anticipated. Although many different conceptualisations exist of such crises, including Black Elephants [12], Grey Rhinos [13], Dragon Kings [14], and fundamental surprises [15], in this study, we utilise Black Swans as our anchoring disaster typology. As defined by Taleb [16], Black Swans are surprising events with a major effect which are only retrospectively predictable through hindsight. Aven [17] further refines the Black Swan concept into three types: type-A Black Swans that are true unknown unknowns; type-B are unknown knowns, recognised by decision-makers but overlooked in risk assessments; and type-C are ignored knowns, acknowledged risks that are dismissed as unlikely. While type-A Black Swans are impossible to anticipate, the ex-ante operationalisation of resilience against type-B and C still seems feasible. As history shows, many type-B or C Black Swans, such as 9/11 [58], Hurricane Katerina [18], Fukushima [19], and COVID-19 [8], were not entirely unforeseeable. However, they failed to be imagined by decision-makers in ways that translated into actionable interventions. Thus, making type-B or C Black Swans imaginable is crucial for supporting the operationalisation of resilience.

The third barrier concerns the conceptual ambiguity of resilience. Despite its widespread use, the term lacks a consistent definition, which hampers efforts to operationalise it [20]. On the one hand, closely tied to the first barrier, ambiguity arises due to resilience being highly context-dependent and related to an organisation's goal [1,21]. For example, an airport operator might require a different operationalisation of resilience than a hospital. On the other hand, the nature of resilience is frequently debated, particularly whether resilience is best conceived as an outcome or a process [6,20,22]. Resilience-as-an-outcome refers to resilience as a state after facing adversity, such as a Black Swan. These outcomes can be further divided into four categories: fragile (losing value in the face of adversity); robust (stability in the face of adversity); adaptive (evolutionary change in the face of adversity); and transformative (revolutionary change in the face of adversity) [7]. Approaching resilience-as-a-process emphasises an organisation and its decision-makers' capabilities to manage adversity, ultimately leading to a resilient outcome [22]. In this study, we predominantly use the "resilience-as-an-outcome" lens.

Following the COVID-19 pandemic, wargaming has increasingly been acknowledged as a promising tool to enhance strategic decision-making in times of uncertainty [23–25]. Originating from the military, a wargame is a model that facilitates decision-making in a synthetic environment of competition or conflict [26]. During a wargame, decision-makers are immersed in a narrative in which they make decisions, immediately see the effects, and react again to these effects, resulting in synthetic experiences. Building on de Wit [23], Gates [24] and Linden [25], and as suggested by Lantto et al. [27] and Wojtowicz [28], we propose that wargaming could help address barriers to operationalising resilience as it provides a structured yet flexible way of simulating the interaction between complex systems [29,30] and Black Swans [18,26]. The outcomes of a wargame may offer insights into the organisation's resilience-as-an-outcome, as we effectively simulate the state of an organisation after facing adversity. Subsequently, organisations could translate these insights into interventions, supporting the operationalisation of resilience.

Although academic knowledge is available on the design of a wargame within the context of complex systems, Black Swans, and resilience-as-an-outcome [31], there remains a gap in empirical knowledge about their actual impact on decision-makers. Specifically, it is unclear whether, and how, wargames can contribute to the operationalisation of resilience. To address this knowledge gap, we investigate the following research question: What do decision-makers within complex systems learn from wargaming Black Swans to operationalise resilience?

The remainder of this article is structured as follows. Section 2 outlines the method used, including the wargame design. Section 3 presents the results. Section 4 offers a discussion, addressing limitations and potential avenues for future research. Finally, Section 5 concludes the article.

2. Method

2.1. Participants & recruitment

We recruited decision-makers from organisations based in the Netherlands that are vulnerable to looming Black Swans and interested in enhancing their organisational resilience. Using convenience sampling, three organisations were included: Amsterdam Airport Schiphol; the Dutch Ministry of Defence; and a crisis management course affiliated with Delft University of Technology. To

conduct an effective wargame, a minimum of six participants were required per organisation. Participants within Amsterdam Airport Schiphol and the Ministry of Defence were recruited in collaboration with an internal sponsor, being respectively a senior manager and a senior policy-maker. Inclusion criteria required participants to hold decision-making authority related to resilience and Black Swans, such as strategic management, crisis management, risk management, and business continuity management. For the crisis management course, participants were recruited based on their enrolment in the overarching program, forming a diverse panel of predominantly Dutch crisis managers from the logistics, aviation, healthcare, and security sectors.

2.2. Wargaming resilience blueprint

Building on our prior research [31], we utilised a wargaming resilience blueprint. This blueprint is a structure to wargame the interaction between complex systems and Black Swans, aimed to provide insights into the operationalisation of resilience-as-an-outcome. The blueprint follows a seminar game approach whereby decision-makers simulate making decisions and experience their consequences through guided dialogue [18]. The blueprint consists of five steps: (0) preparing, (1) understanding complex systems, (2) designing Black Swans, (3) red teaming, and (4) operationalising resilience. Each wargame was planned for 2 h, hosted by at least two facilitators and conducted on-site with the participating organisation.

Step 0 *Preparing*

Before running the wargames, a preparatory process was conducted by authors AN and JG together with an internal sponsor to tailor the wargaming resilience blueprint to the setting of the participating organisation. The process consisted of (1) selecting the relevant system maps, (2) scoping the Black Swans, and (3) dividing the participants into a minimum of two teams with a maximum of five participants per team.

Inspired by gigamapping [32], the system maps were used to visualise and explore the organisations' complex systems. Their selection, as well as the scope of the Black Swans, was determined in consultation with the internal sponsor. For Amsterdam Airport Schiphol, the system maps included a geographical map of the airport, a process map, and a stakeholder map. No restrictions were given regarding the scope of the Black Swan. For the Ministry of Defence, the system maps included a geographical map, a stakeholder map, and several organisational maps. Regarding the Black Swan design, participants were instructed to focus on a military conflict without nuclear exchange, a restriction requested by the Ministry of Defence. Finally, due to the diverse participant group of the crisis management course, the sponsor and authors opted to reuse the Amsterdam Airport Schiphol system maps without any Black Swan restrictions. This choice ensured familiarity among participants, as Schiphol is a widely recognised organisation within the Netherlands.

Step 1 *Understanding complex systems*

The wargame commenced with creating a shared understanding of the participating organisation requiring resilience and its overarching complex system. Therefore, each team collectively reviewed the system maps and discussed and agreed on their organisation's primary goal.

Step 2 *Designing Black Swans*

Second, each team designed their own Black Swan. Inspired by the pre-mortem analysis [33], this process started with participants using a template where they first defined the climax of the Black Swan, or the major effect, consisting of at least three, possibly interrelated, events. The judgement of what constitutes a major effect was up to the participants. After defining the climax, teams took a step back to identify at least three origins that could have led to it, followed by a step forward to determine at least three effects that might emerge from it. Although both origin and effect should be related to the climax, their relation is not required to be linear. Participants were free to define each origin or effect's timing (e.g. a day, week or month before or after the climax). Table 1 provides a fictionalised example of a designed Black Swan inspired by the COVID-19 pandemic and its impact on aviation.

Table 1
Fictionalised example of a designed Black Swan inspired by the COVID-19 pandemic and its impact on aviation.

Origin	Climax	Effects
Airlines express their concern regarding a novel outbreak in China.	The novel disease reaches Europe. In reaction, lockdowns are imposed. Subsequently, working from home becomes the norm.	As the impact of disease subsides, the demand for air travel rises.
There is a surge in domestic travel within China due to a national holiday.	The aviation sector has to deal with major financial losses.	The aviation sector has difficulty hiring new employees and must operate with an inexperienced workforce.
The US closes its borders for all international air travel.	The aviation sector reorganises, leading to a series of layoffs and a brain drain.	The public opinion turns against the aviation sector as it has received a significant amount of governmental aid.

Step 3 *Red teaming*

Third, the participants simulated the interaction between their organisation and the designed Black Swan. This interaction was simulated by utilising red teaming, a tool frequently used in wargaming [30], whereby an adversary's perspective is adopted [34] and Black Swans could be revealed [35]. The simulation starts with each team being split into two subteams: a blue, or defending, team representing the organisation and a red, or attacking, team representing the Black Swan. The red team then merges with another blue team, bringing their previously designed Black Swan scenario. Fig. 1 illustrates this process.

Subsequently, the red team attacks the blue team's organisation with a Black Swan, unknown to them, creating a surprise. The simulation unfolds over three rounds, each focusing on a different phase of the Black Swan: origin, climax and effect. During each round, the red team identifies organisational fragilities related to the origin, climax, and effect, marking them with red sticky notes on the system maps (i.e. geographic, stakeholders, and process). The blue team responds by devising interventions, recording them on blue sticky notes and placing them on the same maps. Fig. 2 illustrates this process.

Step 4 *Operationalising resilience*

After the simulation, the facilitators gave a theoretical introduction to resilience-as-an-outcome to create a shared understanding among the participants. The introduction utilises the categorisation of resilience (fragile, robust, adaptive and transformative) as its frame [7]. Then, the participants focused on operationalising resilience by mapping out their sticky notes of step three on a matrix (Fig. 3). The x-axis encompasses the four aspects of resilience, while the y-axis represents the required effort, from low to medium to high. The effort represents aspects such as time, financial costs, and resources required. Finally, all participants gathered around the matrix and engaged in a moderated roundtable discussion by the facilitators, whereby each red and blue team presented their sticky notes, argued their position on the matrix, and reflected.

2.3. Data collection

The study collected data through (1) field notes, (2) audio recordings of the debrief, and (3) post-questionnaires. First, field notes were taken during the wargames by AN and JG or the sponsor, focusing on frequent discussions amongst participants, the overall atmosphere, and the interaction with the wargame materials such as the system maps, Black Swan design template, and the matrix.

Second, after each wargame, AN and JG or the sponsor, facilitated a debrief whereby all the participants reflected on their experience. Audio recordings captured the debrief after the wargames with Amsterdam Airport Schiphol and the crisis management course, lasting 18 and 10 min, respectively. For confidentiality reasons, audio recordings were not permitted during the wargames with the Ministry of Defence; however, field notes and questionnaires were allowed.

Third, the post-questionnaire explored the participants' experiences with the wargame and their learnings on resilience, complex systems, and Black Swans. This was an open-ended questionnaire with sample questions including: *How was your experience?*; *What are your takeaways?*; *Did your perspective on resilience change? If so, how?*; and *Do you foresee new looming Black Swans? If so, which?* Minor

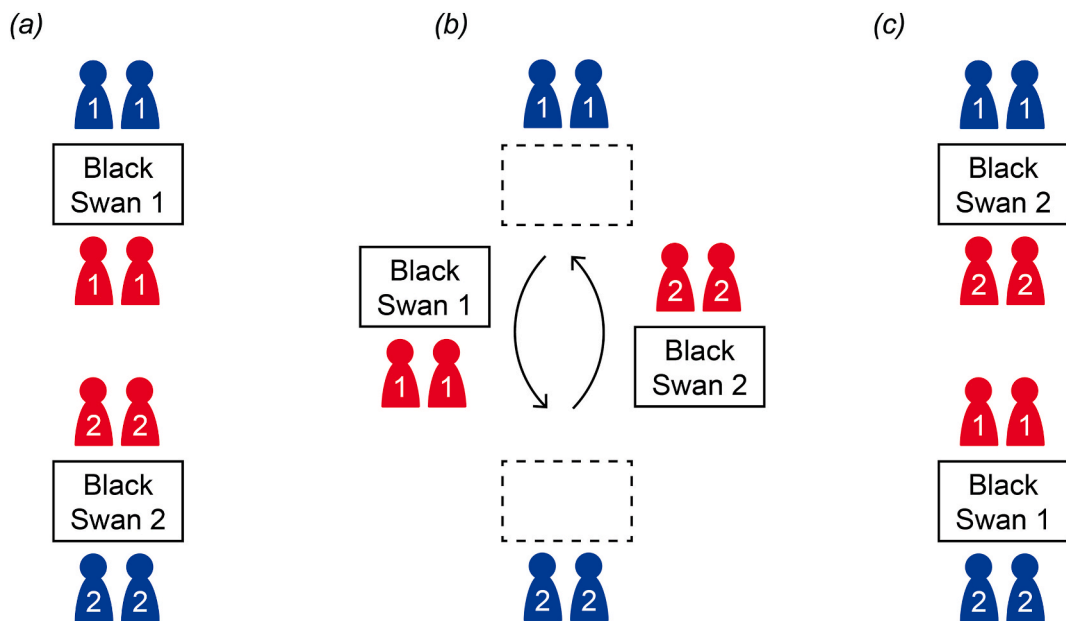**Fig. 1.** (a) Team 1 and team 2 are divided into a red and blue team. (b) Team 1's red team moves with team 1's designed Black Swan to team 2's blue team and vice versa. (c) Finally, team 1's red team and team 2's blue team merge and vice versa.
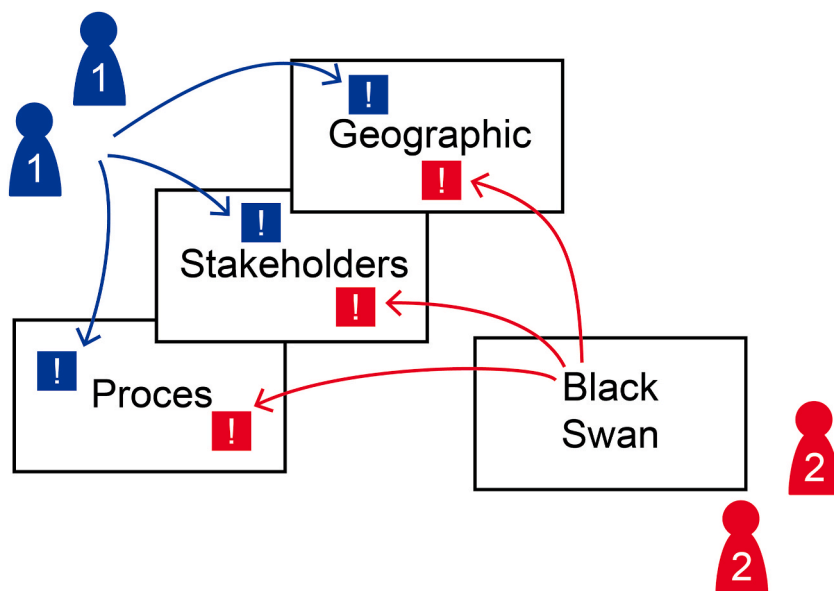
Fig. 2. Red team 2 introduces the three origins and attacks blue team 1 by pasting red sticky notes on their system maps. The blue team defends by pasting blue sticky notes on their system maps. Repeat for the climax and three effects.
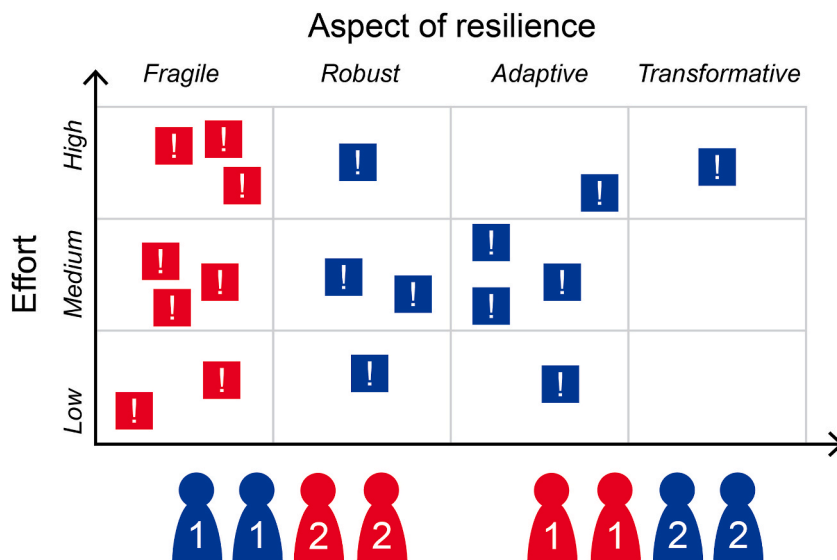

Fig. 3. All participants place their sticky notes on the matrix. The x-axis represents the four aspects of resilience. The y-axis represents the required effort.

modifications were made to tailor the questionnaire to the aviation and defence contexts. While most questions were in Dutch, an English version was provided for non-Dutch speakers in the crisis management course. For the complete questionnaire, see Appendix 1.

2.4. Data analysis

We conducted an inductive and deductive reflexive thematic analysis to identify and develop patterns across the collected data regarding complex systems, Black Swans and resilience [36]. The data analysis followed Braun et al.'s [37] six-phase approach, consisting of (1) familiarising with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) reporting.

In the first phase, authors AN and JG familiarised themselves with the data by reviewing field notes, listening to audio recordings, and reflecting on the responses from the post-questionnaires. Audio transcriptions were then generated using Amberscript's machine-

made transcription service and reviewed and refined by AN. Finally, all field notes, transcribed audio recordings, and questionnaire data were imported into ATLAS.ti, a qualitative data analysis software. In the second phase, a two-step inductive coding process was conducted during a workshop. In the first step, AN and JG independently generated codes using sticky notes and flip-over sheets. In the second step, these codes were compared and refined through discussion. The resulting 27 codes were put into ATLAS.ti.

In the third phase, AN and JG generated the initial themes. In the fourth phase, these themes were reviewed and refined through a deductive approach by AN and JG, resulting in main and subthemes aligned with the wargaming resilience blueprint's core concepts: complex systems, Black Swans, and resilience. In the fifth phase, AN and JG defined and named the themes, which the other authors then reviewed. Finally, the themes were reframed into narratives and drafted in a report, which all authors reviewed. Furthermore, AN extracted exemplary quotes from the audio transcripts and post-questionnaires, with most quotes being translated from Dutch to English. JG reviewed the translations.

2.5. Ethics

This study was approved by the Human Research Ethics Committee of the Delft University of Technology (reference number 4239). All participants signed an informed consent form for their inclusion. Their participation was voluntary, and they could withdraw at any time during the study. Any expressed opinions during the round table discussion were anonymised to protect privacy.

3. Results

Four wargames were conducted: one in collaboration with Amsterdam Airport Schiphol, two with the Ministry of Defence, and one with a crisis management course affiliated with Delft University of Technology. In total, 57 participants and 13 teams participated. Table 2 provides an overview of all participants, their spread over the wargames and the data collected. While we cannot disclose specific details of the designed Black Swans, they primarily centred on (hybrid) warfare and climate-related disasters. Due to technical issues, no questionnaire data could be collected from the third wargame. AN facilitated all the wargames, JG co-facilitated wargames one and four, and the internal sponsor co-facilitated wargames two and three.

Through reflexive thematic analysis, we generated 27 codes. These were then clustered into three main themes and seven sub-themes. Each main theme clusters learnings related to the core concepts of complex systems; Black Swans; and resilience. Table 3 provides an overview of each theme, subtheme with corresponding description and example codes.

3.1. Navigating complex systems

Throughout the wargame, we observed participants gaining proficiency in navigating their organisation and its overarching complex system. First, reviewing the system maps, defining the organisation's goal, and subsequent red teaming helped foster a shared understanding among participants while encouraging creative thinking. Second, through the wargame, participants uncovered the organisation's zone of influence within the broader system.

3.1.1. Creating shared understanding

In general, reviewing the system maps, defining the organisation's goal, and red teaming helped participants create a shared understanding of the intricacies and relational dependencies within their organisation and the overarching complex systems. This was predominantly observed during steps one and three and reaffirmed by several participants during the debriefs and questionnaires of each wargame. As a participant reflects:

> *You also have a real wealth of information, because everybody in the group knows different things and has different backgrounds. […] the most powerful thing of our group is that we all knew such different things – Debrief, Wargame 4*

The wargame two debrief further highlighted the creation of this shared understanding as the system maps sparked debate, whereby the participants collectively reframed their perspective on their organisation while proposing new and adjusted system maps.

Participants also mentioned that defining the organisation's goal created an initial understanding of their organisation's fragilities. This understanding helped them to design and uncover looming Black Swans in step two.

Table 2
Wargame participants and data collection.

Wargame	Participants (teams)	Organisation	Data Collected (response rate questionnaires)
1	16 (3)	Amsterdam Airport Schiphol	Field notes, audio & post-questionnaire (9/16)
2	12 (3)	Dutch Ministry of Defence	Field notes & post-questionnaire (12/12)
3	9 (3)	Dutch Ministry of Defence	Field notes
4	20 (4)	Crisis management course with participants from sectors such as logistics, health, aviation and security	Field notes, audio & post-questionnaire (4/20)

Table 3

Overview of the themes, subthemes, corresponding descriptions and example codes.

Theme		Subtheme		Description	Example codes
3.1	Navigating complex systems	3.1.1	Creating shared understanding	Reviewing system maps, defining organisational goals, and red teaming fostered a shared understanding of the organisation and its role within the overarching complex system.	Scope is crucial; Making sense of complex systems; Red teaming and creativity
		3.1.2	Uncovering organisational zones of control	The organisation's zone of control became more clearly defined.	Black Swan & organisational goal; Scale of the crisis; Autonomy
3.2	Black Swans, unsurprising surprises	3.2.1	Are these really Black Swans?	Discussions arose on the surprise aspect of Black Swans, some only considered type-A Black Swans, while others included type-B and C.	Awareness of Black Swans; Gasp of surprise; "we imagined it";
		3.2.2	Different Black Swans, same fragilities	Repeated exposure to different Black Swans revealed recurring fragilities.	Different stressor, same effect
3.3	Operationalising resilience	3.3.1	Sensemaking through categorising resilience	The categorisation of resilience provided both a theoretical foundation and a sensemaking tool in the operationalisation of resilience.	Perspective on resilience changed; Fragility awareness; Debrief created options
		3.3.2	Pinpointing fragilities	Distinguishing between fragilities and the undesirable situation that caused them proved challenging	Defining fragility versus undesirable situation
		3.3.3	Implicit connotations of resilience aspects	Implicit connotations were often attached to the aspects of resilience (e.g. 'fragility is always undesirable').	Mind the connotation

[…] every time we started to go, what could go wrong? […] We said, okay, wait, what was our goal? What do we say the airport does? […] it did help in formulating […] what could shut down things big time. – Debrief, Wargame 4

Finally, the wargame seemed to create a deeper understanding of the organisation's *raison d'être*. As indicated by a number of participants, they seemed able to unravel the organisational goal underneath their goal established in step one. As illustrated in the following quote:

Through the [wargame] I identified the political and social importance of the airport and how that is also included in the goal, and is even its core […] - Questionnaire, Wargame 4

3.1.2. Uncovering organisational zones of control

Participants also reflected on their organisation's zone of control, realising that multiple Black Swans extended beyond their influence. This manifested predominantly by participants noting that some Black Swans were too disruptive relative to the system maps. For example, a full-scale war affecting an airport system made some system maps, such as a geographic or process map, feel irrelevant for guiding strategic responses as decision-making power shifted towards the national and European level. As one participant reflected:

[…] the Black Swan was such a big issue, you could put a giant cross over the [process map] – Debrief, Wargame 1

In reaction, a few participants stressed the importance of being more aware of dependencies on other stakeholders. As one participant illustrates:

[…] what is interesting is […] we are so interwoven in a [complex] system, with all kinds of dependencies […] it would be interesting to further explore this – Debrief, Wargame 1

3.2. Black Swans, unsurprising surprises

Participants expressed the need to be more proactive in addressing looming Black Swans. However, how to be proactive remained a point of contention, as discussions frequently revolved around the surprising nature of Black Swans. On the one hand, participants questioned whether their Black Swan's design in step two still qualified as a surprise, and thus, as a Black Swan. On the other hand, some participants noticed that regardless of the Black Swan event, the effects on their system were the same, implying that the Black Swan concept itself was unnecessary.

3.2.1. Are these really Black Swans?

The surprising nature of Black Swans was frequently debated among participants. First, when designing a Black Swan, participants often came up with scenarios inspired by recent crises in the media, such as a (hybrid) war (i.e. the Russo-Ukrainian war) or extreme flooding (i.e. global warming). Subsequently, these Black Swans could be considered unsurprising.

Well, I think there is an interesting thing about all three [designed Black Swans], they are all things that we foresee […]. We have a war, we talk about the climate, […], hybrid warfare is addressed in a whole new report. These things are already happening […] –Debrief, Wargame 1

However, because of the rotation in step three, participants were surprised by their new Black Swan. On the one hand, this was

observed by the emergence of an audible sigh of surprise. On the other hand, participants reaffirmed the sense of surprise during the debrief. However, in multiple debriefs, a debate unfolded about the nature of the designed Black Swans; were these events really surprising, and thus Black Swans, or were they just high-impact crises?

A number of participants viewed Black Swans through a type-A lens, stating that Black Swans that are predictable and somewhat expected are, by definition, not Black Swans as they do not come as a surprise and are already known. However, some participants seem to take a type-B or C lens and suggested that knowing a Black Swan can happen does not equate to being prepared or understanding the effects.

> *[…] you could see Black Swans coming because we have not actually designed completely new Black Swans that pop out of nowhere, […] even though we have them in the back of our minds, we are not sufficiently prepared – Debrief, Wargame 1*

3.2.2. Different Black Swans, same fragilities

Multiple participants noted that different Black Swans, independently designed by different teams, exposed similar fragilities within their organisation. Subsequently, participants implied that the Black Swan, or cause, was irrelevant as its effect remained the same. This sparked a discussion about whether Black Swans were still a necessary concept. For example, a (hybrid) war or extreme flooding could nullify the number of aircraft movements as runways would not be operational. Subsequently, it was discussed whether the focus should be on the fragilities of the runways instead of the causal Black Swan.

> *Q: What are your takeaways from the wargame?*
>
> *A: […] the cause of the crisis [i.e. Black Swan] is less important, the effects are in broad strokes, the same […] – Questionnaire, Wargame 1*

3.3. Operationalising resilience

Participants indicated that the wargame offered a novel approach to improve their theoretical understanding of resilience while enabling its operationalisation. They mentioned that the four aspects of resilience (i.e. fragility, robustness, adaptation, and transformation) work as a sensemaking tool, providing direction to the participants in operationalising resilience. However, they did have difficulties defining the fragilities of their organisation as they often referred to the undesirable event that caused it rather than the organisational aspect that enabled it. Finally, participants seemed unaware of the connotations they attached to each aspect of resilience (e.g. 'fragile is always undesirable').

3.3.1. Sensemaking through categorising resilience

Multiple participants highlighted that the wargame enriched their theoretical perspectives on resilience. They approached the aspects of resilience as a sensemaking tool that provided guidance regarding the development of interventions. Subsequently, it helped them to operationalise resilience within their organisation.

> *I think [the aspects of resilience] are a coat rack to hang something on. That worked well in my opinion.*
>
> *Agreed, I see that in recent years, we have had several things that we have missed or that have been done that fall perfectly into those categories – Debrief, Wargame 1*

The matrix (Fig. 3) helped participants to make sense of their organisation's resilience. It showcased areas of opportunity and crucial fragilities, often tacitly known within the organisation but rarely formalised. They also indicated that the mapping and reflection supported the conception of multiple resilience interventions as they created options. Finally, multiple participants were particularly interested in the aspect of transformation but realised that achieving it remained challenging.

> *I like transformation a lot. […] maybe we should consider having waterplanes in case of flooding […] or ground handling by canoe – Debrief, Wargame 1*

3.3.2. Pinpointing fragilities

During the red teaming of step three, multiple participants had difficulties defining fragilities within their organisation. The predominant difficulty lay in pinpointing the core of the organisational fragility, as they were often framed as the undesirable situation that caused them, instead of the organisational aspect that enabled them, for example, defining a power outage as a fragility instead of the organisation's ill-maintained power grid. When reflecting on the difficulties of defining fragilities, a participant attributed it to the Black Swans being too high-level, hampering the step towards concrete fragilities.

> *I think I find [defining fragilities] difficult because the [Black Swans] are so big. So the undesirable event and the fragility […] you get them mixed up […] – Debrief, Wargame 1*

3.3.3. Implicit connotations of resilience aspects

In step four, as observed through field notes, participants implicitly coupled a connotation to each aspect of resilience. In this sense, fragility became an inherently negative aspect that should be avoided at all costs, while transformation was placed on a pedestal.

Nevertheless, this was not the aim of the wargame. The ambition was to provide a connotation-less overview whereby a strategic fragility (e.g. reducing prices in the short term to acquire more customers in the long term) could be beneficial, and that the other aspects, generally regarded more positively, could have drawbacks (e.g. a transformation could spawn undesirable change).

4. Discussion

4.1. General discussion

This study investigated what decision-makers within complex systems learn from wargaming Black Swans to operationalise resilience. To this end, we conducted four wargames with 57 decision-makers. The results of the wargames were then thematically analysed, resulting in three main themes and seven subthemes. Each main theme covers learnings related to the core concepts of complex systems, Black Swans, and resilience.

Starting with the main contribution, our wargame helped decision-makers to operationalise resilience-as-an-outcome while addressing its three barriers: the complexity of modern organisations; the unimaginable Black Swan; and the conceptual ambiguity of resilience. We believe that the matrix (Fig. 3) functions as a capstone to operationalise resilience as it enables the creation of optionality, or the state of having options [38]. Optionality is frequently reported as an essential strategy for dealing with Black Swans [38] and creating resilience [39,40]. However, how to translate the concept of optionality to an actionable and empirically validated practice remains fuzzy. Subsequently, we consider our wargame, especially the matrix, as an initial contribution towards operationalising optionality.

Although we used a resilience-as-an-outcome lens in our study, we observed that our wargames could foster the development of key resilience capabilities. This observation aligns with Hermelin et al. [5], who examined resilience-as-a-process through activities such as tabletop and command post exercises, which are closely related to wargaming. The following sections discuss how the wargame addressed each barrier and link these insights to the resilience capabilities it fostered.

Regarding the first barrier, the complexity of modern organisations, our findings suggest that wargaming supported decision-makers when developing a shared understanding of their organisation and its overarching complex system. We believe this shared understanding was primarily achieved through reviewing system maps and red teaming. These results align with other studies that show the value of system maps in creating shared understanding by visualising interdependencies [32,41,42]. Furthermore, our findings empirically reaffirm the value of red teaming to simulate decision-making [18] and system behaviour [35]. Additionally, our wargame provided decision-makers with an insight into their organisational zone of influence while recognising the influence of other stakeholders. Providing insights into these zones of control could promote a more systemic approach, fostering closer collaboration between organisations, a challenge that proved to be a major hurdle during the COVID-19 pandemic [8] and Black Swans in general [35].

In line with Wehrle et al. [43], we relate our findings to the resilience capability of shared situational awareness (SSA) [44]. Derived from Endlsey [45], SSA refers to the ability of a team to develop a shared perception, comprehension, and projection of their organisation and overarching complex system. In our context, the development of shared perception and comprehension occurred through the collective analysis of system maps. The projection element was addressed during red teaming, as each blue team had to anticipate interventions in response to the simulated Black Swan. Furthermore, this anticipation often coincided with improvisation, or bricolage, which is considered another resilience capability [46].

Regarding the second barrier, the unimaginability of Black Swans, our wargame enabled decision-makers to imagine and simulate the impact of type-B (unknown knowns) and type-C (ignored knowns) on their organisation. These findings empirically support prior research by Perla and McGrady [18] and Masys [35], highlighting the value of wargaming and red teaming in revealing looming Black Swans. Furthermore, our wargame instigated a recurring discussion on the meaning of a Black Swan. Should it solely be approached as an absolute type-A (unknown unknown)? Or is it dependent on perspective, thus including type-B and -C's? We note that the discussion mirrored a prominent debate on whether or not the COVID-19 pandemic was a Black Swan. On the one hand, Taleb [47] and other scholars [23,48] imply an absolute type-A approach; thus, they do not consider the pandemic a Black Swan. On the other hand, Mishra [49] and Sweeney [50] approached the pandemic as a Black Swan, referring to the importance of perspective, implying a type-B or C approach. Subsequently, although the Black Swan literature acknowledges the importance of perspective [16,17], we observe that this is often lost in practice. While resolving this ambiguity lies beyond our study's scope, future research could benefit from exploring alternative conceptualisations which emphasise the importance of perspective such as Black Elephants [12,51], a concept fusing Black Swans and the notion of the elephant in the room, or Grey Rhinos [13], neglected threats with a high probability and impact.

Simulating several Black Swans per wargaming session enabled decision-makers to identify and reflect on recurring fragilities. Determining these recurring fragilities is valuable as it can support organisations in prioritising and consolidating their efforts regarding operationalising resilience. Furthermore, this process could foster the resilience capability of managing keystone fragilities [44] or dealing with organisational aspects that may have significant negative impacts in a crisis. Finally, the design of the Black Swan is assumed to support the resilience capability of anticipating future developments [20], as it helps decision-makers to imagine Black Swans before they occur.

Finally, the third barrier, the conceptual ambiguity of resilience, was addressed by the categorisation of resilience, which provided decision-makers with a structured framework for understanding resilience-as-an-outcome. Reaffirming Nieuwborg et al. [7], decision-makers referred to the fragile, robust, adaptive and transformative aspects as sensemaking tools that support actionable decision-making and strategy development regarding resilience. As conceptual ambiguity is a common issue when working with resilience [20,52], we, consistent with Weick [53], consider this sensemaking as another important resilience capability.

4.2. Limitations and future research

Regarding the operationalisation, it is unclear whether the wargame led to interventions being implemented in the participating organisations. As research on the longitudinal effect of wargames remains scarce [54], we have the ambition to explore this effect further in future research. Furthermore, we also aim to explore the presence and development of resilience capabilities in more depth. In doing so, we intend to draw on observational approaches commonly used in resilience and crisis management studies (e.g. Ref. [46, 55]).

As a practical reflection outside the scope of our research question, we observed that selecting system maps in collaboration with an internal sponsor can be challenging. Determining the appropriate level of detail proved particularly difficult, as we relied on only a single perspective. Subsequently, in future wargames, we would encourage including multiple perspectives within the development of system maps. Other scholars achieve this using co-creation [31,32,42], interviews [41,42] and literature reviews [41]. Furthermore, experimenting with different types of visualisations, such as AcciMaps [56] or the Event Analysis of Systemic Teamwork [57], may yield novel insights.

Reflecting on the categorisation of resilience, we see several areas of improvement regarding the confusion between undesirable situations and fragility and the connotations regarding each resilience aspect. We suggest that both hurdles could be overcome through improved facilitation and the inclusion of examples during the wargame. We aim to investigate these hurdles in future research.

Finally, a limitation regards the cultural context in which most wargames occurred. Conducted primarily within a Dutch setting, characterised by open communication and an egalitarian social structure, our findings may have limited applicability to different cultural contexts. Furthermore, the scope of this study focused on the aviation and defence domains. Given the unique nature of these domains, it is uncertain to what extent the insights gained can be generalised to other domains.

5. Conclusion

In this study, we investigated: what do decision-makers within complex systems learn from wargaming Black Swans to operationalise resilience? Our findings indicate that wargaming helps decision-makers to (1) develop a shared understanding of their organisation within its complex system; (2) imagine the impact of type-B (unknown knowns) and type-C (ignored knowns) Black Swans on their organisation; and (3) operationalise resilience-as-an-outcome while deepening their theoretical understanding of it. Furthermore, conducting wargames may enhance resilience capabilities, namely: shared situational awareness, the management of keystone fragilities, anticipating future developments, and sensemaking. To conclude, these findings suggest that wargaming can be a valuable tool to operationalise resilience.

CRediT authorship contribution statement

Alexander Nieuwborg: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Jesse Geurtsen:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Nicolas Salliou:** Writing – review & editing, Methodology, Conceptualization. **Ed Oomes:** Writing – review & editing, Conceptualization. **Suzanne Hiemstra-van Mastrigt:** Writing – review & editing, Funding acquisition. **Marijke Melles:** Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Alexander Nieuwborg reports financial support was provided by Royal Schiphol Group. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2025.105857.

Data availability

The data that has been used is confidential.

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