Facing climate change: How to manage the arising new crises?

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ABSTRACT

The increasing frequency and intensity of climate change-related disasters highlight the need to develop adaptive crisis management approaches. This paper explores the integration of R-IO Suite, a knowledge-based decision support system, with GAMA, a multi-agent simulation platform, to improve situational awareness and crisis response in a changing climate.

This approach enables decision-makers and local communities to better understand, anticipate, and mitigate crisis impacts by combining real-time data modelling and predictive simulation.

Although the proposed framework has been conceptually defined, its implementation and validation remain open key challenges. The French ANR-funded ATEsT project aims to overcome major technical obstacles—interoperability, semantic alignment, and temporal synchronisation—through concrete use cases. Future work will focus on implementing and testing this integration in realistic crisis scenarios, such as mega-fires and flash floods across different territories, to assess its effectiveness in improving decision-making processes and citizen engagement.

Keywords

Climate change, crisis management, modelling, multi-agent simulation, risk management.

INTRODUCTION

During the last decades, humanity saw a rise in the frequency and intensity of climate-related disasters worldwide. These crises, either from natural causes or fueled by anthropic activities, are hitting areas more diverse than ever and considered safe places until now or at least not subject to such high and intense risks.

On October 29th, 2024, the area of Valencia, on the coastal Spanish Mediterranean Sea, was hit by a DANA[1], causing heavy rains and catastrophic flash flooding in an area where rain is usually scarce. The floods killed more than 230 people and destroyed thousands of housing, vehicles, roads and other critical infrastructures (Khalip & Landauro, 2024). Two weeks later, another DANA hit the Spanish Mediterranean coast. The rise of the sea surface temperature on the Valencian coasts (+2°C to +3°C) due to global warming (Faranda et al., 2024) fuels the magnitude of the DANAs and their sudden and intense rainfalls: a study on current and future climate found that the DANAs' precipitation may increase by 88% in this coastal area, and by 61% in the adjacent Mediterranean areas (Ferreira, 2021).

On December 14th, 2024, tropical cyclone Chido struck Mayotte (an overseas French department in the Indian Ocean) with winds up to 260 $km.h^{-1}$ and heavy rains causing flooding and mudslides. It caused at least 39 fatalities, 830 injured people, and 110.000 displaced people (Météo France, 2024; Plummer, 2025). The airport, the ports,

[1] Depresión Aislada en Niveles Altos, upper-level isolated depression which is isolated from polar or subtropical jet streams.

the hospitals, and the roads were severely damaged and inoperable while the critical networks (water, electricity, telephone) were cut. Mayotte is usually spared from episodes of such magnitude and intensity; Chido superseded the February 18th, 1934 cyclone in terms of devastation (Météo France, 2024).

On the other side of the globe, wildfires devastated Southern California (United States of America) starting January 7th, 2025. The Palisades Fire, the Eaton Fire near Pasadena and the Hughes Fire consumed 47,894 acres, and all reached 90% up to 98% of containment as of January 27th, 2025 (CAL FIRE, 2025). Local authorities counted 28 fatalities, more than 16,000 destroyed structures (homes, schools, hospitals) and at least 110,000 displaced residents, not to mention the devastated biodiversity. Critical infrastructure sustained severe damage, leaving large areas without power, water, or access to emergency services. The Los Angeles County area has gradually become arid since the summer of 2024, and the extreme drought conditions in late December 2024, usually a wet season there, created high fire vulnerability. The dry vegetation and the offshore Santa Ana winds fueled the fires which broke out in residential areas.

These are only examples of recent disasters whose origin and/or magnitude are related to global climate change. They emphasise the urgent need for enhanced preparedness for these new at-risk regions (such as Valencia and Mayotte) or the exponentially increasing risk-prone areas (such as Southern California) facing these more frequent and more intense crisis situations. How to allow not only the authorities but also the citizens to better represent, understand and know their territories' new risks and stakes? In this paper, a citizen (or community of citizens) is any individual, association or organisation that is not a professional in the sense of civil protection crisis management) and whose intervention is not part of a civil protection profession, as defined by (Batard, 2021)). In other words, how can we identify the new local risks and stakes to support crisis management in a time of climate change?

This paper addresses the following research question: *How can we model the interactions between evolving and extreme climatic conditions, local critical infrastructures and social dynamics to prepare and mitigate the impact of crises?*

This paper is structured as follows: The first section presents state-of-the-art modelling frameworks and tools dedicated to crisis management for decision-makers and communities of citizens. The second section will present the R-IO Suite and an illustrative use case of a severe weather event in the area of Valencia, Spain. The integration of the GAMA multi-agent simulation platform will be discussed before concluding.

STATE-OF-THE-ART

The state-of-the-art focuses on the SCOPUS database, which references a broader range of publishers (contrary to ScienceDirect or IEEE Xplore), including the ISCRAM digital library. The query is presented in Table 1. It is structured in blocks of interest. Each row corresponds to one of the four aspects of the query. They are linked together with the "AND" operator. The first column gives the name of the aspect. The second column indicates whether this aspect is mandatory in the title part (i.e. TITLE) or in the tryptic title-abstract-keywords parts (i.e. TITLE ABS KEY) of the articles. We used the bibliometrix package (Aria & Cuccurullo, 2017) to improve the query by iterating on pertinent, missing keywords from the corpus. It includes the study of the most frequent author keywords and the most frequent bigrams and trigrams from the titles and abstracts.

Table 1. Details of the SCOPUS query.

Block of interest	Type	Sub-query
A system to…	TITLE	(system* OR tool* OR software* OR framework* OR platform* OR architecture* OR gam* OR "web app*" OR "mobile app*")
…prepare for crises…	TITLE ABS KEY	(reduc* OR prevent* OR respon* OR manag* OR monitor* OR prepar* OR simulat* OR model* OR vizu* OR visu* OR display* OR analyz* OR analys* OR "anticipat*" OR project* OR forecast* OR percep* OR compreh* OR underst* OR sense* OR assess* OR support* OR aware* OR picture* OR recover* OR adapt* OR mitigat* OR enhanc* OR react* OR educat* OR coordinat* OR cooperat*) W/1 (vulnerability OR resilience OR emergency OR crisis OR crises OR disaster* OR catastroph* OR earthquake* OR flood* OR hurricane* OR tornado* OR tsunami* OR wildfire* OR landslide* OR mudslide* OR "Volcanic Eruption*" OR drought* OR heatwave* OR blizzard* OR avalanche* OR cyclone* OR hailstorm* OR thunderstorm* OR "Dust Storm*" OR "Ice Storm*" OR sinkhole* OR "Oil Spill*" OR "Quick Clay*")
…with citizens engagement…	TITLE ABS KEY	((citizen* OR individual* OR person OR people OR tourist* OR inhabitant* OR resident* OR community OR civil* OR volunteer*) W/1 (particip* OR engagement* OR collaborat* OR centred OR centered OR centric OR science OR volunteer*))
… adapted to each context	TITLE ABS KEY	(situation* OR knowledge OR information OR context*) W/1 (adapt* OR aware* OR sens* OR centered OR centred OR centric OR receiv* OR assimilat* OR get* OR collect* OR access* OR input*) OR ((shared OR common) W/1 picture*)

The cost and user-friendliness of modelling tools and simulation tools are some of the main hurdles faced by local authorities and communities of citizens. In this regard, we applied the following criteria:

- Friendliness of the end-user interface (e.g. code, web app, mobile app, GIS (Geographical Information System), etc.).
- Scope or genericity level, i.e., the capacity to adapt to the specificities of each territory (e.g. none, generic or specific to a region or a hazard).
- Contextual awareness (e.g. none, manual, semi-automatic, or automatic). On the contrary, the citizen can be the source of information (and not the target).

The corpus obtained with the query presented in Table 1 contains 71 results. Irrelevant papers were excluded from the study. It includes 2 retracted papers, 11 papers (15% of the total) with no link to crisis management, 9 reviews or studies, 2 vision papers, 2 books, 1 double, 4 with unavailable full text, 5 without authors, and 8 papers published before 2015. The ISCRAM conference is a major contributor with 3 documents (10% of the cleaned corpus). We identified four categories among the remaining 27 results:

- Systems or frameworks that include citizens as end-users.
- Systems or frameworks that include emergency managers as end-users
- Systems or frameworks that include other types of end-users, such as software developers, technology deployment, or medical support.

In the research work presented in this paper, we exclude the last two categories. The exclusion includes works on collecting and using volunteered geographic information for the benefit of decision-makers. The 14 other systems that include citizens as end-users, are presented in the Table 2 below. ISCRAM references are highlighted in bold. From these results, the most frequent indexed keywords are presented in Figure 1.

Table 2. Corpus of 14 documents including citizens as end-users of their framework (F) or system (S)

	Reference and document title	Friendliness	Scope/Genericity	Contextual Awareness
F	(Yazdani & Haghani, 2024) A conceptual framework for integrating volunteers in emergency response planning and optimization assisted by decision support systems	N/A	Generic	None
F	(Konstantoudakis et al., 2023) Common operational picture and interconnected tools for disaster response: The FASTER toolkit	N/A	Generic	Semi-automatic
S	(Takenouchi & Choh, 2021) Development of a support system for creating disaster prevention maps focusing on road networks and hazardous elements	Prevention maps	Evacuations	Manual
S	(Basak et al., 2020) A crowdsourcing based information system framework for coordinated disaster management and building community resilience	Web app summarized reports	Bengal	Semi-automatic
F	(Razali et al., 2019) Management system for disaster management	N/A	Generic	None
S	**(Meesters et al., 2015, 2019)** Designing disaster information management systems 2.0: Connecting communities and responders & Gamification for data gathering in emergency response exercises	GIS & Web apps	Specific Jakarta & USAR	Manual & Manual
S	(Liang et al., 2019) Crowdsourcing platform toward seismic disaster reduction: The Taiwan scientific earthquake reporting (TSER) system	Web app; GIS for reporting	Taiwan Earthquake	Source
S	(Krommyda et al., 2019) Integrated monitoring system for environmental and river data measurements	Mobile app	Rivers	Source
S	**(Batard et al., 2019)** Integrating citizen initiatives in a technological platform for collaborative crisis management	Web app	Generic	Semi-automatic
S	(Osaragi & Niwa, 2018) Development of system for real-time collection, sharing, and use of disaster information	Web app; GIS; Simulation	Fire spread	Source
S	(Estuar et al., 2017) The challenge of continuous user participation in eBayanihan: Digitizing humanitarian action in a nationwide web mobile participatory disaster management system	Mobil and web app	Philippines	Source
S	(Horita et al., 2015) Development of a spatial decision support system for flood risk management in Brazil that combines volunteered geographic information with wireless sensor networks	Web app; GIS	Brazil Flood	Source
F	**(Bossu et al., 2015)** The EMSC tools used to detect and diagnose the impact of global earthquakes from direct and indirect eyewitnesses' Contributions	Questionnaire Tweets	Mediterranean Earthquake	Manual

Figure 1. Most frequent indexed keywords of the 14 documents using *bibliometrix*.

Current crisis management modelling frameworks primarily focus on decision-makers (~1.5k documents on Scopus), with limited consideration for citizen or community engagement (58 documents). While numerous generic frameworks exist, only one truly generic tool has been identified: R-IOSUITE from (Batard et al., 2019). There is a clear need for adaptive, context-aware solutions that serve both authorities and citizens, fostering cooperation and inclusivity. Additionally, the lack of open data, open knowledge, and open-source implementations limits accessibility and innovation. Future developments should prioritize transparency and openness to enhance crisis preparedness and response.

MODELLING WITH R-IO SUITE

In this paper, the focus is set on the situation modelling capabilities of R-IO Suite. Detailing the design and the monitoring of the collaborative crisis response (based on the situation model) by R-IO Suite is out of the scope of this paper.

A Generic Meta-Model to Fit All Situations

R-IO SUITE[2] is a decision support system which can be used for crisis or supply chain management. This modular software platform is an open-source (AGPLv3) research prototype designed and developed following model-driven engineering principles (Fertier et al., 2021). It features a user-friendly human-machine interface with a no-code approach, accessible to domain experts regardless of their background in programming. The different modules of the R-IO SUITE platform allow the interpretation of data into information (situation modelling), the exploitation of information into decisions (business process modelling) and the implementation of decisions to act (business process monitoring and adaptation).

These steps from data to action are supported by a knowledge base embedding knowledge instances of a crisis management metamodel. This metamodel consists of three main packages representing the concepts related to (i) the context and partners (territory, resource, person, role, function, etc.); (ii) the objectives (objective, negative and positive potentialities, etc.); (iii) the process (tasks, start and end events, etc.) (Rebière-Pouyade & Salatgé, 2025). The territorial dimension of a crisis situation makes it challenging to replicate scenarios from one region to another. From the R-IO Suite perspective, the metamodel that defines the abstract concepts underlying the crisis remains unchanged regardless of the situation. This generic metamodel ensures increased flexibility and adaptability to various crisis scenarios. Therefore, this approach allows for the uniform representation of different situations, thus facilitating the integration of heterogeneous data and collaboration between various actors.

The R-IO Suite knowledge base can be enriched on the fly by using a large language model-based conversational agent, such as ChatGPT (Congès et al., 2024), to update the complementary knowledge when facing an unexpected event or lacking intel from the end-users.

Illustration: Preparing Tourists for Severe Weather Events

The aim of this illustrative use-case is two-fold: (i) it shows how R-IO Suite enables to model a given territory (here, the city of Valencia, Spain, and its surroundings), with its points of interest, their risks, the involved stakeholders and their skills in a few minutes; (ii) it highlights the possibility to model any territory using information provided by either the user or a GPT (Generative Pre-trained Transformer). The presented model is

[2] R-IO Suite is available at https://r-iosuite.atlassian.net/wiki/spaces/RIOSUITE/overview

available at https://gitlab.mines-albi.fr/barthe/atest for download and test.

In this scenario, the focus is set on the Valencia region, and more particularly its key touristic spots such as the City of Arts and Sciences, the Bioparc Zoo, natural parks and beaches. The chosen perspective of the R-IO Suite user is that of a tourist office manager who aims to enhance preparedness in case of an adverse event and develop communication strategies concerning evacuation plans and shelter locations. To better represent and understand the risks and stakes of a severe weather event (DANA) in these touristic areas, they use the R-IO Suite as follows.

Figure 2 illustrates the initial phase of territory modeling using R-IO Suite. For clarity in this article, the focus is placed only on the City of Arts and Sciences, the Bioparc Zoo, the natural park of Albufera, and the Malvarossa and El Saler beaches. The modeling begins with creating these locations within R-IODA, the design module of R-IO Suite (left panel).

A search engine related to Google Maps supports the user in adding relevant places to the map, either an entire area (here, the city of Valencia) or specific points of interest (the touristic attractions). These locations are then linked to their parent entity, the city of Valencia, ensuring a structured representation of the territory as a knowledge graph in R-IOGA (governance module panel, top right) or a map in R-IOPLAY (Geographical Information System —GIS— module panel, Figure 2 bottom right).

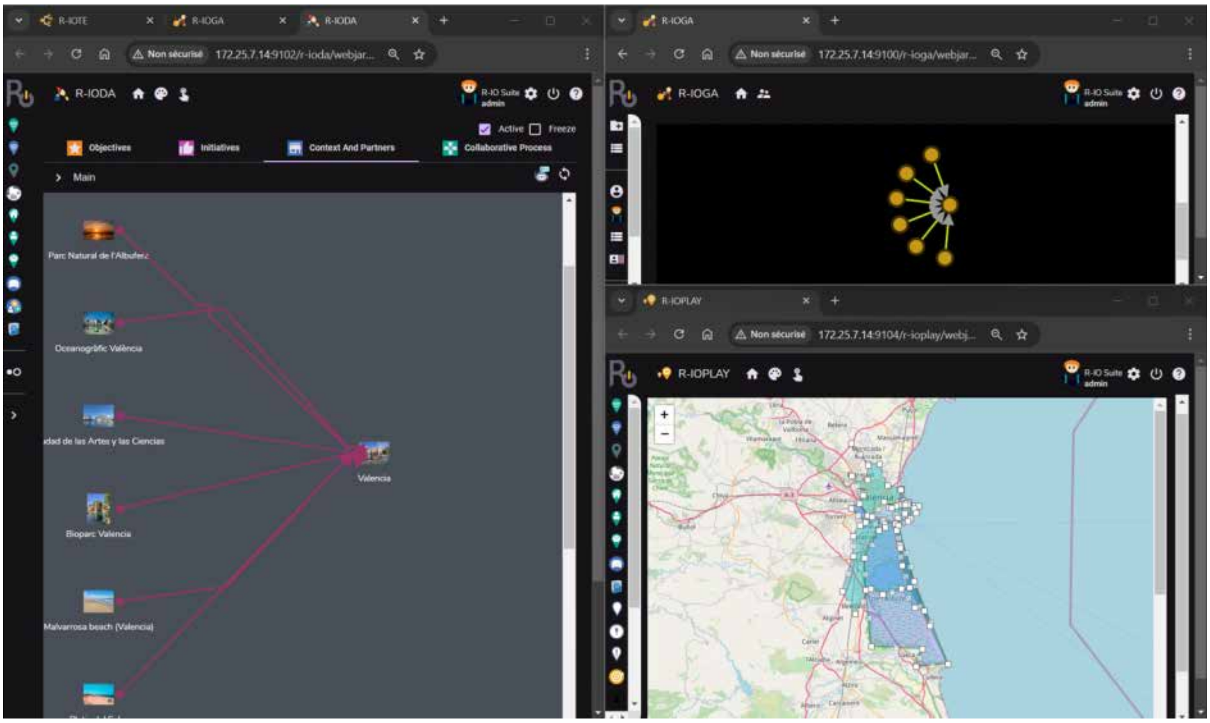

Figure 2. Screenshot of R-IO Suite showing the initial setup of key touristic locations: R-IOPLAY (GIS module), R-IODA (design module) and R-IOGA (governance module).

A default knowledge base (*reference knowledge*) is integrated into the R-IO Suite to support crisis management scenarios, incorporating essential stakeholder roles such as firefighters and emergency services (Figure 3). This reference knowledge (Figure 4, left) is further enriched with case and domain-specific information (*active knowledge*) related to the selected tourist sites (Figure 4, right), allowing for the next step of the modelling, i.e. tailored risk assessment.

Figure 5 illustrates the dynamic integration of events (*facts*) in R-IO Suite, either actual events occurring in real-time for monitoring purposes or synthetic events based on actual events for training purposes. In our case, the user seeks to study and analyse the impacts of a severe weather event (DANA) in the Valencia region on the key touristic locations mentioned above. Such a synthetic event is incorporated into the model to do so. This is facilitated by the *AI Creator Assistant*, which leverages ChatGPT and Google GIS data to retrieve and contextualise relevant information.

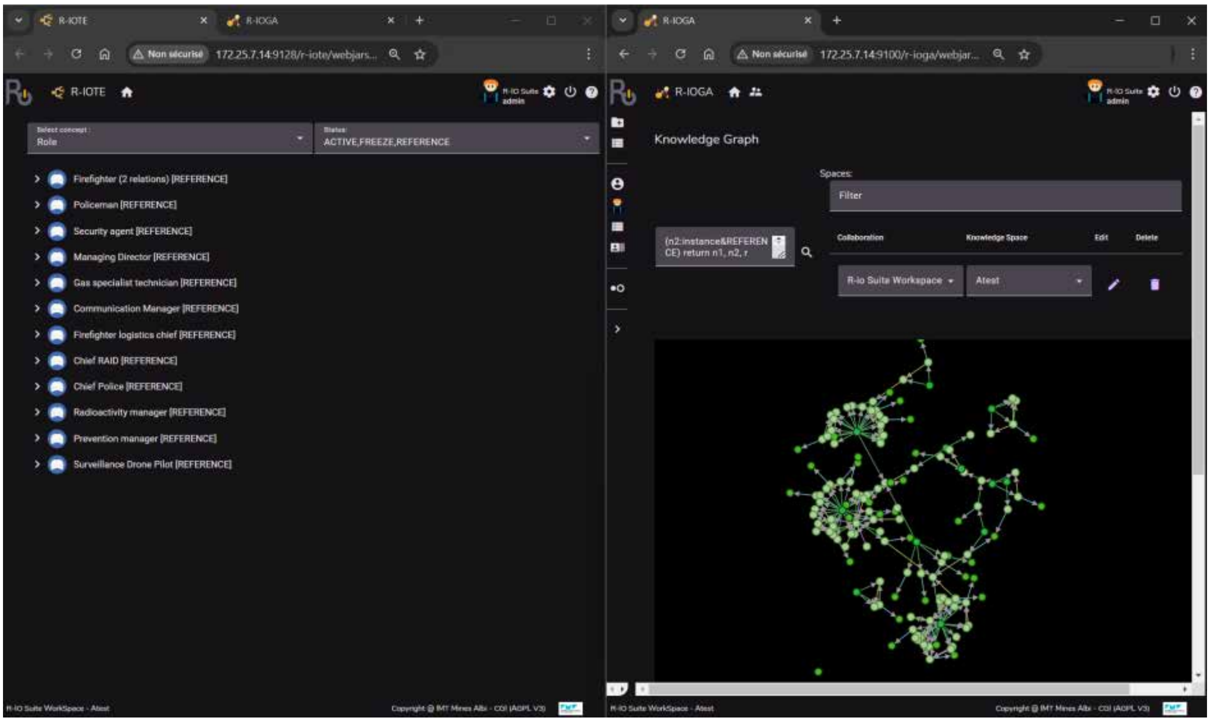

Figure 3. Reference knowledge embedded in R-IO Suite: stakeholder roles as a list (left) and as a graph (right)

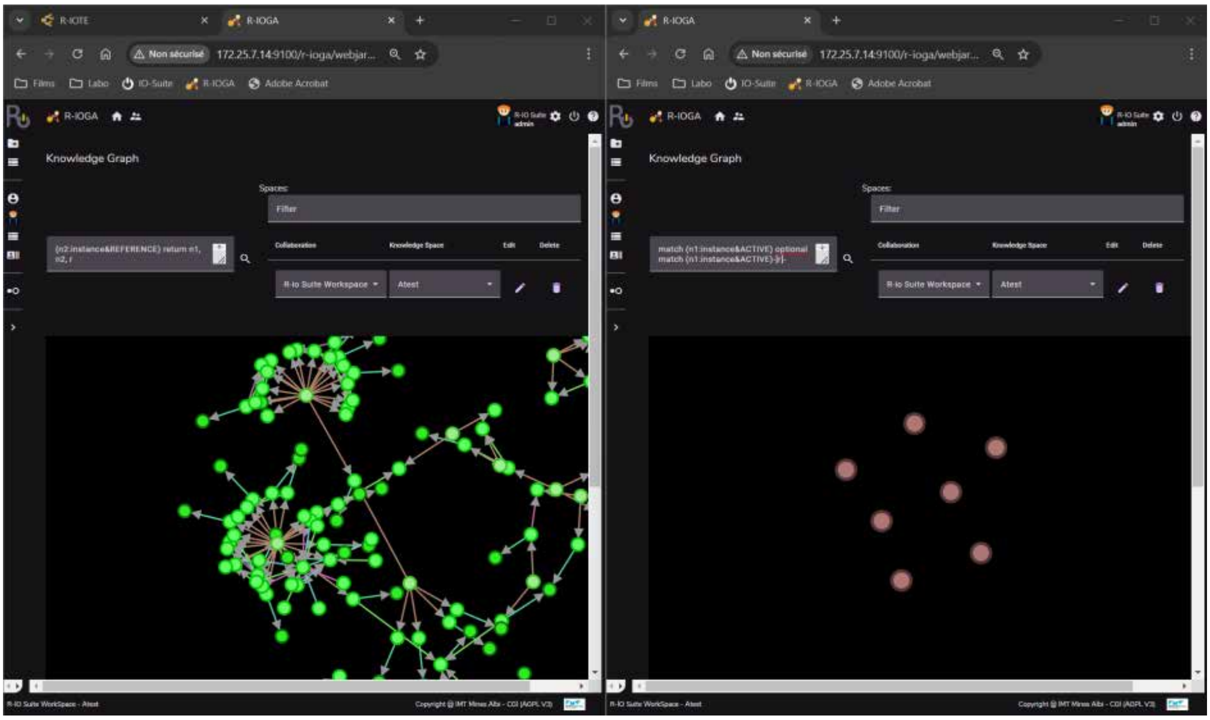

Figure 4. Reference knowledge (left) embedded in R-IO Suite, and active knowledge (right) added through the design module.

The user can review and edit the proposed facts before validating their integration into the model. Once validated, these facts are linked to the specific locations, automatically enabling a refined risk assessment for each site of the model (Figure 5, left: the touristic places are in orange, the risks in teal). At this stage, the user can review the graph of assessed potential risks to the sites along with their probability (Figure 5, right panel), ensuring that the model reflects current threats to enhance crisis preparedness. We can note that there may be cascading risks: a critical infrastructure damage risk leads to a public safety risk and a service disruption risk. In addition, objectives and their priority are also proposed to mitigate the risk, pictured by the orange targets on Figure 5 (right panel). Probabilities and priorities are calculated by R-IO Suite and can be edited their value according to the user's experience on this matter.

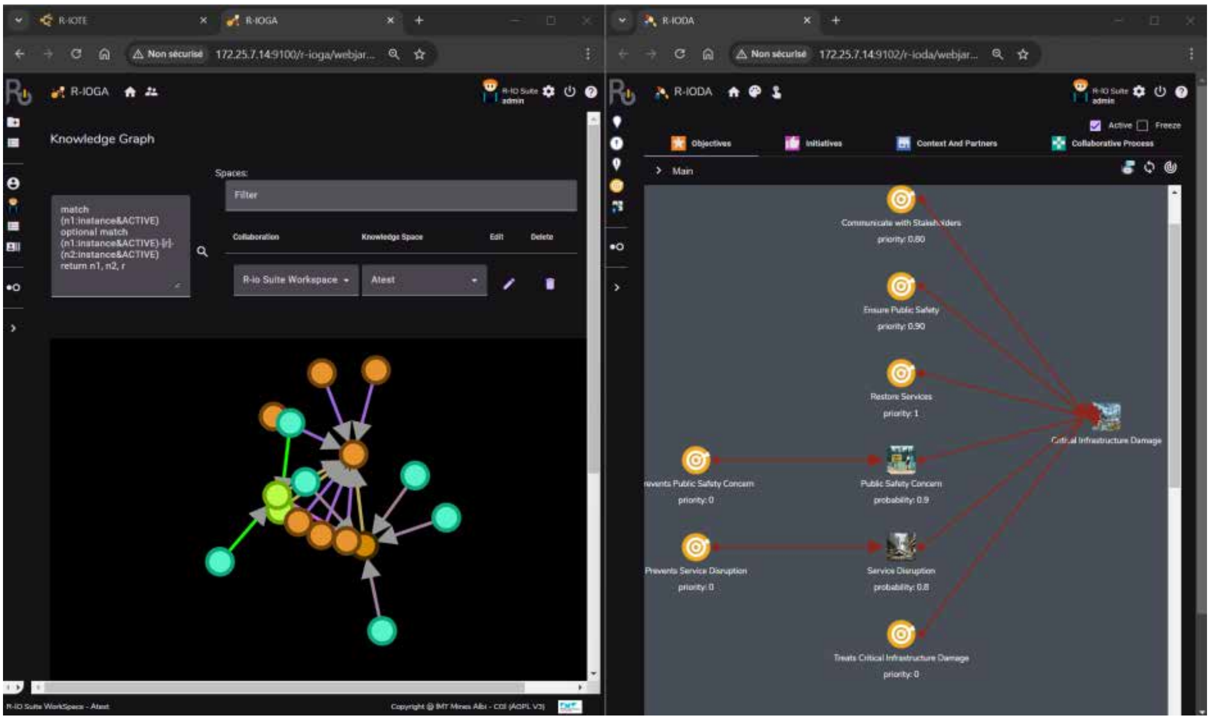

Figure 5. Screenshot of R-IO Suite demonstrating the addition of facts and AI-assisted data enrichment about risks and objectives

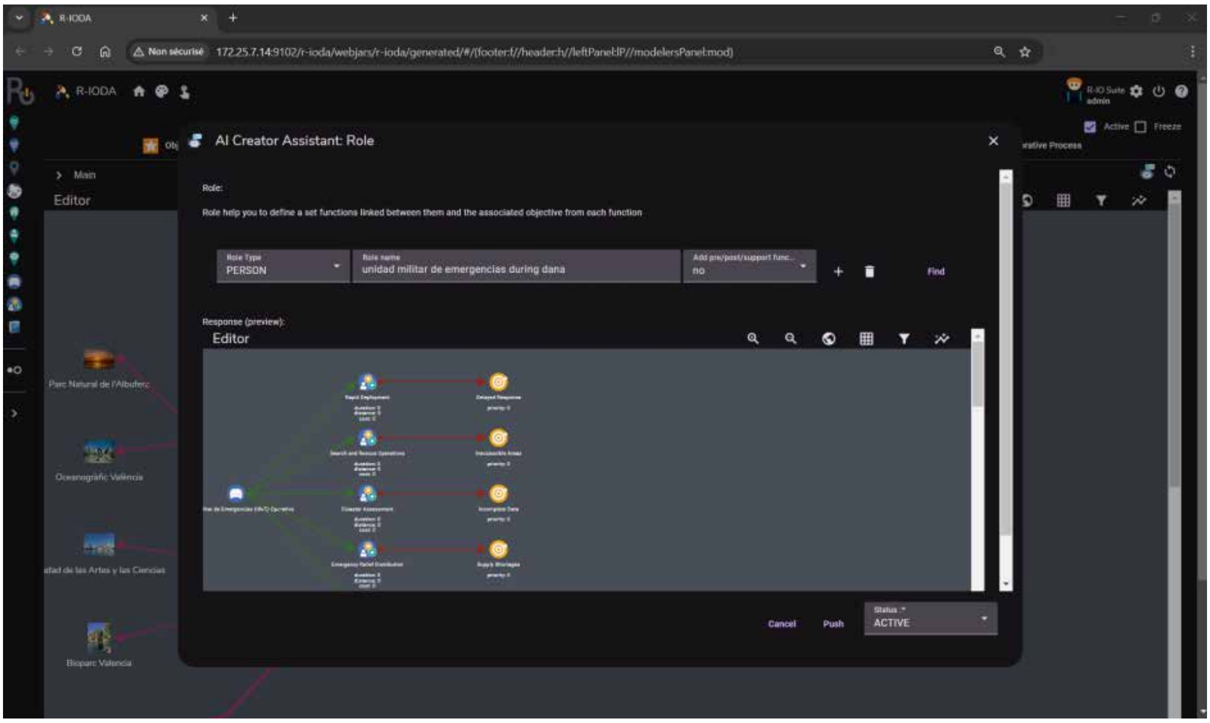

Figure 6. Screenshots from R-IO Suite illustrating the enrichment of the active knowledge base with crisis management roles helped by the AI Creator Assistant.

To enhance the contextual relevance of the crisis model, additional roles can also be incorporated into the R-IO Suite knowledge base (active knowledge). This enrichment allows for a finer representation of emergency response structures, considering the specific cultural and institutional characteristics of each crisis location.

Figure 6 showcases the R-IO Suite AI Creator Assistant to query generative AI to refine the definition of the Unidad Militar de Emergencias'[3] (UME) role, its generic functions (e.g. search and rescue, emergency relief distribution) and their related objectives (e.g. reach inaccessible areas, supply shortages).

Figure 7 illustrates the rapid creation and assignment of ten personnel to the UME role within the Valencia territory, facilitated by the AI Creation Assistant. Figure 8 displays the updated knowledge base, now incorporating these ten individuals as entities within the active knowledge graph (cf. right panel, the new ten green dots).

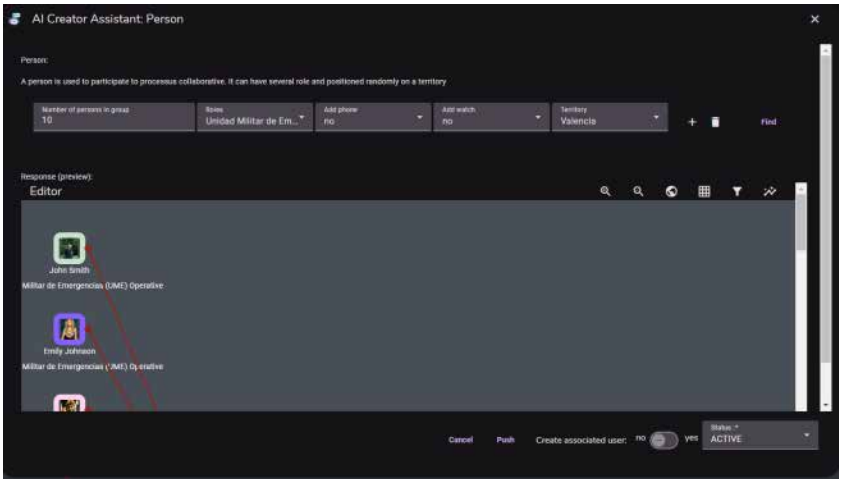

Figure 7. Screenshot from R-IO Suite illustrating the enrichment of the *active* knowledge base with crisis management stakeholders.

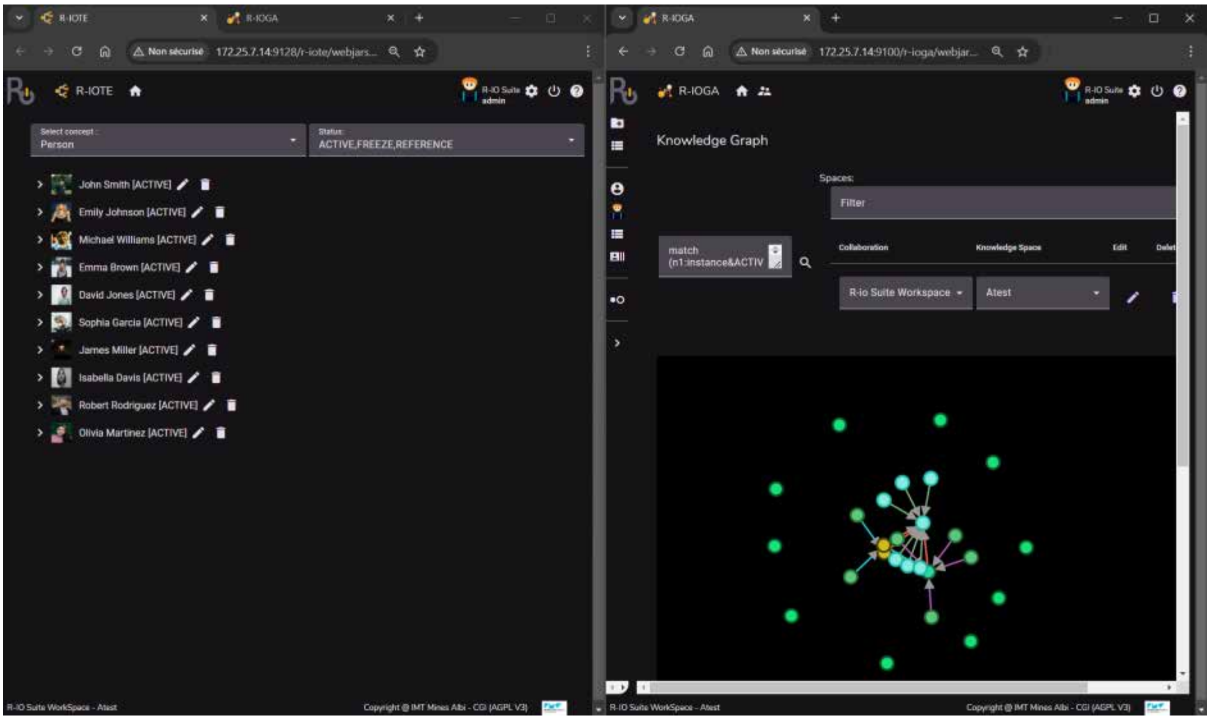

Figure 8. Screenshot from R-IO Suite displaying the updated *active* knowledge base.

[3] The UME is a specialised emergency response unit in Spain, particularly active during severe weather events such as a DANA.

Then, the user matches the generic objectives associated with the assessed risks to the specific objectives of the UME's role. This semantic matching can be perfect or partial, with the option to specify a matching percentage from 0 to 100%. R-IO Suite infers this additional knowledge, and expands the entire crisis knowledge graph—both reference and active—by linking the individuals' skills to an assessed risk through their shared objectives, as shown in Figure 9 (red highlights). Once the user has modelled all the information about the situation, they can ask R-IO Suite to deduce a fitted crisis response, i.e. the collaborative process played by the stakeholders.

Figure 9. Screenshot from R-IO Suite displaying a part of the *expanded* knowledge base.

R-IO SUITE x GAMA: TOWARDS MODELLING AND SIMULATION ON DEMAND

We saw in the previous section that the R-IO Suite modelling activities heavily rely on the well-known Data, Information, Knowledge trinity to represent and instantiate concepts (risks, objectives, roles, persons, etc.) and infer relations between these concepts. The same applies for the monitoring and adaptation of the crisis response by R-IO Suite: the system is dependent on the collected data about the states of activities, ongoing events on the field, etc.

Historical Knowledge vs. Prediction Insights

In a constantly evolving context marked by the effects of climate change, it is essential to enrich the R-IO Suite knowledge base to better represent the situation and to anticipate previously non-existent or considered unlikely risks. This continuous updating process enables the reassessment of crisis mitigation, preparedness, and response strategies.

While artificial intelligence models such as ChatGPT allow for the dynamic enrichment of the R-IO Suite active knowledge base, the generated knowledge remains inherently rooted in historical data. But, because of climate change, historical data alone is no longer sufficient. New local risks and vulnerabilities must be identified without relying solely on pas occurrences. Therefore, it is crucial to adopt a forward-looking approach capable of anticipating unprecedented events and analysing their potential impacts on our systems.

To this end, integrating a multi-agent simulation engine to R-IO Suite could represent a key advancement. This technology not only enables the modeling of unexpected weather phenomena related to climate change but also their consequences on the studied territory by enabling the exploration of what-if scenarios. It facilitates the study of their repercussions on citizens, the resilience of critical infrastructures, and, more broadly, the entire socio-technical system. By simulating these dynamics, new data can be generated to feed the situation model in R-IO Suite. Thus, we can gain deeper insights into existing vulnerabilities, develop more effective adaptation strategies, and engage communities of citizens (locals or tourists) more efficiently in preparedness.

GAMA Platform: A Free Open-Source Multi-Agent Simulation Platform

The GAMA platform (GIS Agent-based Modeling Architecture) is a multi-agent-based simulation environment built around an agent-based modeling (ABM) framework, enabling the creation of heterogeneous agents with distinct behaviors and interactions (Taillandier et al., 2019).

These agents can represent individuals, organisations, animals, vehicles, or abstract entities, allowing for the modeling of complex socio-technical and environmental systems. GAMA provides native support for GIS, which facilitates the integration of real-world spatial data for modeling infrastructures, mobility patterns, and environmental processes.

Several factors drove the choice of the GAMA platform in these research works:

- Accessibility: GAMA is a free, open-source (GPL3) software.
- Education: GAMA offers a no-code approach, which is suitable for citizen engagement and educational purposes.
- Research sustainability: GAMA development and maintenance are ensured by a long-term committed consortium of several research teams and industrial partners, led by the IRD research unit UMMISCO[4] (France). Moreover, GAMA is used in numerous research projects worldwide, with applications ranging from crisis management to urban traffic modeling and environmental simulations, among other applications.

Coupling R-IO Modelling and GAMA Simulation

Integrating R-IO Suite with the GAMA Platform aims to establish a bi-directional information exchange to enable both systems to enrich and refine their respective models dynamically. As shown in **Figure 10**:

- R-IO Suite provides the global situational model in real-time, including instances of concepts ranging from risks to tasks.
- GAMA simulates real-time dynamics of given phenomena, such as the spread of an extreme weather event or citizen behavior during an evacuation.
- Outputs from GAMA update R-IO's situational awareness, while R-IO's situational model refines GAMA's simulations.

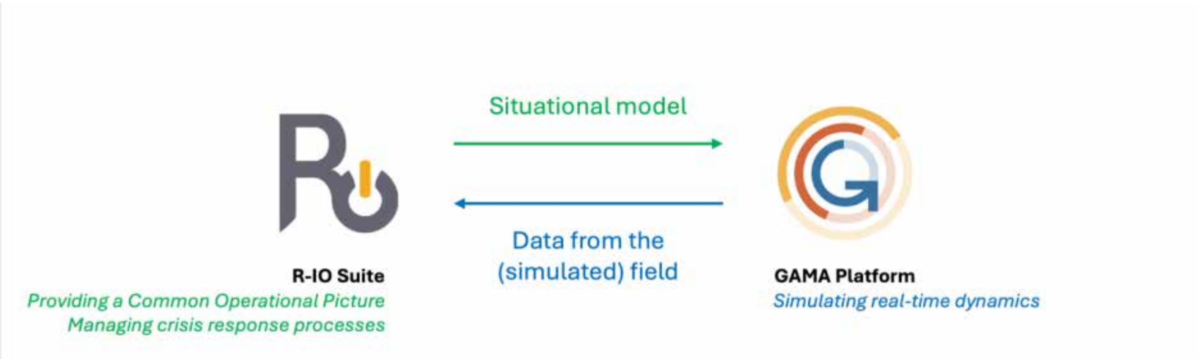

Figure 10. Integration of R-IO Suite and GAMA: a bi-directional information data exchange.

The integration of R-IO Suite with GAMA, as proposed in this article, is an exploratory and methodological approach aimed at enriching the modeling and simulation of crisis in a time of climate change. To our knowledge, this integration has not yet been implemented.

We have identified the main challenges to be addressed to ensure effective interoperability between the two systems. In addition to the usual risks and pitfalls in an information systems integration project (keeping versions up to date, avoiding regressions, etc.), there are challenges related to the intrinsic nature of GAMA and R-IO Suite's purposes, which are not trivial:

[4] Unité Mixte de Modélisation mathématique et informatique de systèmes complexes, naturels, biologiques ou sociaux (Joint Unit for Mathematical and Computer Modeling of Complex, Natural, Biological or Social Systems).

Conceptual and semantic alignment. GAMA is focused on multi-agent simulation (with a logic of states, behaviors and interactions). R-IO Suite represents a situation model (concepts and relationships) and processes (workflows, tasks, transitions) via its knowledge base. There may be differences in the granularity of the representation and abstraction of objects in GAMA and the R-IO Suite, as well as semantic differences. These issues will require establishing common semantics (via a shared ontology and vocabulary) to ensure that the data and events from GAMA are aligned with R-IO Suite and vice versa.

Temporal differences. In GAMA, the simulation generally advances by time steps or discrete events, while the R-IO Suite monitors potentially asynchronous or real-time processes. Synchronising the two logics —for example, when GAMA must trigger a process update in R-IO Suite or receive a new state in return— can be complex. A scheduling or event management mechanism should be clearly defined to avoid time lags or inconsistencies, using the following strategies: pre-trained simulation, substitution of stochastic mechanisms by actor choices or proxy models (An et al., 2017).

Technical interoperability. At the technical interoperability level, GAMA and R-IO offer JSON file exchange format input and output. However, the JSON data exchange structure is different in both cases. This requires model transformation to ensure the data's technical interoperability based on the semantic alignment results. It will also be necessary to design and develop an interface or an API to ensure and orchestrate data exchange between the two information systems in both ways to provide data at the most relevant time, either synchronously or asynchronously, to tackle the temporal differences.

Performance. On the one hand, GAMA models can be complex and resource-intensive as they compute many agents. On the other hand, R-IO models ask for knowledge to be gathered and inferred and to monitor and update business processes in real time. The global load increases, especially when large-scale or near-real-time scenarios are executed. A modular architecture with resource parallelisation and distribution should help to reduce the CPU/GPU load.

To address these challenges and validate the proposed integration of the R-IO Suite with GAMA, the French-funded ANR (National Research Agency) ATEsT[5] project aims to tackle these identified obstacles by implementing and evaluating this approach. This project will focus on developing technical interoperability, ensuring semantic alignment, addressing temporal synchronisation, and optimising performance. Use-case scenarios and case studies will be conducted with the support of end-users (emergency services and communities of citizens in France and Vietnam) to assess:

- The technical feasibility of such an information system interoperability.
- The relevance and contribution of GAMA simulations in improving situational awareness and decision support in R-IO Suite; R-IO Suite in improving simulations in GAMA.
- The usability and effectiveness of this information system for stakeholders, including local authorities and citizen communities.

This exploratory work paves the way for future experiments aimed at testing and refining the integration of these two platforms to better understand and manage the impacts of climate change on local territories.

CONCLUSION

The increasing frequency and intensity of climate change-related crises highlight the critical need to improve crisis management systems' preparedness and adaptability. This paper proposes an innovative integration between R-IO Suite, a knowledge-based decision support system, and GAMA, a multi-agent simulation platform, to improve situational representation and response to climate crises.

By combining data-driven modelling, real-time representation, and simulations of phenomena or behaviours, we aim to provide crisis managers and local communities with more accurate identification of new risks and dynamic decision-support tools. Four main integration challenges were identified at the information system levels: semantics, temporality, interoperability, and performance.

While this integration's conceptual framework and technical challenges have been defined, its implementation and validation remain to be achieved. This is one of the contributory objectives of the ATEsT project, which will address the identified challenges, such as semantic alignment and temporal synchronisation, through concrete case studies (flash floods in France and Vietnam, mega forest fires in France). The next steps will consist of

[5] "Transdisciplinary approach of emerging risks on a territory: reframing crisis management processes to face climate change".

implementing the proposed roadmap: defining an integration architecture allowing technical and semantic interoperability, synchronising temporalities, and then testing the proposed integration on crisis scenarios to assess its impact on the effectiveness of decision-making and citizen engagement in crisis management.

With the mutual contribution of knowledge-based modeling and multi-agent simulation, this work will develop a more adaptive and anticipatory approach to crisis management, meeting the growing needs for the resilience of socio-technical systems in the face of climate change challenges.

ACKNOWLEDGMENTS

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