

Response to Referee #1

Dear Editor and *Reviewer*,

We are grateful to the referee for the time and effort devoted to evaluating our manuscript during the open discussion phase. The comments and feedback provided have been invaluable in identifying areas for improvement and enhancing the overall quality of our work.

We have carefully considered each point raised by the referee and provide below our point-by-point responses, outlining the revisions we have made (and will incorporate into the final revised manuscript) to address these suggestions:

The following are a few concerns that need clarification:

1. On page 8, a Boolean search strategy was mentioned with a few keyword combinations. However, there is no clarity in the choice of these terms, including whether synonyms and plurals were captured, and whether there were any field restrictions or exclusionary criteria. The choice of search terms may also introduce bias and omit relevant literature. This bias needs to be addressed.

Response:

Thank you for this helpful comment. In the revised manuscript, we have expanded the description of the search strategy in Section 2 (Methodology) to clarify the rationale and implementation of the Boolean search. Specifically, the search terms are now organized around three conceptual dimensions of this review: (1) emergency/disaster context, (2) automation and intelligent technologies, (3) response-related activities.

To improve retrieval coverage and reduce potential bias, we have clarified that synonyms and closely related terms within each concept group were combined using the Boolean operator “OR”, while the three concept groups were connected using “AND”. In addition, wildcard operators and lexical variants were applied where supported by the databases (e.g., automat to capture variants such as automation, automated, and automatic).

We have also explicitly specified that searches were primarily conducted within title, abstract, and keyword fields (or equivalent topic fields depending on database functionality) to balance retrieval precision and coverage. Furthermore, the selection of search terms was informed by preliminary scoping searches and commonly used terminology in the emergency management and intelligent systems literature, helping to reduce the risk of systematic omission of relevant studies. These clarifications have been added to Section 2 of the revised manuscript (Page 8–10).

In addition, following the reviewer’s suggestion, we have added a discussion of

potential retrieval bias in the revised manuscript. We now acknowledge that keyword-based retrieval in an interdisciplinary field may miss studies using alternative terminology, and that restricting the review to English-language literature and selected databases may have excluded some relevant studies. These issues are now discussed in the subsection “Limitations of the Systematic Review.”

These revisions improve the transparency, reproducibility, and methodological rigor of the review.

"Following the PRISMA guidelines (Page et al., 2021a), we conducted a comprehensive search for 2010–2025 (last search across all sources: 27 September 2025) (last search across all sources: 7 Mar 2026).

As illustrated in Fig. 2, the evidence base is heavily skewed towards recent work: 90.4% of the cited studies were published in 2010 or later, and almost 60% appeared between 2020 and 2025. Only a small number of classic references prior to 2000 were retained to provide historical and theoretical context. As shown in Figure 2, the reviewed literature is strongly weighted toward recent work. Among the studies included in the systematic review, 43 were published in 2010–2015, 64 in 2016–2020, and 86 in 2021–2025, indicating a clear increase in ERA-related research over time. A small number of earlier references published before 2010 were retained only to provide historical or conceptual background. Figure 3 presents the PRISMA (Page et al., 2021b) 2020 flow of records through identification, screening, and inclusion. Searches spanned Web of Science, Scopus, IEEE Xplore, and PubMed, supplemented by Google Scholar (top 10% per year by relevance and citations; n = 54) (Zhang et al., 2019). The Boolean strategy combined three concept groups with “AND”: The search strategy was developed around three core conceptual dimensions of this review: (1) emergency or disaster contexts, (2) automation and intelligent technologies, and (3) response-related activities. Accordingly, the Boolean strategy combined three concept groups with “AND”:

- (1) emergency (“emergency,” “disaster,” “pandemic,” “incident,” “accident”);
- (2) automation (“automate,” “autonomous,” “AI”);
- (3) activities (“response,” “planning,” “monitoring,” “prediction”)."

2. The conceptual evolution diagrams presented in Figures 4, 5, and 6 are interesting. Since the review includes 198 studies, the authors could significantly strengthen the analysis by quantitatively categorizing the reviewed papers according to these stages. For example, presenting the number or proportion of studies corresponding to each phase and how these evolve over time would provide support for the proposed framework and illustrate the evolution of ERA research more clearly.

Response:

We sincerely thank the reviewer for the constructive feedback. In response to these suggestions, specifically regarding point 5 of the revisions, we have re-evaluated the literature dataset and further clarified the temporal scope of this systematic review.

To eliminate any ambiguity concerning the time window, we re-screened the literature to ensure the core analytical corpus of the systematic review is strictly limited to studies published between 2010 and 2025. Regarding research published prior to 2010, we conducted a re-assessment and retained only a few seminal works essential for establishing the historical context or conceptual foundations of ERA research. These earlier works are included in the full reference list as background citations but are excluded from the systematic review's analytical corpus and PRISMA flow statistics.

Following this reorganization, we repeated the PRISMA screening process, yielding a final selection of 193 studies meeting the inclusion criteria within the 2010–2025 timeframe. Accordingly, the methodology section of the revised manuscript has been clarified to explicitly distinguish between the systematic review corpus and the earlier literature used for background context.

Furthermore, we have enhanced the quantitative support for the ERA framework:

1. **Structural Classification:** The included studies have been systematically categorized according to the four architectural levels proposed in this paper. The distribution and proportions of research across these levels are now detailed in Table 2, providing quantitative validation for the proposed ERA framework.

2. **Temporal Evolution Analysis:** We have added a new evolutionary analysis (see Figure 4; detailed data in Appendix B) illustrating development trends across three stages: 2010–2015, 2016–2020, and 2021–2025.

3. **Key Findings:** The results indicate a clear technological shift in ERA research—evolving from early manual or rule-driven automation toward more intelligent, data-driven, and AI-augmented systems. This analysis provides quantitative backing for the conceptual evolution shown in Figures 4–7 (now renumbered as Figures 5–8) and more clearly elucidates the developmental trajectory of the ERA field.

These updates, including the new quantitative results in Table 2 and Figure 4, have been integrated into the revised manuscript.

"To further enhance the quantitative support for the ERA framework, the included studies were systematically categorized according to these four architectural layers. The corresponding number of studies and their proportions are detailed in Table 2, which provides quantitative support for the proposed ERA architecture. Furthermore, we introduced a temporal evolution analysis (as illustrated in Figure 4; the underlying data for this figure has been included as Appendix B following the conclusion) to demonstrate the developmental trends of ERA-related research across three distinct phases: 2010–2015, 2016–2020, and 2021–2025. The analysis reveals that the technological focus of ERA research has progressively transitioned from early forms of automation, which were predominantly human-intensive or rule-driven, toward more intelligent, data-driven, and artificial intelligence-enhanced systems. This temporal analysis provides a quantitative basis for the conceptual evolution presented in Figures 5 through 8, and more clearly elucidates the developmental trajectory of ERA research."

Table 2. Quantitative distribution of included studies across the four-layer ERA architecture (2010–2025)

Architecture layer	Core thematic focus	Number of studies	Proportion (%)
Perception layer	From manual sensing to intelligent surveillance	47	24.35
Decision-making layer	Evolution of data-driven decision-making	56	29.02
Response and control layer	Automated response and control mechanisms	47	24.35
Feedback layer	Enabling adaptive learning and continuous optimization	43	22.28
Total		193	100.00

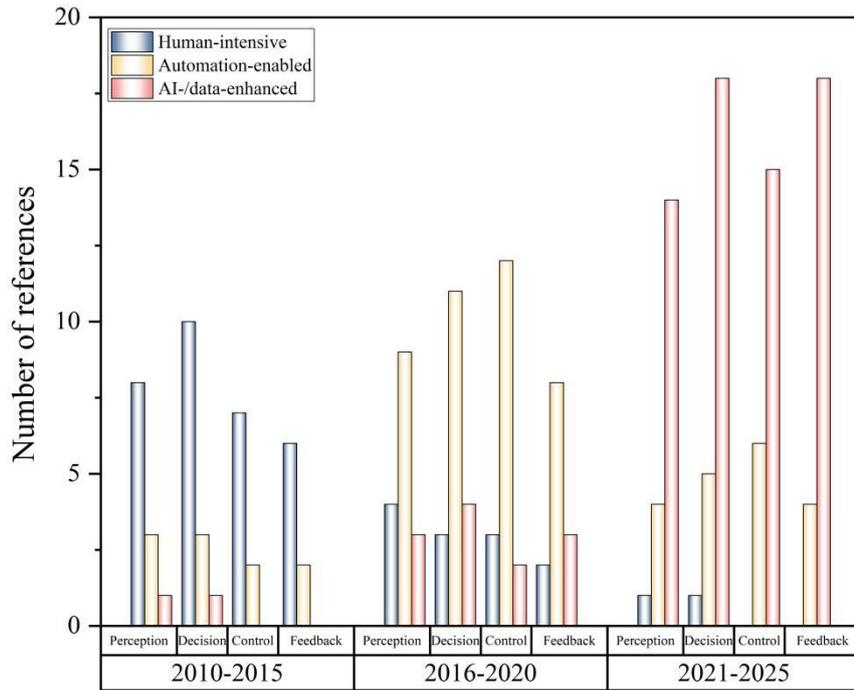


Figure 4 Evolutionary trends of the four ERA architectural layers across three developmental phases (2010–2025).

Appendix B: Underlying data for temporal evolution analysis

Table B1. Quantitative distribution of technological paradigms across ERA layers and time periods (2010–2025).

Time	stage	Human-intensive	Automation-enabled	AI-/data-enhanced
2010-2015	Perception	8	3	1
	Decision	10	3	1
	Control	7	2	0
	Feedback	6	2	0
2016-2020	Perception	4	9	3
	Decision	3	11	4
	Control	3	12	2
	Feedback	2	8	3
2021-2025	Perception	1	4	14
	Decision	1	5	18
	Control	0	6	15
	Feedback	0	4	18

3. The rating methodology described in Section 5.1 and summarized in Table 3 is currently unclear. The categories “Strong,” “Medium,” and “Weak” are not explicitly defined, and the criteria used to assign these ratings are not sufficiently explained. It would strengthen the manuscript if this could be clarified in the evaluation procedure, including whether these ratings are based on defined thresholds, quantitative indicators, or a structured set of assessment conditions.

Response:

We thank the reviewer for highlighting the need to clarify the rating methodology. In the revised manuscript, the evaluation procedure in Section 5.1 has been expanded to provide clearer definitions of the three rating categories (Strong, Medium, and Weak) and to describe the criteria used in assigning them.

Specifically, the revised text now explains that the ratings are based on an evidence-grading approach, considering factors such as field or multi-site validation, comparative or pre–post analyses, sample size and reporting completeness, and the availability of quantitative indicators (e.g., detection latency, false-alarm rate, and task-success ratio). The meanings of the three rating levels have also been clarified: “Strong” corresponds to capabilities supported by well-documented implementation and validation evidence; “Medium” reflects partial or moderate validation such as prototype demonstrations; and “Weak” denotes capabilities with limited empirical support or primarily conceptual descriptions.

These clarifications have been incorporated into Section 5.1, and the description of the evaluation framework has been refined accordingly. Furthermore, the former Table 3 (now renumbered as Table 4) now more clearly embodies the evidence-based interpretation of capability ratings.

These revisions improve the transparency and interpretability of the evaluation procedure.

"Each system’s performance was semi-quantitatively rated as strong (S), medium (M), or weak (W) under an evidence-grading scheme emphasizing reproducibility and rigor. In this scheme, a strong (S) rating indicates that the capability is supported by clear implementation evidence and well-documented validation results (e.g., field deployment, multi-site testing, or reported quantitative performance indicators). A medium (M) rating denotes partial or moderate evidence, such as prototype demonstrations, limited validation, or incomplete reporting of performance metrics. A weak (W) rating corresponds to capabilities that are primarily conceptual, minimally implemented, or supported by limited empirical validation.

Ratings considered field or multi-site validation, comparative or pre–post analyses, sample size and reporting completeness, and the availability of quantitative indicators e.g., detection latency, false-alarm rate, task-success ratio. Where several forms of evidence were available, the rating reflected the overall strength and consistency of the reported validation. "

"Table 4. System × Capability Matrix.

Notes: ^a Capability ratings are interpreted alongside the evidence band (Reproducibility and Rigor, R&R). S (Strong): Supported by field deployment and/or well-documented quantitative validation. M (Medium): Supported by prototype demonstrations or limited empirical validation. W (Weak): Primarily conceptual or minimally implemented with limited validation."

4. While the paper provides a broad synthesis of ERA research, the limitations of the review process are not explicitly discussed. As mentioned earlier, potential biases may have influenced the selection of papers, which is one of the other limitations.

Response:

We thank the reviewer for raising this point. We agree that a rigorous systematic review must acknowledge its methodological limitations, particularly regarding potential biases in the literature selection process.

To address this comment, we have added a new subsection titled "6.6 Limitations of the Systematic Review" in the revised manuscript (placed just before the Conclusion). In this section, we transparently discuss the limitations from three critical perspectives:

Selection Bias: We acknowledge that restricting the search to English-language peer-reviewed publications and excluding grey literature may have omitted localized response systems and government reports. We also address the challenge of highly heterogeneous terminology across multidisciplinary fields, which might have led to the inadvertent omission of studies using unconventional keywords.

Publication Bias: We explicitly discuss the tendency of academic literature to overrepresent successful prototypes and positive evaluations while underreporting real-world system failures or operational limitations.

Evaluation Subjectivity: We note that despite utilizing a structured evaluation rubric (R&R) with high inter-rater reliability, interpreting system capabilities and evidence levels inevitably involves a degree of qualitative judgment.

The following text has been added to the revised manuscript as Section 6.6:

"While this review provides a comprehensive synthesis of ERA, several limitations regarding the methodology and literature selection process must be acknowledged.

First, the search strategy may introduce selection bias. The review was restricted to peer-reviewed studies published in English. Consequently, relevant ERA deployments or localized disaster response systems published in other languages, as well as grey literature such as government technical reports and industry white papers, were excluded. Furthermore, because ERA intersects with multiple disciplines (e.g., computer science, safety engineering, public health), the terminology is highly fragmented. Although our Boolean search was designed to be inclusive, some relevant studies utilizing unconventional or highly domain-specific keywords might have been inadvertently omitted.

Second, the review is inherently susceptible to publication bias. Academic literature tends to overrepresent successful technological implementations, prototype demonstrations, and positive simulation results, while failed deployments or system vulnerabilities in real-world extreme environments are rarely published. This bias may lead to an overestimation of the operational readiness of certain AI-driven ERA technologies.

Third, despite utilizing a standardized Reliability & Reproducibility (R&R) rubric and achieving high inter-rater reliability (Cohen's $\kappa = 0.86$), the capability mapping and evidence grading process retains a degree of qualitative interpretation. The classification of system capabilities into "Strong," "Medium," and "Weak" relies on the transparency and completeness of the original authors' reporting, which varied significantly across the 193 included studies. Future systematic reviews could address these limitations by incorporating *multilingual databases* and employing automated natural language processing tools to capture a broader spectrum of grey literature and operational incident reports.

5. The conclusion section currently focuses mainly on design principles for future ERA systems. While these recommendations are valuable, the section could be strengthened by providing a clearer synthesis of the main findings of the review. In particular, summarizing the key insights emerging from the analysis of the literature, limitations identified from the literature, and other major insights would help reinforce the contribution of the study.

Response:

We appreciate the reviewer's comment. We agree that a strong conclusion should synthesize the core findings and research gaps identified in the literature, serving as a basis for proposing future design principles and addressing the research questions posed in our Introduction.

In the revised manuscript, we have completely rewritten Section 7 (Conclusion) to provide a structured summary of the study's contributions. The revised conclusion follows a clear logical progression, addressing the reviewer's suggestions as follows:

1. **Synthesis of Key Insights:** We summarize the main findings from the 193 reviewed studies, highlighting the paradigm shift of emergency response systems towards the "four-layer ERA architecture," as well as the practical performance improvements brought by the deep integration of AI and IoT technologies.

2. **Summary of Limitations and Threats:** We identify the gap between technological innovation and practical operational maturity, noting that many advanced automation functions remain confined to simulation or prototype stages. We also summarize the cross-cutting threats identified in the literature, including interoperability barriers caused by data

3. **Integration with Design Principles:** By clearly outlining the aforementioned specific findings and limitations in the first half of the conclusion, the transition to

proposing future design principles (e.g., “ Privacy-by-design, ” “Interoperability-by-design,” and “Human-centred automation”) in the second half becomes more natural and well grounded in our analysis of the literature.

We believe the restructured conclusion strengthens the contribution of this systematic review and directly addresses our initial research questions (RQ1 – RQ3). The full text of the updated conclusion is as follows:

This systematic review synthesized 193 peer-reviewed studies published between 2010 and 2025 to examine the evolution, architecture, and reliability implications of ERA. By analysing ERA through a four-layer architecture — risk perception, decision-making, automated response, and feedback — the review reveals a clear transition from human-intensive and rule-based emergency management toward increasingly data-driven and AI-enabled response systems. Across multiple hazard domains, emerging technologies such as IoT sensing, artificial intelligence, and digital twins are expanding the capabilities of automated situational awareness, predictive analysis, and coordinated response.

At the same time, the evidence base indicates that the operational maturity of ERA remains uneven. While automated sensing, early-warning analytics, and decision-support tools show moderate to strong empirical support in several hazard contexts, many higher-level automation functions — including autonomous response coordination and adaptive system learning—remain largely confined to simulations, prototypes, or limited pilot deployments. This gap highlights a persistent challenge in translating technological innovation into dependable safety-critical systems.

The review also identifies several cross-cutting threats to ERA dependability. Key concerns include interoperability barriers caused by fragmented data infrastructures, limited resilience under degraded communication conditions, insufficient fail-safe and fail-operational design, and persistent challenges in human – automation coordination and algorithmic transparency. These issues underscore the importance of integrating safety science and resilience engineering perspectives into ERA development.

To address these challenges, the synthesis suggests that future ERA systems should be guided by several core design principles. Privacy-by-design and fail-safe architectures should be treated as fundamental requirements for trustworthy automation. Interoperability-by-design is essential for enabling cross-organisational coordination during complex multi-hazard events. In addition, human-centred and transparent automation is necessary to ensure that automated decision-support systems augment rather than displace human expertise.

Overall, the findings highlight that advancing ERA requires not only technological innovation but also systematic attention to reliability assurance, governance frameworks, and socio-technical integration. Future research should therefore prioritize large-scale empirical validation, standardized evaluation metrics, and interdisciplinary collaboration to ensure that automated emergency response systems remain robust, accountable, and effective in real-world disaster environments.

Other modifications:

1. Line 86, add appropriate references for the sentence 'Moreover, few studies provide a systematic synthesis... '.

Response:

We appreciate the reviewer's attention to this omission. We agree that this statement requires stronger literature support. In the revised manuscript, we have incorporated two relevant references (Bhanye, 2025; Frykmer et al., 2021) that explicitly highlight the existing research gaps in integrating technological advancements with broader disaster response frameworks. To better align with the specific research focus of these newly cited works, we have also revised the sentence to explicitly mention the 'social, behavioural, and governance dimensions.'

The updated sentence in the revised manuscript now reads as follows:

"Moreover, few studies provide a systematic synthesis linking technological evolution with social, behavioural, and governance dimensions, and existing integration across these dimensions remains partial (Bhanye, 2025; Frykmer et al., 2021)."

[1] Bhanye, J., 2025. Flood-tech frontiers: smart but just? A systematic review of AI-driven urban flood adaptation and associated governance challenges. *Discov. Glob. Soc.* 3, 59. <https://doi.org/10.1007/s44282-025-00190-9>

[2] Frykmer, T., Tehler, H., Uhr, C., Wester, M., 2021. Advancing the field of disaster response management: toward a design science approach. *Int. J. Disaster Risk Sci.* 12, 220–231.

2. Table 1 shows the recent literature reviews. It would be helpful to readers if the caption included the duration, which considers recent reviews, such as 2020-2025. Also, it would be good if the articles were listed in the table in chronological order of publication year. The first author's name is written and then again in-text citation in parentheses. Either all the author names can be listed and keep the in-text citation as a separate column, or just keep a 'Reference' column is fine.

Response:

We thank the reviewer for these suggestions regarding the formatting and clarity of Table 1. We have implemented these changes in the revised manuscript to improve readability.

Specifically, we have made the following three modifications to Table 1:

1. Caption Update: We updated the table caption to explicitly include the reviewed timeframe. It now reads: "Table 1. Overview of recent literature reviews in emergency response and disaster management (2021 – 2025)."

2. Chronological Ordering: We have reordered all the listed literature reviews in strict chronological order based on their publication year, from 2021 to 2025.

3. Column Simplification: To eliminate the redundancy pointed out by the reviewer, we changed the "Authors" column to a single "Reference" column. We removed the redundant first author's name and kept only the standard in-text citation format.

Table 1. Overview of recent literature reviews in emergency response and disaster management (2021 – 2025).

Serial No.	Reference	Focus Area
1	Dwarakanath et al., 2021	A comprehensive review of the role of social media in emergency response after disasters based on machine learning.
2	Feng and Cui, 2021	<i>A review of the disaster emergency response system covering the current situation and future prospects.</i>
3	Khan et al., 2023	Overall assessment of disaster management systems, with a focus on methods/tools and challenges.
4	Damaševičius et al., 2023	<i>A comprehensive overview of the Internet of Emergency Services and its implications for emergency response and disaster management.</i>
5	Li et al., 2024	<i>A review of Digital Twins in wildfire management.</i>
6	Lagap and Ghaffarian, 2024	<i>Applications and challenges of Digital Twin in post-disaster risk management.</i>
7	Jazairy et al., 2025	<i>The role of drones in emergency logistics and material delivery.</i>
8	Saputra et al., 2025	<i>An overview of IoT applications in the urban/infrastructure domain.</i>
9	Abid et al., 2025	<i>Applications of AI methods based on social media and crowdsourced data in disaster management.</i>

3. *Since many readers would not know what a PRISMA review of literature is, it would be good if an appropriate reference could be added wherever the term 'PRISMA' is used, as shown in line 128.*

Response:

We appreciate this suggestion, which improves the clarity of the methodology section for readers less familiar with systematic review protocols.

In the revised manuscript, we have fully addressed this comment through the following modifications:

1. Expanding the acronym: Upon its first appearance in the main text, we have explicitly spelled out the full name of the framework: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

2. Adding appropriate references: Wherever the term "PRISMA" is mentioned, we have inserted the foundational PRISMA 2020 guidelines (Page et al., 2021a; Page et al., 2021b), along with an application example of this framework previously published in this journal (Enu et al., 2023).

The specific updates in the revised manuscript are as follows:

1. Based on a review conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)(Page et al., 2021a; Enu et al., 2023)

2. Following the PRISMA guidelines(Page et al., 2021a)

3. Figure 3 presents the PRISMA(Page et al., 2021b) 2020 flow of records through identification, screening, and inclusion.

[1] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D., 2021a. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev* 10, 89. <https://doi.org/10.1186/s13643-021-01626-4>

[2] Page, M.J., Moher, D., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., McKenzie, J.E., 2021b. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 372, n160. <https://doi.org/10.1136/bmj.n160>

[3] Enu, K.B., Zingraff-Hamed, A., Rahman, M.A., Stringer, L.C., Pauleit, S., 2023. Review article: potential of nature-based solutions to mitigate hydro-meteorological risks in sub-saharan africa. *Nat. Hazards Earth Syst. Sci.* 23, 481 – 505. <https://doi.org/10.5194/nhess-23-481-2023>

4. Figure 1 - the figure needs to be in high resolution (300 dpi). The caption needs to elaborate on what it represents - what each layer represents, and refer back to the section where these layers are explained in detail. Also, change 'Fig.1' to 'Figure 1'.

Response:

We agree with the reviewer's suggestions. A clear, self-explanatory caption is important for a complex framework diagram like this.

In the revised manuscript, we have made the following modifications:

1. Expanded Caption: We have elaborated on the caption for Figure 1. The new caption defines the four functional layers corresponding to the quadrants, explains the evolutionary progression depicted by the expanding concentric rings, and includes direct cross-references to the specific subsections (Sections 3.2 to 3.5) where each layer is thoroughly analyzed.

2. Formatting and Resolution: We have corrected the label from 'Fig. 1' to 'Figure 1' strictly following the journal's formatting guidelines. A new high-resolution version of Figure 1 has also been generated and uploaded for better clarity.

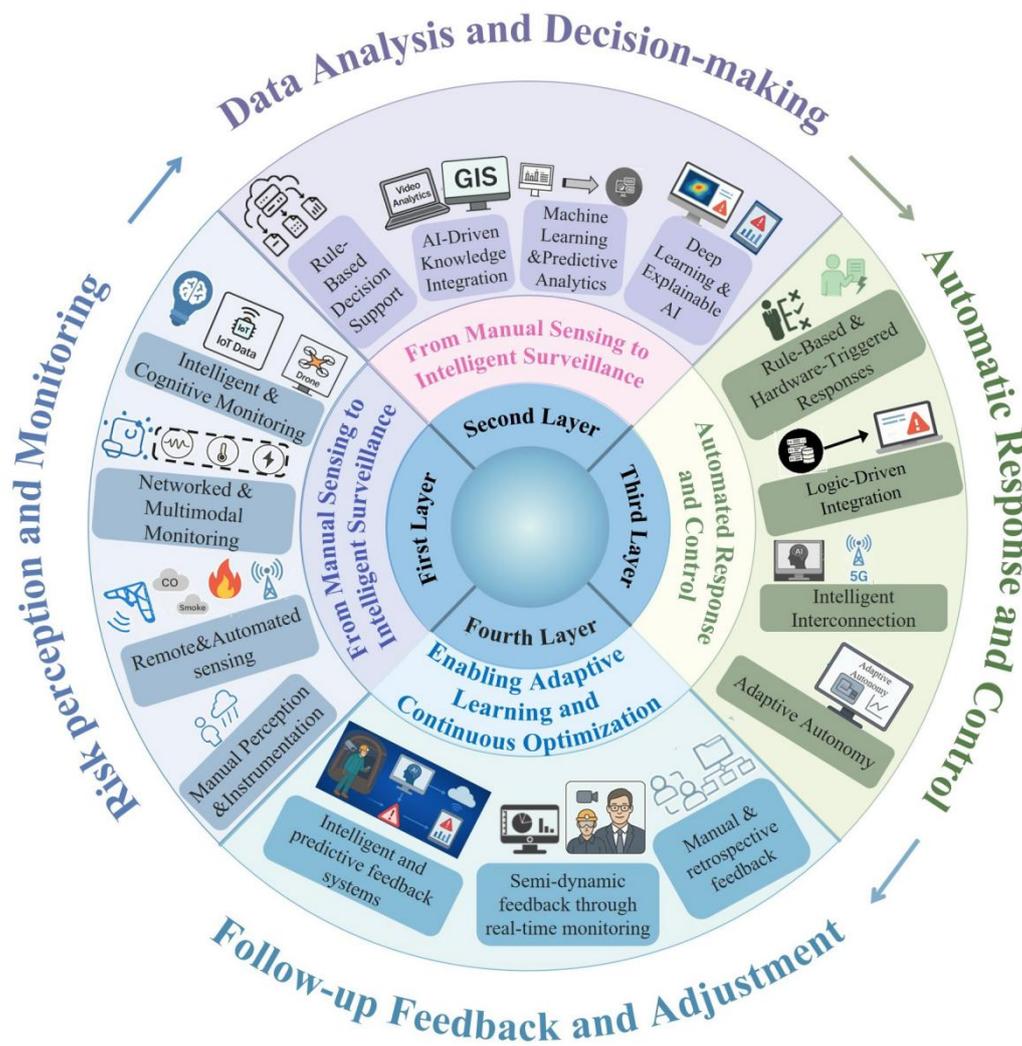


Figure 1 The four-layer architecture and evolutionary framework of Emergency Response Automation (ERA). The framework is divided into four functional layers (represented by the four quadrants): Risk Perception and Monitoring (First Layer; detailed in Section 3.2), Data Analysis and Decision-making (Second Layer; detailed in Section 3.3), Automated Response and Control (Third Layer; detailed in Section 3.4), and Follow-up Feedback and Adjustment (Fourth Layer; detailed in Section 3.5). The concentric rings, expanding from the inner core outward, illustrate the technological evolution within each layer—progressing from early manual or rule-based methods to advanced, AI-driven, and autonomous paradigms.

5. Line 129 - include the sources where articles were searched. It is mentioned that the focus of publication duration is 2010 to 2025. But the search results also included articles published before 2010, which were retained. This contradicts the statement that the review duration is from 2010 to 2025. It would be good if a clarification is added here stating whether the articles published before 2010 are included in the systematic review or not.

Response:

We thank the reviewer for this careful reading. As described in our response to clarification question #2 above, we have addressed this temporal discrepancy.

Briefly, we have re-screened the dataset, strictly limiting the core analytical corpus of the PRISMA systematic review to the 193 studies published between 2010 and 2025. Any classic articles published prior to 2010 have been retained exclusively as background references and are excluded from the systematic review analysis.

Furthermore, as requested, the revised Methodology section not only clarifies this time frame but also lists the specific source databases used for our literature search. We have also redrawn the PRISMA flow diagram (Figure 3) to clearly present the screening, exclusion, and inclusion process.

PRISMA 2020 flow diagram for literature identification, screening and inclusion

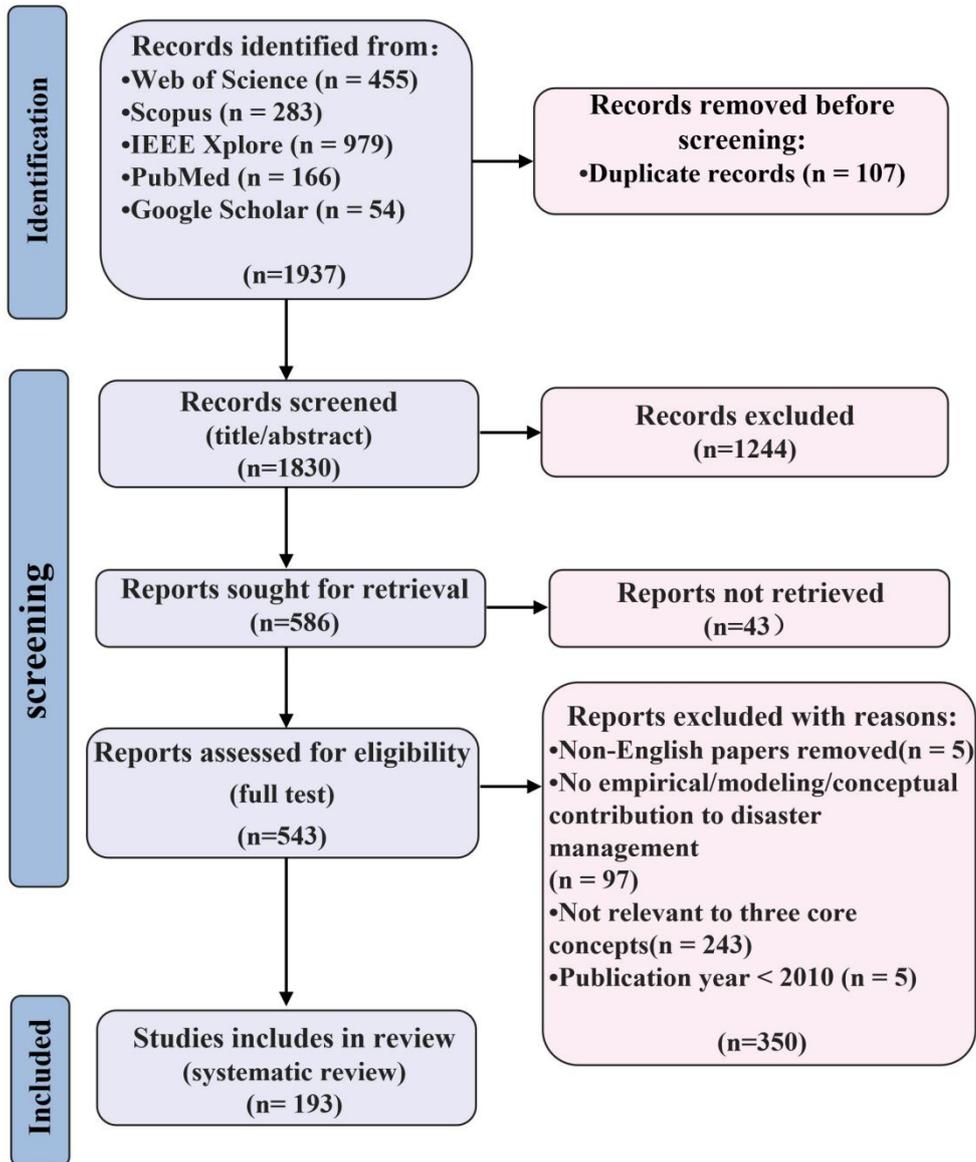


Figure 3 PRISMA 2020 flow diagram for the systematic review (2010-2025).

6. Figure 2 - More spacing can be added between the bars so that the x-axis values have space between them. Or make the x-axis values tilt.

Response:

We appreciate this suggestion for improving the readability of Figure 2.

We have modified the figure by increasing the spacing between bars. As demonstrated in the revised figure (see below), this adjustment provides ample whitespace between the x-axis values (years). This adjustment has made all labels clearly legible in a horizontal orientation, eliminating the need to tilt them.

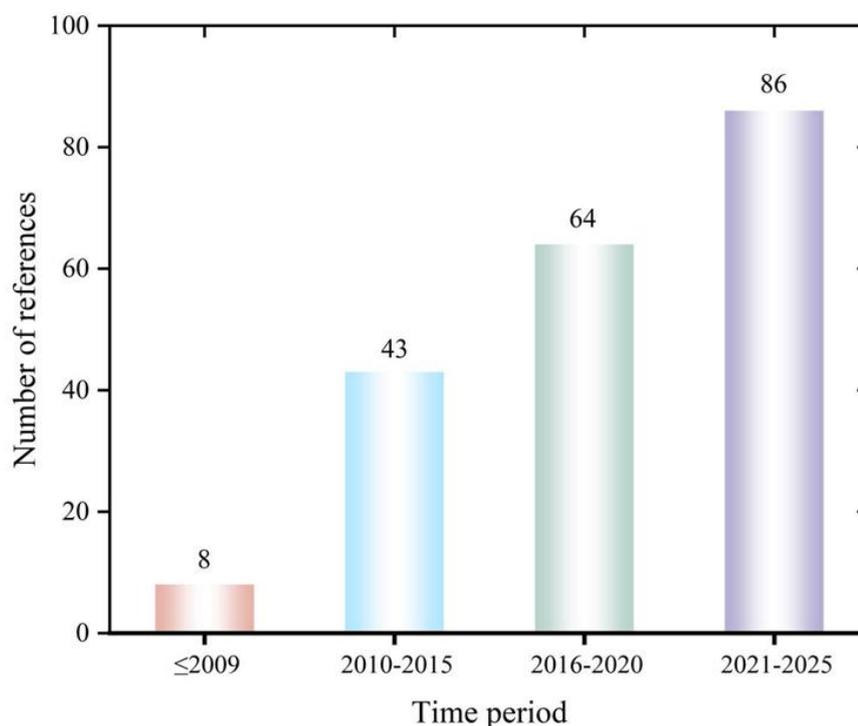


Figure 2 Temporal distribution of ERA-related references.

7. All figures need to be in 300 dpi for high resolution.

Response:

We apologize for the low resolution of the figures in the initial submission. Following this suggestion, we have replaced all figures with high-resolution versions (300 DPI) for better print quality. These updated figures are presented below.

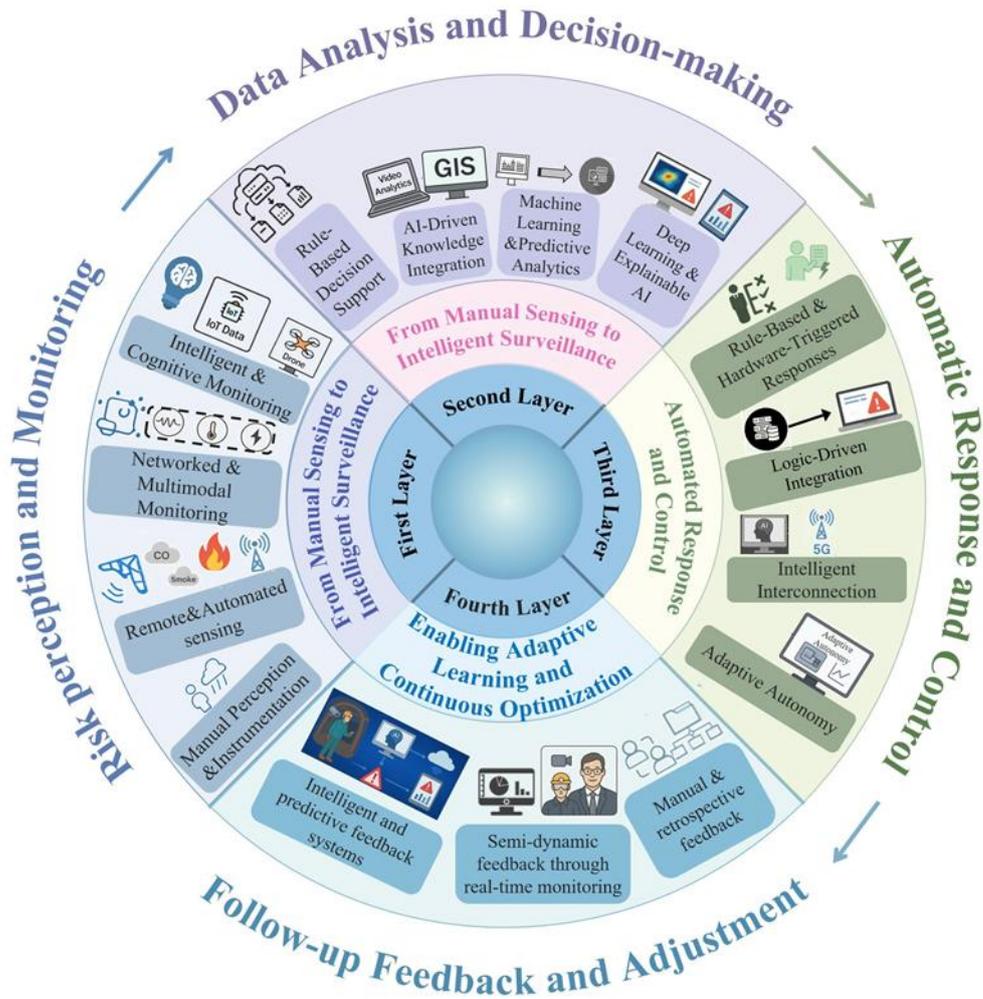


Figure 1 The four-layer architecture and evolutionary framework of Emergency Response Automation (ERA). The framework is divided into four functional layers (represented by the four quadrants): Risk Perception and Monitoring (First Layer; detailed in Section 3.2), Data Analysis and Decision-making (Second Layer; detailed in Section 3.3), Automated Response and Control (Third Layer; detailed in Section 3.4), and Follow-up Feedback and Adjustment (Fourth Layer; detailed in Section 3.5). The concentric rings, expanding from the inner core outward, illustrate the technological evolution within each layer—progressing from early manual or rule-based methods to advanced, AI-driven, and autonomous paradigms.

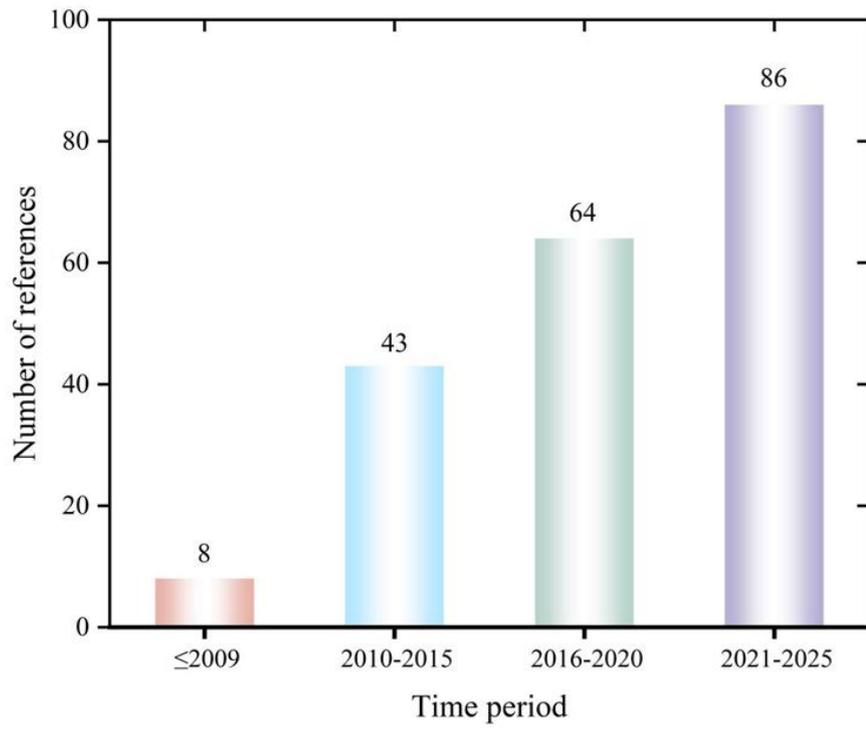


Figure 2 Temporal distribution of ERA-related references.

**PRISMA 2020 flow diagram for
literature identification, screening and inclusion**

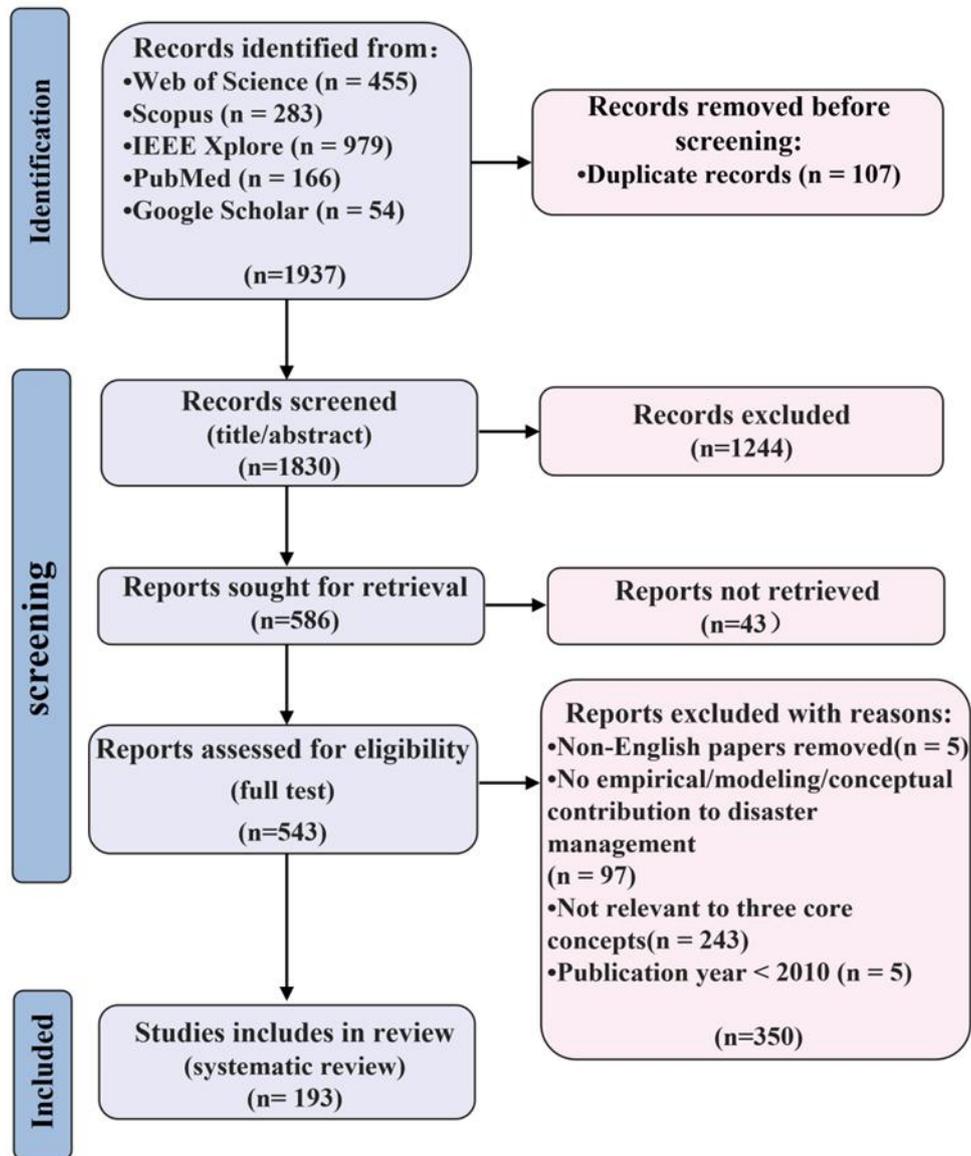


Figure 3 PRISMA 2020 flow diagram for the systematic review (2010-2025).

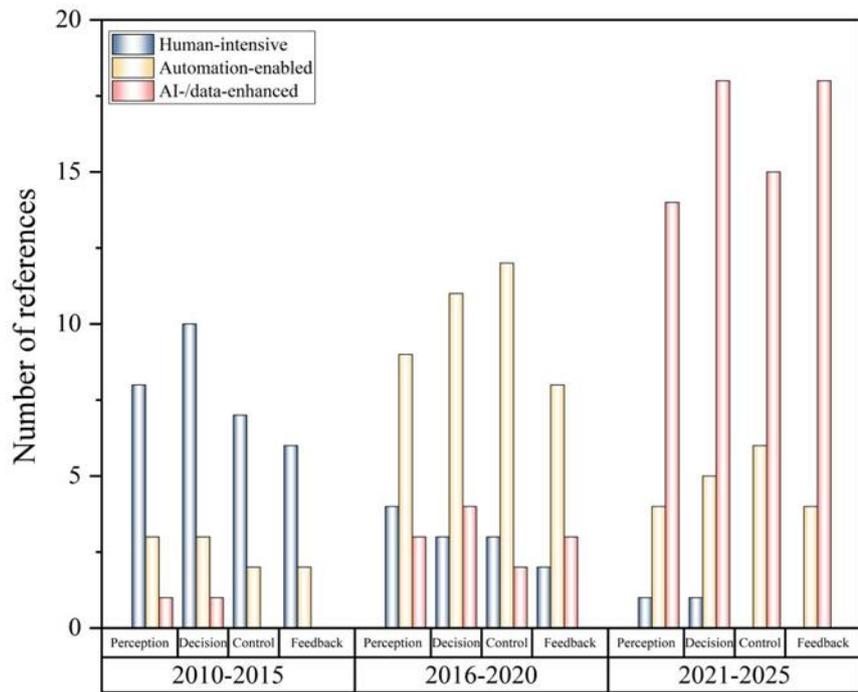


Figure 4 Evolutionary trends of the four ERA architectural layers across three developmental phases (2010–2025).

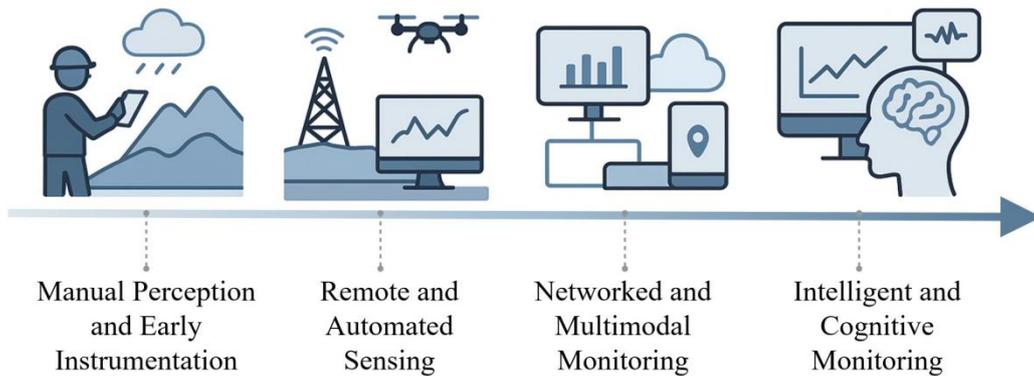


Figure 5 Diagram of the evolution of the risk perception and monitoring layer.

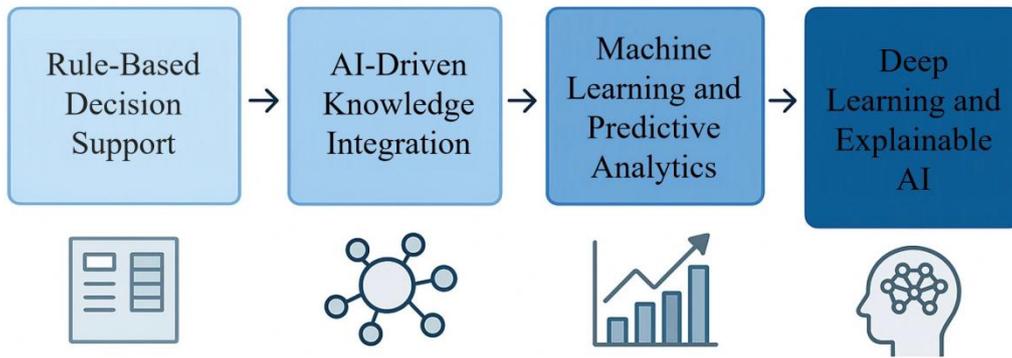


Figure 6 Diagram of the evolution of data analytics and the decision-making hierarchy.

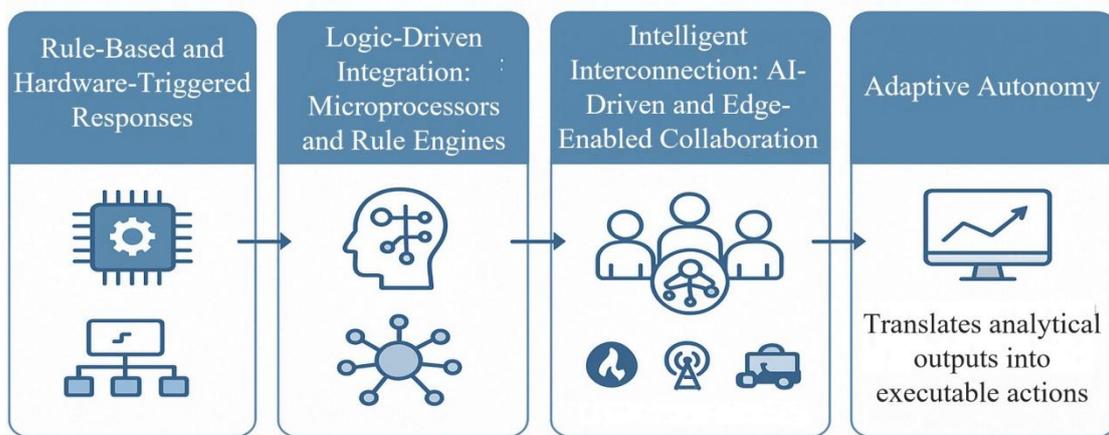


Figure 7 Diagram of the evolution of the automatic response and control layer.

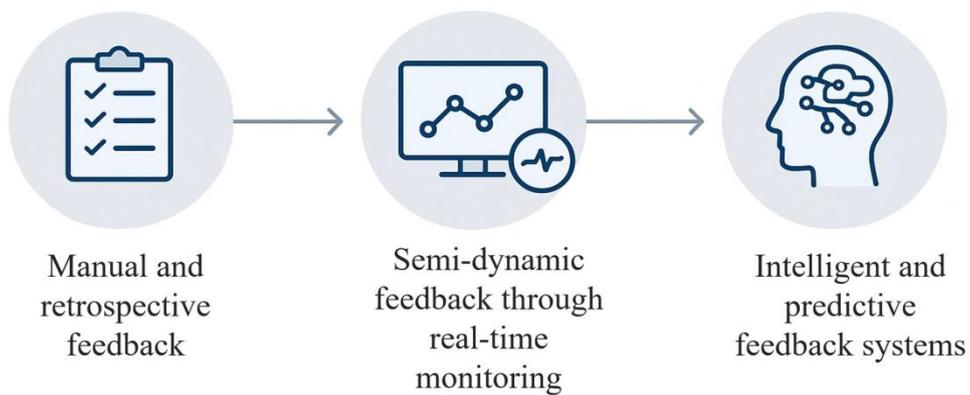


Figure 8 Diagram of the evolution of the subsequent feedback and adjustment layer.

Next-Generation ERA Framework

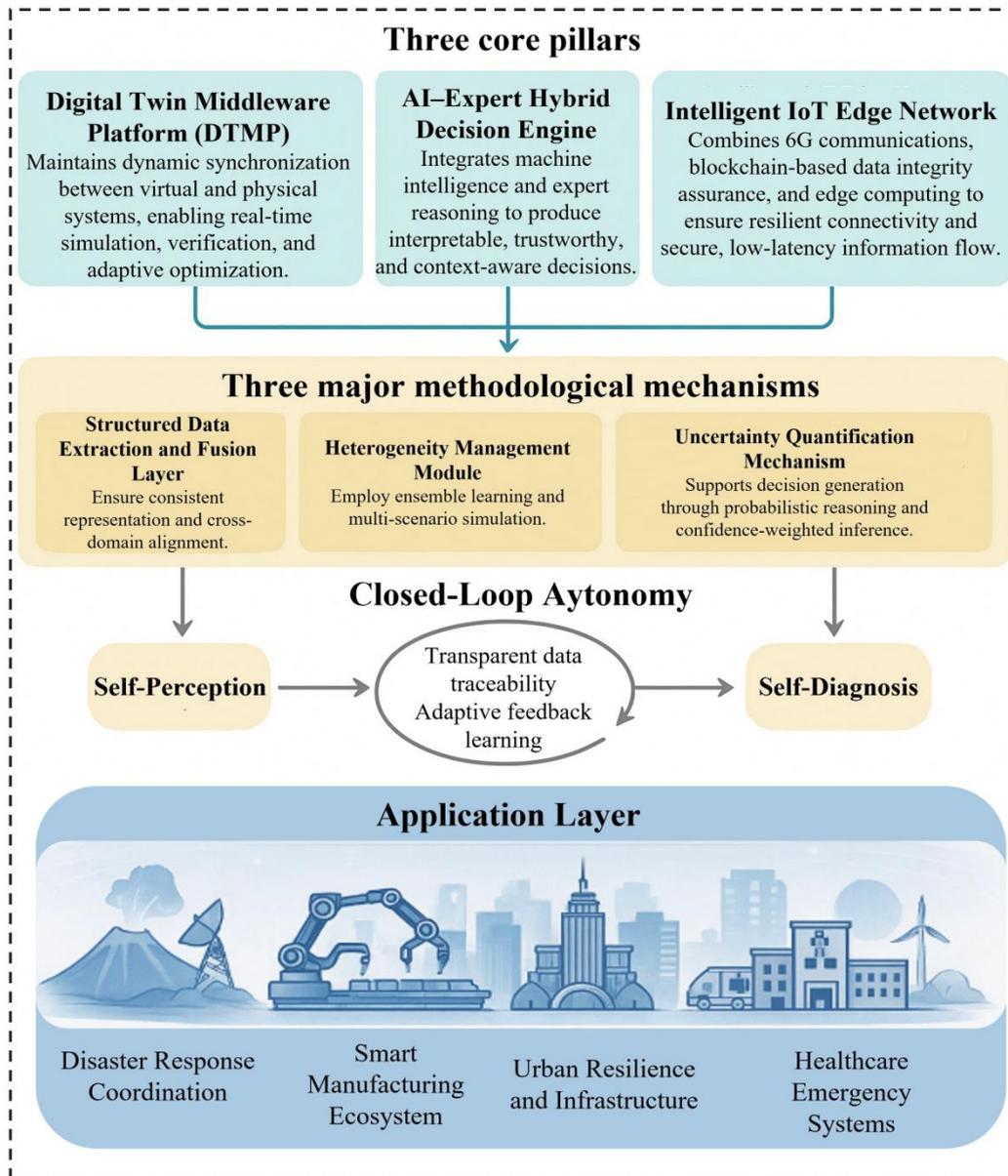


Figure 9 Key Interaction Flow of ERA System.

Minor Typos:

1. Add a space before a parenthesis begins, such as in lines 54, 55, 57, 69, and more. Check the whole document for such spacing issues.

Response:

We appreciate this careful observation and apologize for the oversight. We have corrected the spacing issues before parentheses throughout the manuscript. A thorough check has been conducted to ensure all similar formatting errors are rectified.

2. Line 64, make the first letters of the word 'artificial intelligence' in capital letters, as it shows an abbreviation using '(AI)'.

Response:

We are grateful for the reviewer's attention to this detail. In accordance with the suggestion, we have capitalized "artificial intelligence" in line 64 and introduced the acronym as "Artificial Intelligence (AI)."

3. Line 216 - the comma appearing before the word 'forest' should be placed after the word 'management' and then a space.

Response:

We thank the reviewer for this attention to formatting. The comma in line 216 has been moved from before "forest" to after "management," followed by a proper space.

"In natural disaster management, forest fire monitoring relies on IoT,"

4. Lines 222, 267, 328 - the space between the in-text citation and fullstop can be removed.

Response:

We thank the reviewer for this careful reading. The extra spaces between in-text citations and full stops in lines 222, 267, and 328 have been removed. Furthermore, a thorough check has been conducted throughout the manuscript to ensure that all citations strictly adhere to the required punctuation format.

5. All figure captions - change 'Fig.' to 'Figure'.

Response:

We thank the reviewer for pointing this out. All abbreviations of "Fig." have been changed to "Figure" in the revised manuscript.

6. Line 297 - spacing required before and after in-text citation parentheses.

Response:

We thank the reviewer for this observation. We have revised the spacing around the parentheses for the citation in line 297 and addressed similar spacing inconsistencies throughout the manuscript.

7. Line 300 - for in-text citation, 'Azid et al.', provide the year as well. Same for line 301.

Response:

Following the reviewer's helpful suggestions, we have included the missing publication years for the narrative citations in lines 300 and 301. We have also reviewed the rest of the manuscript to ensure that all author mentions in the text are accompanied by the respective publication years. All similar oversights have been corrected.

"For example, Azid et al. (2022) developed an Android-based flood warning application utilizing web services for automatic notifications (Sung et al., 2022), while De Souza et al. (2015) integrated real-time hydrological monitoring with user geolocation to deliver context-aware SMS alerts (De Souza et al., 2015)."

8. Line 321 - remove the extra parentheses for the in-text citation provided.

Response:

We thank the reviewer for their attention to detail. The redundant parenthesis ")" has been deleted.

"integrating sprinkler control and escape route optimization (Annadurai et al., 2024; Jiang et al., 2023; Mondal et al., 2023)."

9. Line 408-409 - capitalise the first letters of 'unmanned aerial vehicle' as it represents the abbreviation 'UAV' given in line 409.

Response:

We appreciate the reviewer's careful attention to detail. We have corrected the text to "Unmanned Aerial Vehicle (UAV)" in the specified

lines. We have also conducted a thorough check and capitalized the first letters of this term wherever it appears in the text, to ensure consistency throughout the manuscript.

10. Table 2 - better to repeat table headers in all the pages where the table is present.

Response:

We thank the reviewer for this suggestion. We have revised Table 2 (now Table 3) to ensure that the headers are repeated on every page. We have also reviewed all other multi-page tables in the manuscript and applied the same correction. The revised tables have been updated in the resubmitted manuscript.

Table 3 (continued).

System	Core function	Key technologies	Typical deployment / scenario	Reported effect / evidence	Evidence strength	Limitations / failure modes
UIoT fire monitoring(Bisquert et al., 2012; Chen et al., 2024; Ramadan et al., 2024; Zhou et al., 2023)	Fire source localization and spread tracking	UAVs, thermal imaging, IoT sensors, CV algorithms	Wildfire/structural fire monitoring	Real-time localization; performance degrades in smoky/occluded conditions	Prototype / pilot deployments (low-medium)	Detection degrades in smoke/occlusion; vulnerable to power/network loss; limited large-scale trials.
Healthcare Automation & Telemedicine System (Li et al., 2021; Rathore et al., 2016; Shen et al., 2021)	Dynamic allocation of medical resources and AI-assisted remote diagnosis during pandemics	AI decision support, IoT networks, telemedicine platforms, data integration	Public health / emergency / epidemic response	Automated staff scheduling, bed allocation, tele-consultation; improved triage efficiency reported during COVID-19	supported by multiple case studies and operational data from pandemic deployments (medium-high)	Heavy reliance on hospital IT; data quality and bias issues; uneven staff adoption.
Smart City Emergency Response Platforms (e.g., Singapore ITS)(Martinez et al., 2010; Telang et al., 2021)	Integrated urban traffic management and incident response	IoT sensors, AI analytics, traffic control systems, real-time data fusion	Urban safety / transportation / large-event management	Automated signal control and emergency-lane optimization; enhanced urban response coordination	validated through municipal implementation reports and performance summaries (medium)	Complex integration; core failures can cascade; legacy-system interoperability remains patchy.
Drone medical logistics (Homier et al.)(Homier et al., 2021)	Urgent medical delivery in mass-casualty / disrupted-access scenarios	UAV logistics, routing/dispatch algorithms, regulatory integration	Urban & disaster logistics	Empirical trial: median delivery 17 min vs 29 min by ground (41% faster)	Field trial / empirical (high)	Weather/airspace limits; small payload and endurance; needs tight EMS workflow integration.

Table 5 (continued).

Technology	Environmental & Natural Hazards	Industrial & Infrastructure Emergencies	Public Health & Social Safety	Cross-domain Insights
Digital Technology	Twin Simulates evolution and deployment for disaster and resource preparedness and recovery.	Mirrors industrial systems to predict failures and optimize maintenance.	Models hospital or urban systems for real-time health and mobility management.	Advantage: Enables virtual testing and proactive control. Limitation: Requires high-quality, continuous data and significant computational resources.
Next-generation Communication (5G/6G, Edge Computing)	Ensures low-latency data transmission for drone coordination and early warning dissemination.	Supports ultra-reliable communication for critical infrastructure operations.	Enables telemedicine, emergency alerts, and high-volume health data transfer.	Advantage: Provides reliable, real-time connectivity under extreme conditions. Limitation: High deployment cost and uneven global coverage.

11. Good to add a table showing the list of abbreviations.

Response:

We appreciate this suggestion. Given the multidisciplinary nature of this review and the numerous technical terms involved, we agree that a dedicated list of abbreviations improves readability.

In the revised manuscript, we have compiled a comprehensive table that organizes all the key acronyms in alphabetical order. To ensure easy reference for the readers without interrupting the narrative flow, this table has been added as an Appendix (Appendix A: List of abbreviations) immediately following the Conclusion section.

Appendix A: List of abbreviations

Table A1. List of abbreviations.

Abbreviation	Full Term
AI	Artificial Intelligence
AI-E	AI-Expert Hybrid Decision Engine
BIM	Building Information Modeling
CNN	Convolutional Neural Network
DSS	Decision Support System
DST	Dempster-Shafer Theory
DTMP	Digital Twin Middleware Platform
EAL	Emergency Action Level
ERA	Emergency Response Automation
FAR	False Alarm Rate
GIS	Geographic Information System
HITL	Human-in-the-Loop
ICS	Incident Command System
I-IEN	Intelligent IoT Edge Network
IoES	Internet of Emergency Services
IoT	Internet of Things
LEO	Low-Earth-Orbit
MTBF	Mean Time Between Failures
MTTR	Mean Time To Recovery

Table A1 (continued).

Abbreviation	Full Term
NIMS	National Incident Management System
OODA	Observe, Orient, Decide, Act
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
R&R	Reliability and Reproducibility
SDN	Software-Defined Networking
SEMS	State Emergency Management System
SVM	Support Vector Machine
UAV	Unmanned Aerial Vehicle
XAI	Explainable Artificial Intelligence

12. For in-text citations of multiple papers, good to give them in the order of year of publication for better readability. For example, line 356 lists 3 papers, but not in the order of publication year.

Response:

We appreciate this observation regarding citation order, which helps improve the manuscript's readability.

The specific case on line 356 has been corrected, with the citations now arranged in strict chronological order. Additionally, we have performed a thorough check of the whole manuscript to ensure consistency. Every multi-source citation has been carefully verified and adjusted to follow the order of publication years.

1. Moreover, few studies provide a systematic synthesis linking technological evolution with social, behavioural, and governance dimensions, and existing integration across these dimensions remains partial (Bhanye, 2025; Frykmer et al., 2021).
2. Based on a review conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Enu et al., 2023; Page et al., 2021a).
3. With the rise of remote sensing satellites, radar networks, and early wireless sensor systems, monitoring gradually shifted toward automation (Kodali and Yerroju, 2017; Stähli et al., 2015).
4. Satellite-based systems enabled continuous observation of floods, landslides, and wildfires (Al-Hady et al., 2023; Mois et al., 2017).

5. Fixed gas and infrared sensors provided near-real-time industrial monitoring (Ni et al., 2018; Chraim et al., 2015; Jain and Kushwaha, 2012)
6. In public health, AI-driven systems integrate genomic sequencing data with population mobility and social indicators to forecast epidemic trajectories (Ongesa et al., 2025; Hadfield et al., 2018).
7. COVID-19 early-warning system (EWS) uses hospital diagnostic data and thermal sensors for contactless screening (Ding et al., 2025; Haque et al., 2024).
8. In industrial safety, computer vision and reinforcement learning models autonomously diagnose abnormal equipment behavior, while explainable AI enhances operator trust in automated alerts (Rivas and Abrao, 2020; Sayed and Gabbar, 2017).
9. In natural disaster management, forest fire monitoring relies on IoT, thermal imaging, drones, and AI algorithms to achieve early fire detection and spread prediction (Kavitha et al., 2023; Mehta et al., 2021),
10. And provide decision support (Montasari, 2024; Florea et al., 2022; Robertson et al., 2019).
11. Bayesian networks and GIS-based tools enabled dynamic, multi-source situational assessment and predictive mapping (Schneider et al., 2025; David et al., 2010).
12. Applications included wildfire propagation prediction (Bot and Borges, 2022; Pereira et al., 2022; Sayad et al., 2019), explosion early warning, and evacuation optimization (Huang et al., 2024; Zverovich et al., 2016; Ruppel and Schatz, 2011).
13. With the integration of deep learning, the Internet of Things (IoT), and 5G/B5G communication networks (Dixit et al., 2022; Euchi, 2021), automated response systems entered the stage of intelligent interconnection. Technologies such as device-to-device communication (Ever et al., 2020; Ahmed et al., 2019) and the Internet of Emergency Services (IoES) enabled multi-channel.
14. IoT + BIM systems for fire detection and suppression, integrating sprinkler control and escape route optimization (Annadurai et al., 2024; Jiang et al., 2023; Mondal et al., 2023).
15. With advances in sensing, communication, and computational technologies, feedback layers gradually incorporated real-time monitoring and automated evaluation capabilities (Ding et al., 2022; Newman et al., 2017; Sattele et al., 2015).
16. Researchers began improving alarm performance, enhancing the utilization of monitoring data, and integrating location-based path planning models to coordinate disaster logistics and resource deployment (Giroto et al., 2024; Wang and Nie, 2023).
17. The convergence of BIM - GIS - IoT technologies further enhanced system interoperability, enabling more efficient spatial and situational data exchange (Sani and Abdul Rahman, 2018; Boguslawski et al., 2015).
18. ERA systems can dynamically reallocate resources and adjust operational priorities in evolving scenarios (G. Zhang et al., 2024; Zhang et al., 2014).
19. While reinforcement learning models continuously refine decision policies based on performance feedback (Li, 2024; Arulkumaran et al., 2017).

20. Similar mechanisms have been implemented in Japan's Earthquake Early Warning System, where automated seismic data processing allows alerts to be issued within seconds (H. Zhang et al., 2024; Kumar et al., 2022).
21. while human coordinators ultimately decide when and how to issue community alerts (Jafarzadegan et al., 2023; Lam et al., 2023).
22. Accurate localization at the incident scene is a critical function of ERA systems (Ang et al., 2022; Khan et al., 2022).
23. In addition, real-time tracking of rescue personnel and materials has ensured highly coordinated and efficient response operations (Damaševičius et al., 2023; Balta et al., 2017).
24. Effectively alleviating shortages and enhancing coordination efficiency (Lv et al., 2021; Van Der Schaar et al., 2021).
25. Despite the diversity of application scenarios, the core logic of these systems all adhere to a closed-loop framework of “monitoring-assessment-decision-response” (Casartelli et al., 2025; Cook and Dorussen, 2021; Stoto et al., 2018).
26. while communication disruptions caused by damaged infrastructure in disaster-affected areas further exacerbate this issue (Cao et al., 2023; Rak et al., 2021).
27. Personal information leakage incidents in multiple countries during the pandemic have exacerbated public concerns (Z. Wang et al., 2024; Chan and Saqib, 2021).
28. When using drones for rescue missions, network security issues must be considered (Papyan et al., 2024; Sindiramutty et al., 2024).
29. In line with our findings that explainable AI and human – machine collaboration are pivotal for trustworthy ERA (Hoff and Bashir, 2015; Hancock et al., 2011).
30. Cross-agency operations benefit from standards-aligned data models and interfaces consistent with incident-management practice (Elmhadhbi et al., 2020; Salvador et al., 2019).
31. To deepen the theoretical foundations of the next-generation ERA architecture, a comparative analysis was conducted with three representative theoretical models in the emergency response domain: the OODA loop (Tanui, 2021; Sullivan and Kamensky, 2017).
32. And gas sensors for real-time detection of diverse hazards such as fires, toxic releases, and structural deformations (Donta et al., 2023; Nanda et al., 2023; Ortiz-Garcés et al., 2023).
33. While blockchain integration enhances secure data storage and interagency information sharing (Habib et al., 2024; Treiblmaier and Rejeb, 2023).
34. However, scalability remains a central technical bottleneck for large-scale blockchain implementation (Satheesh et al., 2025; Chamola et al., 2020).
35. AI-driven decision frameworks will increasingly emphasize adaptability, interpretability, and multimodal data fusion (Hsiao et al., 2025; Wibowo et al., 2025).
36. Low-Earth-Orbit (LEO) satellite constellations—are poised to deliver seamless and resilient connectivity for emergency operations (Aldrees et al., 2025; Liu et al., 2025; Uusitalo et al., 2021).

37. The convergence of AI and 6G technologies will ultimately enable a closed-loop emergency management ecosystem, integrating pre-disaster forecasting, real-time response, and post-disaster recovery (Zio and Miqueles, 2024; Ariyachandra and Wedawatta, 2023).
38. Future architectures should integrate multi-agent coordination frameworks and human – machine collaboration models to optimize task allocation, minimize operational conflicts, and enhance system robustness (Mourtzis et al., 2024; Daud et al., 2022).

We again thank the reviewer for these detailed and thoughtful comments, which have helped improve the rigor and clarity of our manuscript. We hope our responses and the corresponding revisions adequately address all the concerns raised. We welcome any further questions or requests for clarification.