Interreg Co-funded by the European Union

Italy – Croatia

REALIST

D1.2.1 REPORT ON GAPS AND MISSING ELEMENTS

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Executive summary

This deliverable (D.1.2.1) provides an evidence-based analysis of gaps and missing elements in the current set-up of project partners' Early Warning Systems (EWS) across the Interreg Italy–Croatia Programme Area, with particular relevance for coastal flooding and compound coastal events. The report adopts a strictly diagnostic perspective: it identifies limitations, inconsistencies, and insufficiently specified elements that may affect EWS effectiveness, comparability, and cross-border coherence. It does not propose solutions or recommendations; these are addressed in Deliverable D.1.2.2 (*Joint analysis of improvement areas*).

The analysis is based on partner questionnaire inputs and on the consolidated WP1 evidence base, applying an evidence-bound approach: where elements are not consistently documented in the available dataset, this is reported transparently as a **missing element**, rather than inferred. Findings are synthesised thematically to highlight recurring and cross-cutting issues, with special attention to interfaces along the end-to-end warning workflow (technical assessment, governance authorization, dissemination, operational activation, public warning).

Across the Programme Area, core EWS functions are present; however, the gap assessment indicates that weaknesses and missing elements concentrate in the following areas:

- Technical and data interoperability: heterogeneous platforms and territorially specific architectures, with limited systematic visibility of stable system-to-system interfaces for routine cross-border exchange. Common conventions for minimum interoperability datasets and metadata (e.g., time references, warning zones, version identifiers) are not consistently evidenced.
- Warning semantics and procedures: warning levels are widely used but not uniformly comparable in operational meaning; explicit crosswalks between warning levels and expected actions/activation posture are not consistently specified. Alert lifecycle management (updates, escalation/downgrade, cancellation/stand-down) is not uniformly documented in a benchmarkable way.
- Governance and decision-making: uneven comparability and specification of decision rights, sign-off pathways, delegation/substitution rules, escalation triggers and activation matrices, and traceability mechanisms (decision logging, versioning, audit trail), which are critical under time pressure.
- Last-mile public warning and communication: fragmented last-mile arrangements, heterogeneous channel mixes and redundancy visibility, accessibility/inclusiveness measures not consistently specified, and limited visibility of structured public feedback mechanisms supporting learning.

- Monitoring/forecasting and real-time data: uneven monitoring density and real-time data availability, limited comparability of accuracy/timeliness indicators in available sources, and uneven visibility of operational thresholds and impact-based interpretation practices.
- Cross-border preparedness and coastal specificity: cross-border routines and shared situational awareness mechanisms are not consistently documented; systematic joint exercising is not uniformly evidenced. For coastal flooding, meteo-marine integration and minimum comparable operational outputs (variables, thresholds, alert areas, update frequency) are not consistently specified across territories.

The report also outlines the risk areas generated by these gaps, including potential asynchronous activation across neighbouring territories, fragmented shared situational awareness, misinterpretation of warning meaning across borders, inconsistent update/stand-down messaging, uneven public warning reach, and reduced learning capacity where feedback loops are weak.

Overall, D.1.2.1 establishes a structured baseline of "what is missing or misaligned" and highlights that EWS maturity differences are often interface-driven, especially along the alert lifecycle and at governance–communication handover points. The findings provide a traceable foundation for D.1.2.2, which will define and prioritise joint improvement areas to strengthen cross-border coherence and coastal flood preparedness across the Programme Area.

1. Introduction

1.1 Background

Early Warning Systems (EWS) are a cornerstone of disaster risk reduction, enabling authorities, emergency services and exposed communities to anticipate hazardous events and implement timely preparedness and response actions. In the Interreg Italy–Croatia Programme Area, coastal territories are increasingly exposed to complex and rapidly evolving hazards, including coastal flooding driven by storm surges, extreme precipitation, sea-state conditions, and compound events affecting both coastal and inland drainage systems. In such contexts, EWS effectiveness depends not only on forecasting and monitoring capabilities, but also on the clarity of decision-making chains, the consistency of alert classification and communication, and the reliability of institutional and public warning interfaces. The REALIST project contributes to strengthening preparedness and resilience across the Adriatic area by supporting a structured understanding of existing EWS, their governance arrangements, and their capacity to enable coordinated action. A core added value of the Programme lies in the cross-border dimension: neighbouring territories may be impacted by the same meteorological and marine drivers, yet operate under different institutional mandates, technical configurations of instruments, protocols and platforms, as well as public warning practices. This creates a need to identify where system differences represent legitimate territorial specificities and where they constitute gaps or missing elements that may reduce comparability, interoperability, and operational coherence.

1.2 Objectives and scope of this report

This deliverable (D.1.2.1) provides an evidence-based analysis of gaps and missing elements in the current set-up of project partners' Early Warning Systems. The report adopts a diagnostic perspective and focuses on identifying limitations, inconsistencies, and insufficiently specified elements that may affect:

- cross-border interoperability and information exchange;
- procedural and semantic consistency of warning levels and alert lifecycle management;
- governance clarity (decision rights, authorisation pathways, escalation, update and stand-down);
- last-mile public warning responsibilities and communication practices;
- monitoring coverage, real-time data availability, and operational timeliness.

Importantly, this report does not define solutions, recommendations, or improvement measures. Those elements will be addressed in the subsequent deliverable "D.1.2.2 – Joint

analysis of improvement areas". The purpose of D.1.2.1 is to establish a structured and traceable diagnostic baseline of "what is missing or misaligned", creating a solid foundation for the joint identification and prioritisation of improvement areas in the next project step.

1.3 Link with previous mapping and governance deliverables

The present analysis builds directly on the methodological and evidence base developed in the previous WP1 mapping deliverables.

First, the "D1.1.1 - Mapping report on existing EWS" provided a structured "as-is" overview of operational EWS, related policies, core functional features, communication fluxes, and an inventory of instruments and IT platforms across the Programme Area. The mapping was intentionally descriptive and evidence-based, applying explicit interpretation rules and avoiding assumptions where information was not available.

Second, the "D1.1.2 - Mapping of the governance and decision-making structures activated during an EWS alert" established a comparable baseline of alert-related governance, focusing on decisional architectures, roles and responsibilities, and the alert lifecycle from detection through validation, classification, authorisation, dissemination, activation/escalation, updates, and stand-down. It introduced a shared functional reference model (a "chain of command" approach) to support comparability across different national and regional institutional contexts, and highlighted interoperability-relevant touchpoints in decision-making and public warning interfaces.

In addition, the project methodology underpinning data collection and comparative analysis was designed to ensure consistency across partner regions through structured questionnaires, validation, and thematic synthesis.

By capitalising on these baselines, D.1.2.1 moves from mapping ("what exists") to diagnosis ("what is missing or inconsistent"), maintaining methodological continuity while focusing specifically on gaps and missing elements that may affect EWS effectiveness and cross-border coherence in the Adriatic area.

2. Methodology

In this chapter, the methodology used to carry out the analysis, data sources and limitation is provided, following the same set-up od D.1.1.1 deliverable.

2.1 Analytical framework and guiding principles

This deliverable applies a structured analytical framework designed to ensure consistency and comparability across partner territories in the Interreg Italy–Croatia Programme Area. The methodology builds on the project-wide approach for data collection and comparative analysis of Early Warning Systems (EWS), which combines qualitative and quantitative elements and is based on structured partner self-assessment questionnaires, as complemented by validation and thematic synthesis provided by deliverables D.1.1.1 and D.1.1.2. The purpose of the methodology in D.1.2.1 is to move from baseline mapping to a diagnostic assessment of gaps and missing elements. The analysis is guided by the following principles:

- Evidence-based reporting: gaps are identified only where supported by partner inputs and/or consolidated evidence from the mapping phase; assumptions are avoided.
- Comparability across heterogeneous contexts: national and regional differences are treated as system features; gaps are identified where differences reduce interoperability, comparability, or operational coherence.
- Separation of diagnosis from prescription: this deliverable identifies gaps and missing elements but does not formulate improvement measures, which are addressed in D.1.2.2.

2.2 Data sources and collection process

The primary data source for this gap analysis consists of partner responses to the standardized EWS questionnaire distributed within WP1. As stated in D.1.1., partners completed the questionnaire directly and/or in coordination with competent authorities and operational stakeholders (e.g., civil protection/emergency management authorities, meteorological and hydrological services, responder organisations). To ensure coherence with the established project baseline, this deliverable also capitalises on the structured outcomes of previous WP1 mapping reports:

- D1.1.1**,** which provided an “as-is” mapping of EWS operational features, tools/platforms, and communication fluxes, explicitly documenting where information was not specified in available sources.

- D1.1.2**,** which mapped governance and decision-making structures activated during an EWS alert, adopting a functional "chain of command" model across the alert lifecycle and highlighting interoperability-relevant governance touchpoints.

These deliverables provide a consolidated baseline that supports traceable identification of gaps without duplicating mapping content.

2.3 Validation and reliability approach

In line with the project methodology, collected inputs were subject to screening and consistency checks to support reliability and cross-territory comparability.
Where the available dataset does not provide sufficient detail to confirm a specific element (e.g., formal approval steps for public message updates, or explicit termination/versioning rules), the analysis records this transparently as a *missing element / insufficiently specified element*, rather than inferring practices from other territories.
This approach reflects the evidence-based reporting principles applied in the mapping phase, including explicit interpretation rules aimed at avoiding assumptions and preserving traceability.

2.4 Comparative analysis approach and gap identification steps

The gap analysis follows a thematic and comparative approach, designed to identify patterns across partner territories while retaining the ability to distinguish systemic gaps from context-specific limitations. The analysis proceeded through four steps (fig. 2.4.1):

1. Baseline review: examination of partner questionnaires and consolidated mapping outputs to characterise the current EWS setup across the Programme Area, including technical features, governance arrangements, and communication flows.
2. Thematic clustering: grouping observations into a limited set of analytical dimensions aligned with WP1 objectives and the structure of the questionnaires. Core dimensions include:
    - technical and data interoperability;
    - warning classification and semantics;
    - governance and decision-making (including alert lifecycle management);
    - last-mile public warning and communication;
    - monitoring/forecasting capacity and real-time data availability;
    - cross-border coordination and operational preparedness.
3. Gap and missing-element identification: within each dimension, identification of:

- gaps, understood as limitations or discontinuities that may reduce effectiveness, interoperability, or operational coherence; and
- missing elements, understood as components that are absent, unevenly implemented, or not consistently specified/documented across partner territories in a way that limits comparability and benchmarking.

4. Impact-oriented interpretation (non-prescriptive): description of how the identified gaps may affect operational readiness, coordination, decision-making clarity, and cross-border coherence, without proposing solutions or improvements. This step supports the subsequent transition to D.1.2.2, while maintaining the diagnostic scope of D.1.2.1.

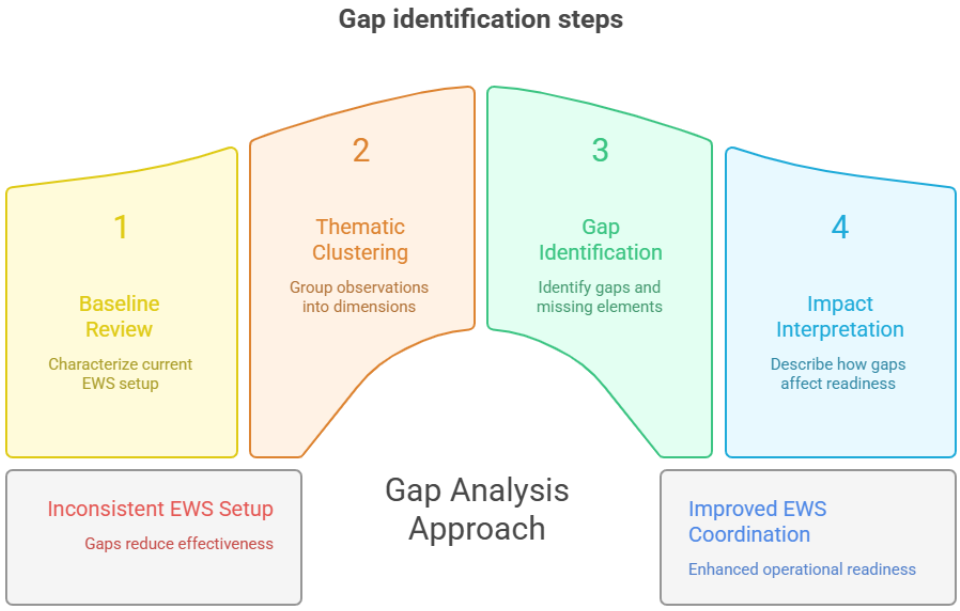

Figure 2.4.1: schematic overview of methodological steps uses for identifying EWS gaps.

2.5 Use of a functional governance reference model

For governance-related gaps, the analysis leverages the functional "chain of command" model introduced in the governance mapping deliverable, which describes the alert lifecycle through comparable decision points (cfr. Par. 4.1 of D.1.1.2: detection, validation, classification, authorisation, dissemination, activation/escalation, update, stand-down).

Using this functional reference enables identification of governance gaps without forcing equivalence between different institutional labels. In practice, governance gaps are identified where decision rights, delegation rules, escalation triggers, update/termination authority, or public warning interfaces are unclear, inconsistently documented, or unevenly implemented across territories.

2.6 Scope and limitations

This deliverable reflects the information available through partner self-assessments and consolidated mapping outputs within the project timeframe. While the structured questionnaire approach supports comparability, the analysis is subject to the following limitations:

- Variability in mandates and visibility: not all partners are competent authorities issuing alerts; some contribute as responders, support organisations, research bodies, or coordination entities. This may affect the level of detail available for certain governance and operational elements.
- Differences in reporting granularity: partner inputs vary in completeness, particularly regarding procedural details (e.g., timelines, versioning rules, formal stand-down procedures) and public warning authorisation chains.
- No performance benchmarking: the analysis does not assess quantitative system performance beyond what is necessary to interpret the presence of gaps and missing elements within the available evidence base.

Despite these limitations, the methodology provides a robust basis for a comparative and traceable diagnostic assessment, producing a structured gap baseline to inform the subsequent joint analysis of improvement areas in D.1.2.2.

3. Overview of existing early warning systems and governance maturity

This chapter provides a concise overview of the current Early Warning System (EWS) landscape across the Programme Area, as a contextual baseline for the gap analysis presented in Chapter 4. This analysis has been performed in D.1.1.1 and D.1.2., therefore, only a synthesis of the main structural characteristics emerging from partner inputs and from the previous WP1 mapping deliverables, which document "what exists" (EWS features, tools, and communication fluxes) and "how decisions are taken" (governance and chain-of-command structures activated during an alert) is reported.

3.1 General characteristics of EWS across the Programme Area

Across the Programme Area, EWS operate within multi-level civil protection ecosystems that combine technical monitoring and forecasting functions with governance arrangements responsible for authorisation, dissemination, and operational activation. Overall, partner inputs confirm that EWS implementation commonly relies on: i) meteorological and hydrological information services; ii) structured alert classification practices (often colour-coded); iii) institutional dissemination chains connecting technical bodies to civil protection operational structures and municipalities; and iv) a mix of communication channels for institutional recipients and public visibility. The degree of detail and maturity described varies across territories, reflecting differences in mandates, institutional roles, and reporting visibility.

A recurring feature is that partners do not all occupy the same position in the EWS chain. Some partners act as competent or coordinating authorities (or operate in direct connection with them), while others contribute primarily through operational response roles, support functions, research, or coordination interfaces. This plurality is a structural characteristic of the Programme Area EWS ecosystem and is reflected in the mapping outputs.

At a system level, a functional EWS backbone can be observed across both countries, typically including: detection and monitoring, technical assessment and validation, alert classification, formal authorisation and issuance, dissemination to institutions, activation of coordination structures and response actors, and alert lifecycle management through updates and termination/stand-down practices where described.

3.2 Governance and decision-making maturity: a functional view

To enable comparability across different institutional contexts, the governance mapping established a shared functional model of the alert "chain of command", recognising that institutional labels differ while core governance functions remain identifiable. The model

structures alert management through key functional steps (from detection and validation through classification, authorisation, dissemination, activation/escalation, and alert updates/termination). This approach supports a maturity-oriented interpretation focused on decision points and handovers, rather than on organisational names alone.

3.2.1 Italy: national framework with regional operationalisation

Within the Italian partner territories, the mapped governance patterns show a system anchored in national civil protection principles and operationalised at regional level. Technical functions (monitoring, forecasting, and alert classification) are typically positioned within Regional Functional Centres, in some cases supported by equivalent technical bodies, while regional civil protection structures coordinate governance decisions and institutional dissemination. Municipal authorities play a central role in local implementation and last-mile measures, consistent with a decentralised operational posture where municipalities translate alerts into locally relevant actions and public guidance. The mapping also indicates the presence of designated regional operational rooms and coordination structures activated during alert phases. These hubs facilitate multi-agency coordination, information flow, and escalation interfaces (including, where applicable, prefecture-led structures for severe or wider-scale events). At the same time, activation logic and level-by-level governance detail vary in visibility across partners, reflecting differences in reported granularity rather than necessarily indicating differences in operational capability.

3.2.2 Croatia: national mandate with structured operationalisation

Within the Croatian partner territories, the governance mapping reflects a highly consistent multi-level architecture where nationally anchored technical warning sources (notably DHMZ and Croatian Waters, as described in partner inputs) provide hazard warnings that are operationalised through civil protection coordination structures and the 112 system. The mapping highlights the role of the National 112 Operations Center together with Regional 112 Centres as operational hubs for multi-hazard monitoring and alert coordination, interfacing with county and municipal/city civil protection headquarters and responder organisations.

This governance architecture is characterised by clear operationalisation pathways linking national technical warnings to territorial activation. County-level headquarters, municipal/city structures, and (where described) operational-communication centres support coordination continuity during alert situations. Public warning is implemented through a combination of nationally supported dissemination mechanisms and local channels, with local authorities contributing to last-mile guidance in line with territorial plans and operational practice.

3.2.3 Cross-cutting governance maturity considerations

Across the Programme Area, the governance mapping suggests that differences in EWS governance are less about the presence of core functions and more about how decision rights and responsibilities are distributed and how handovers are formalised. In particular, the transition points between technical assessment and authorisation, authorisation and dissemination, and dissemination and activation/escalation represent critical governance interfaces. The clarity and traceability of alert updates and termination/stand-down decisions also emerge as a relevant dimension of governance maturity, as it affects coherence of institutional notifications and public-facing messaging over time.

3.3 Cross-border cooperation baseline and interoperability context

The mapping deliverables confirm that EWS operation in the Programme Area is primarily organised within national and regional governance frameworks. Cross-border cooperation exists in practice through a combination of EU-level services, informal exchanges, and project-based collaboration, alongside national coordination mechanisms. The mapping captured references to EU principles and frameworks relevant for civil protection and risk governance (including EU-level services and broader policy alignment), contributing to a shared baseline context for cooperation across the Adriatic area.

From an operational perspective, partner inputs and mapping outputs indicate that shared situational awareness and information exchange may occur through a diverse set of channels, including official portals, institutional messaging pathways, and, where applicable, interfaces to EU platforms and services. The mapping phase also documented that architectures and toolsets are territorially specific but broadly convergent by function (monitoring and forecasting, situational awareness, alert publication and routing), providing a baseline for comparative interpretation without implying uniformity.

At the governance level, the cross-cutting comparison identifies interoperability-relevant touchpoints likely to matter for cross-border coordination, including: synchronisation and versioning of warning updates, clarity on who authorises public-facing messages (including updates and stand-down), and alignment of roles and handovers between institutional notifications and local public warning. These touchpoints provide the governance context for the gaps identified in Chapter 4, particularly where differences in alert lifecycle management and public warning interfaces may affect coherence across borders during shared hazard scenarios.

4. Identified gaps and missing elements

This chapter presents the main gaps and missing elements identified across the Programme Area, based on partner questionnaire inputs and the consolidated evidence base established through the WP1 mapping deliverables. The analysis is structured into thematic dimensions aligned with the project's comparative framework, with particular attention to cross-border interoperability and operational coherence. In line with the evidence-based approach adopted in previous deliverables, where specific elements are not consistently documented in the available dataset, this is reported transparently as a missing element (i.e., "not consistently specified in available sources"), rather than inferred. Identified gaps starts from final considerations given in Chapater 7 of D.1.1.1 and Chapter 8 of D.1.1.2

4.1 Technical and data interoperability gaps

A recurring gap emerging from the comparative review concerns the limited visibility and consistency of technical interoperability arrangements across territories. While partners report a broad functional convergence (monitoring/forecasting tools, situational awareness dashboards, official portals, and institutional dissemination mechanisms), the underlying architectures are territorially specific and often operate in parallel. The mapping baseline already documented the presence of heterogeneous platform landscapes and highlighted that interoperability at Programme Area scale depends on the existence of common data/metadata conventions and exchange interfaces, which are not systematically evidenced in the available sources.

G1.1 - Parallel tools and heterogeneous IT architectures

The Programme Area features multiple portals, webGIS solutions, databases, and operational dashboards, reflecting national and regional institutional arrangements. This diversity is not, in itself, a weakness; however, it becomes an interoperability gap where cross-territory exchange requires manual conversions, non-standardised formats, or ad hoc procedures. The mapping phase explicitly noted limited visibility on how monitoring/forecasting tools, decision-support functions, and dissemination tools are integrated (or whether workflows rely on manual transfer).

G1.2 - Limited evidence of stable system-to-system interfaces

Available sources provide limited systematic documentation of permanent, operational "system-to-system" interfaces enabling real-time cross-border exchange of warning-relevant datasets (e.g., common situation reporting templates, shared dashboards, or automated bulletin exchange routines). Where cross-border exchange occurs, it is not consistently

described as being embedded in daily operational workflows across partners, limiting the ability to assess interoperability maturity at baseline level.

G1.3 - Missing elements: minimum interoperability dataset and metadata conventions

For Programme Area benchmarking and cross-border coordination, a minimum comparable dataset is necessary (e.g., alert zone references, timing conventions, update/version markers, hazard descriptors, and minimum content requirements for bulletins/messages). The mapping deliverable explicitly introduced the concept of minimum comparable datasets (for reporting consistency), but the available evidence base does not demonstrate that an agreed minimum cross-border interoperability dataset is operationally institutionalised across all . Overall, the technical interoperability gap is best characterised not as an absence of tools, but as a lack of consistently evidenced interface arrangements and shared conventions that would allow territorial platforms to operate as part of a cohesive cross-border information ecosystem.

4.2 Procedural and semantic gaps in warning management

Beyond technical exchange, interoperability depends on shared understanding of warning meaning and on comparable handling of warning lifecycle steps (issue, update, downgrade/escalation, termination). The analysis identifies gaps related to the semantic and procedural comparability of warning levels and alert management.

G2.1 - Variability in warning levels and operational interpretation

The mapping baseline confirms that colour-coded warning levels are widely used across the Programme Area, but operational meaning is not consistently comparable across territories. Even where labels appear similar, the underlying triggers, governance implications, and activated measures may differ. The mapping addressed this by proposing pragmatic terminology bridges for functional comparability; however, the presence of bridging constructs itself highlights a gap: common labels do not guarantee shared semantics in cross-border contexts.

G2.2 - Missing elements: explicit crosswalks between “level” and “actions”

While many systems clearly rely on alert levels to trigger operational phases or activation postures, the dataset does not consistently document a cross-territory functional crosswalk linking warning levels to expected preparedness actions and governance activations. This missing element limits the ability to compare “what a warning implies” across borders and therefore reduces semantic interoperability during joint risk scenarios.

G2.3 - Update and termination logic not consistently specified

A recurring missing element concerns the lifecycle management of warnings: how alerts are formally updated (including versioning), downgraded, cancelled, or terminated ("all clear"), and how these steps are communicated institutionally and publicly. The mapping report on existing EWS explicitly flagged update/downgrade/termination logic as not consistently described in available sources, and the governance mapping further reinforced the importance of the Alert/Update/Cancel lifecycle as a governance-sensitive dimension.

G2.4 - Time expectations and responsiveness markers rarely documented

Several systems operate structured cycles and duty arrangements; however, the mapping phase noted that target timelines (e.g., expected time from detection/validation to dissemination) are rarely specified in a benchmarkable way, limiting comparative assessment of responsiveness based on the available dataset. This represents a missing element for Programme Area benchmarking and for understanding cross-border synchronisation challenges in fast-evolving hazards.

In summary, procedural and semantic gaps reflect differences (and incomplete visibility) in how warning levels are interpreted and how warning lifecycle steps are governed, documented, and communicated—factors that may affect coherence during transboundary events.

4.3 Governance and decision-making gaps

Governance arrangements and decision rights distribution are central determinants of operational effectiveness, particularly under time pressure. The governance mapping deliverable established a shared functional "chain of command" model and identified recurring ambiguities that directly inform the present gap analysis.

G3.1 - Gaps in decision rights and sign-off clarity

Across territories, core governance functions are identifiable; however, the documentation of decision rights is not uniformly complete. The governance mapping explicitly flagged that sign-off procedures (who formally authorises issuance, escalation/downgrade, updates, and stand-down) are not always specified in a comparable way across partners. Where decision authority involves multiple bodies or co-signature practices, the extent to which approval chains are formalised and time-efficient is not consistently evidenced in the available sources.

G3.2 - Limited documentation of delegation, substitution, and replacement rules

Under operational stress, continuity of decision-making depends on clear delegation and replacement arrangements. The governance mapping identifies limited documentation of delegation and replacement rules as a recurring missing element, reducing confidence in the comparability of governance robustness across territories based solely on available sources.

G3.3 - Escalation and activation triggers not consistently formalised

Many territories activate coordination structures (operational rooms/centres, crisis units, municipal centres) based on severity levels or situational judgement. However, escalation triggers and activation-by-level matrices are not uniformly described across partners. The governance mapping highlights variability in completeness of activation matrices and escalation rules, which creates comparability limitations and may represent friction points for cross-border coordination if neighbouring territories adopt different escalation timing and decision thresholds.

G3.4 - Incomplete decision logging, versioning, and audit trail practices

Traceability supports accountability and learning and is also relevant for cross-border coherence (e.g., ensuring that the same "version" of an alert is being referenced across jurisdictions). The governance deliverable explicitly notes incomplete decision logging/versioning/audit trail practices as a recurring gap in available sources. This affects both governance comparability and the ability to benchmark lifecycle management maturity.

G3.5 - Missing elements: public warning message approval chains (including updates and cancellations)

The governance mapping emphasises that public warning is managed through a message lifecycle (Alert/Update/Cancel/Stand-down) and that clarity on who approves public-facing content—including updated and cancellation messages—is critical to avoid contradictory messaging. The available dataset does not consistently document these approval pathways across territories, representing a key missing element for assessing governance clarity in public communication.

Overall, governance gaps are not primarily about absence of governance structures, but about incomplete comparability and uneven documentation of decision rights, escalation rules, lifecycle management, and traceability mechanisms—elements that matter for coordinated action and cross-border interoperability.

4.4 Last-mile public warning and communication gaps

Communication to the public is a major determinant of EWS effectiveness. The mapping of existing EWS documented that institutional dissemination chains are generally well described, while last-mile public warning arrangements are the main source of variability.

G4.1 - Fragmented last-mile arrangements and heterogeneous channel mixes

Across territories, last-mile public warning is frequently implemented through municipal/local practices, often combining websites, social media, local apps, sirens or loudspeakers (where available), and field-based communication supported by responders or volunteers. This

structure supports local adaptation but creates variability in reach, redundancy, and message consistency across neighbouring municipalities affected by the same event. The mapping phase flagged fragmented last-mile arrangements as a recurring communication gap cluster.

G4.2 - Uneven redundancy of public warning channels and maturity of mobile-based alerting

The mapping inventory confirms that multiple channels exist, but the dataset does not consistently evidence minimum redundancy arrangements or channel-by-level rules (e.g., which channels must be used at higher severity). Mobile-based public alerting maturity is described as uneven across contexts. This does not imply that territories lack public communication capacity; rather, it indicates that common minimum practices for redundancy and mass-reach dissemination are not consistently documented at Programme Area level.

G4.3 - Accessibility and inclusiveness not consistently specified.

Only some partner inputs explicitly reference accessibility measures or tailored outreach for vulnerable groups. For other territories, the mapping cannot confirm whether accessible formats, multilingual options, or alternative channels are routinely applied. This constitutes a missing element from a people-centred warning perspective and limits benchmarking of inclusiveness using available sources.

G4.4 - Weak or inconsistent feedback mechanisms.

The evidence base provides limited systematic visibility on whether structured mechanisms exist to collect public feedback after alert activation (message clarity, behavioural response, channel reach). Where feedback processes are not specified, learning loops may remain informal or dependent on local practices, limiting comparability and continuous improvement visibility across partners.

In summary, last-mile gaps are characterised by variability in responsibilities, channel mixes, redundancy visibility, and inclusiveness, and by limited systematic evidence on feedback loops, rather than by an absence of communication channels.

4.5 Monitoring, forecasting, and real-time data gaps

Monitoring and forecasting provide the technical foundation of warnings. The mapping baseline confirms that partners rely on observation networks, modelling outputs, and operational workflows for monitoring, validation, and alert issuance. At the same time, gaps and missing elements emerge regarding comparability of monitoring coverage, data availability, and performance visibility.

G5.1 - Uneven monitoring density and real-time data availability

Partner inputs describe a range of monitoring assets (telemetry, radar/satellite products, model outputs), but sensor density and coverage are not uniform across the Programme Area. The mapping deliverable noted that some partners provided limited detail or have restricted visibility due to institutional role, affecting completeness of reported information. As a result, real-time data availability and coverage limitations—particularly relevant for geographically remote areas—are not consistently benchmarkable based on available sources.

G5.2 - Limited comparability of accuracy/timeliness indicators in available sources

The mapping is intentionally baseline-oriented and does not evaluate technical performance beyond what is necessary to interpret system characteristics. Consequently, while the dataset supports identification of "what exists," it does not provide a consistent set of quantitative indicators to compare forecast accuracy, lead times, or warning dissemination speed across territories. This is not a deficiency of EWS operation per se, but a limitation/missing element for Programme Area benchmarking using the current evidence base.

G5.3 - Missing elements: explicit operational thresholds and impact-based interpretation visibility

EWS commonly combine threshold-based logic with expert judgement, including consideration of antecedent conditions and local exposure factors. However, the level of detail provided on threshold logic and impact-based interpretation is uneven across partner inputs, limiting the comparability of how forecasts translate into warning decisions across territories.

Overall, monitoring/forecasting gaps are primarily expressed as uneven coverage and limited performance comparability using available sources, rather than as an absence of forecasting capability.

4.6 Cross-border cooperation and operational preparedness gaps

A core rationale for WP1 is to support a more cohesive and interoperable EWS landscape across the Adriatic area. The mapping baseline confirms that EWS are primarily organised within national/regional governance systems. Cross-border cooperation exists, but the available evidence does not systematically document stable, operationalised cross-border protocols.

G6.1 - Cross-border protocols and routines not consistently specified

The mapping report on existing EWS flagged that cross-border protocols are not consistently described in partner inputs and that most alerting and public warning processes are presented as nationally/regionally organised. Similarly, the governance mapping highlights that interoperability-relevant touchpoints (handover points, update/version synchronisation,

public warning approval chains) are critical but not uniformly documented in a cross-border frame.

G6.2 - Shared situational awareness mechanisms not systematically evidenced
The available dataset provides limited consistent evidence of shared cross-border dashboards, common situation reporting templates, or formal routines for exchanging and aligning warning updates between neighbouring territories. This represents a missing element for structured cross-border coordination under time pressure, particularly during hazards that evolve across the Adriatic area.

G6.3 - Joint exercises and operational testing not systematically described

While exercises and simulations are widely recognised as important for preparedness, the evidence base does not consistently document systematic joint cross-border exercising. The governance mapping emphasises the importance of testing the full alert lifecycle (including updates and stand-down) and identifies incomplete documentation of lifecycle governance as a comparability gap that can also affect operational testing visibility.

In summary, cross-border preparedness gaps concern the limited evidence of institutionalised protocols, shared situational awareness routines, and systematic joint operational testing, rather than the absence of any cooperation.

4.7 Coastal flood–specific gaps (storm surge and compound coastal events)

Given the focus on coastal flooding within the REALIST scope, the analysis also considers the extent to which coastal/marine components are explicitly embedded within EWS operational chains across the Programme Area.

G7.1 - Uneven integration of marine/coastal components within EWS operational cycles
The mapping baseline demonstrates that EWS commonly integrate meteorological and hydrological information; however, the explicit inclusion of meteo-marine elements (sea state, storm surge, coastal impacts) is not uniformly described across partner inputs at a level sufficient for structured comparison. This does not indicate that coastal hazards are ignored; rather, it represents a missing element in terms of consistently documented baselines for coastal flood warning production, thresholds, and operational outputs across the Programme Area.

G7.2 - Missing elements: common minimum operational outputs for coastal flooding
For cross-border comparability, coastal flooding would benefit (at baseline description level) from consistent documentation of: monitored variables, warning thresholds, territorial delineation of coastal alert areas, typical update frequency, and linkage to operational

phases/actions. The evidence base does not show that such a minimum shared description is consistently available across all partners, limiting the ability to assess coastal-flood-specific interoperability using the current dataset.

G7.3 - Alert lifecycle coherence for coastal events

Coastal flooding events may evolve quickly and may require multiple updates or rapid stand-down decisions. As described in Sections 4.2 and 4.3, update/termination/versioning practices are not consistently specified in available sources, which is particularly relevant for coastal hazards where timing and message coherence are critical.

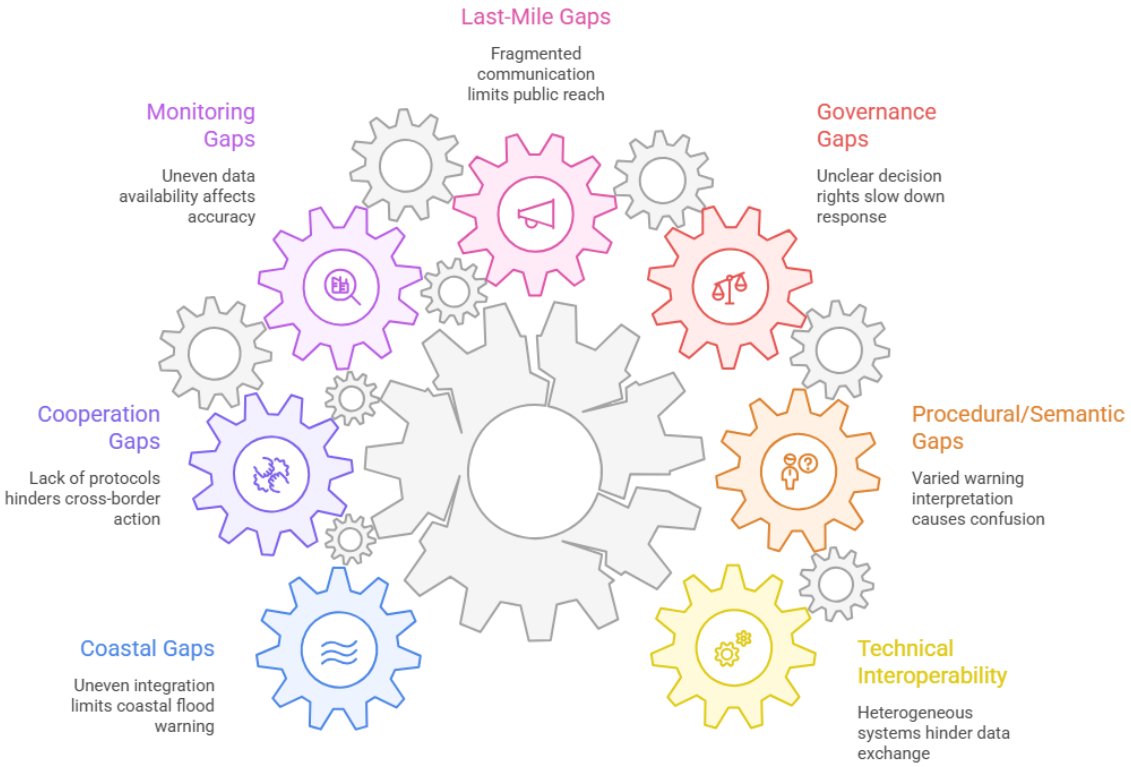

Figure 4.1: resume of identified gaps

5. Risk areas generated by the identified gaps

This chapter outlines the main risk areas generated by the gaps and missing elements identified in Chapter 4. The purpose is not to provide a hazard risk assessment for the Programme Area, but to describe how specific systemic limitations may translate into operational risks during EWS activation and emergency management, particularly in cross-border scenarios and in fast-evolving coastal flood events. In line with the diagnostic scope of D.1.2.1, the discussion focuses on potential impacts arising from identified gaps, without proposing improvement measures (addressed separately in D.1.2.2).

5.1 Risks to operational coordination and decision-making

R A.1 - Asynchronous decision-making and activation across territories

Where alert levels, escalation triggers, or governance handovers are not comparable or not consistently specified, neighbouring territories may reach different activation postures at different times for the same evolving hazard driver. The governance mapping emphasises that core functions are present across contexts but that differences in decision rights distribution and escalation practices can reduce comparability and create friction points for coordination. In practice, this may generate asynchronous activation of coordination structures, uneven readiness levels across adjacent coastal areas, and reduced capacity to align protective actions in transboundary contexts.

R A.2 - Bottlenecks in authorisation and update decisions under time pressure

If multi-step sign-off pathways exist or if delegation/replacement rules are not clearly documented, decision-making continuity may be challenged during rapidly evolving events. In coastal flooding, where warning messages may require frequent updates, governance ambiguity regarding who can approve escalations/downgrades, updates, and stand-down decisions can affect response timing and the coherence of operational posture over time.

R A.3 - Reduced traceability and accountability during complex alert lifecycles

Incomplete decision logging, versioning, and audit trail practices (where not consistently evidenced) can reduce traceability of what decisions were made, when, and on what basis. The governance mapping identifies these elements as recurring gaps in available sources. This creates an operational risk during multi-agency coordination, as different actors may reference different versions of warning information, and it reduces the quality of after-action learning and institutional memory.

5.2 Risks to information exchange and situational awareness

R B.1 - Fragmented situational awareness due to limited interoperability visibility

Where platform ecosystems are heterogeneous and stable system-to-system interfaces are not consistently evidenced, cross-territory situational awareness may depend on ad hoc exchanges, manual conversions, or external platforms rather than on embedded operational routines. The mapping report on existing EWS documented parallel tool landscapes and highlighted limited visibility on integration and interface arrangements in available sources. During a shared coastal event, this may translate into partial or delayed visibility of evolving conditions and protective actions taken across the border, reducing the ability to coordinate escalation and resource mobilisation.

R B.2 - Misinterpretation of warning meaning across borders

Semantic interoperability risks arise where warning levels, terminology, and operational interpretation differ between territories. The governance mapping introduced a terminology bridge precisely because equivalence between labels cannot be assumed. In cross-border settings, this may lead to misinterpretation of severity, expected impacts, and activation implications, particularly when warnings circulate informally across boundaries or through media reporting.

R B.3 - Limited comparability of coastal flood warning baselines

For coastal flooding, coherent situational awareness requires comparable use of marine and coastal variables (e.g., sea state, storm surge drivers) and consistent warning outputs. Where the explicit integration of coastal/marine components is not uniformly documented at Programme Area level, the baseline for shared understanding may be uneven, increasing uncertainty during compound coastal events.

5.3 Risks to public warning effectiveness and community response

R C.1 - Uneven public warning reach and redundancy

Last-mile communication models vary across territories and frequently depend on municipal capacity and channel mixes. The mapping baseline identified significant variability in last-mile arrangements and limited systematic visibility of minimum common practices across the Programme Area. During high-impact coastal events, this variability may lead to unequal reach of warnings and uneven redundancy of communication channels, increasing the probability that certain population segments do not receive timely and actionable information.

R C.2 - Inconsistent message coherence over the alert lifecycle (Alert/Update/Cancel)

Public warning is not limited to initial issuance; it includes updates, downgrades/escalations, and cancellations/stand-down. The governance mapping highlights that clarity on who authorises public-facing messages—especially for updates and cancellation messages—is critical to avoid contradictory messaging. Where these pathways are not consistently specified in available sources, there is a risk that institutional notifications and public-facing communication become misaligned, particularly when information evolves rapidly.

R C.3 - Reduced learning capacity due to limited feedback mechanisms

Where structured feedback loops are not specified or are unevenly implemented, authorities may have limited visibility on message comprehension, behavioural response, and channel effectiveness. The mapping methodology is baseline-oriented and does not systematically capture performance indicators; therefore, absent feedback mechanisms constitute a risk to sustained effectiveness because learning remains informal, localised, or inconsistent across territories.

5.4 Risks to cross-border operational preparedness

R D.1 - Reduced preparedness due to limited institutionalisation of cross-border routines

The mapping and governance deliverables provide limited consistent evidence of formalised cross-border protocols, shared situation reporting routines, or systematically documented joint exercising. In practice, this may reduce collective preparedness for transboundary coastal flood scenarios, where coordinated timing of warnings, aligned operational posture, and synchronized public messaging are essential for effective response.

R D.2 - Divergent escalation timing and coordination handovers

Differences in escalation rules, activation-by-level matrices, and the completeness of documented governance handovers may result in divergent escalation timing between territories. This creates a risk of "coordination mismatch," where one territory escalates early while another remains in a lower activation posture, complicating mutual aid discussions, shared situational awareness, and cross-border communication.

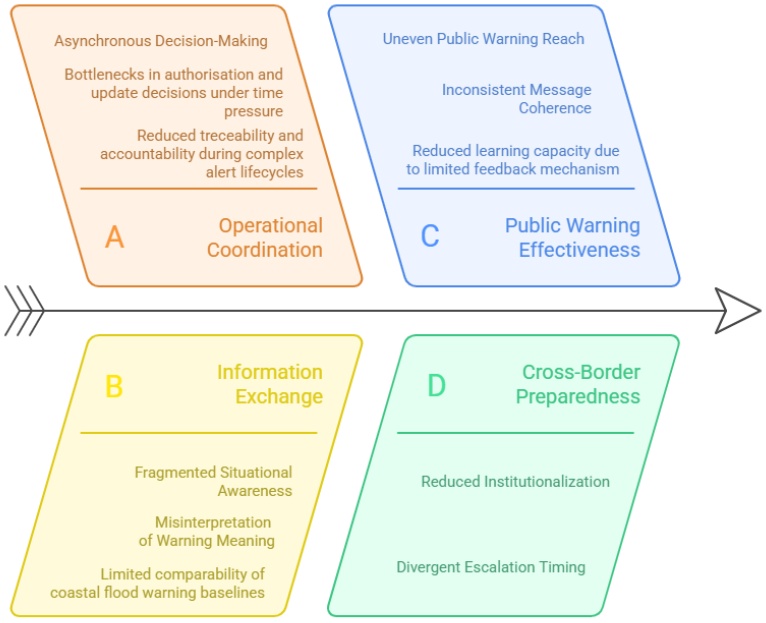

Figure 5.1: risk areas identification

6. Cross-cutting observations

This chapter provides cross-cutting observations that emerge from the gap analysis, with the aim of supporting interpretation of the findings presented in Chapters 4 and 5. The focus is on how gaps interact across dimensions and how differences in EWS maturity and documentation affect comparability and interoperability across the Programme Area. In line with the diagnostic scope of D.1.2.1, this chapter does not define improvement measures; it clarifies patterns and interdependencies that shape the overall risk profile generated by the identified gaps.

6.1 Systemic gaps versus context-specific gaps

A first cross-cutting observation concerns the distinction between systemic gaps (recurring across multiple territories) and context-specific gaps (linked to local governance arrangements, institutional mandates, or territorial characteristics). The evidence base confirms that core EWS functions are present across the Programme Area, but that gaps are often concentrated at the interfaces—particularly where information must move between technical assessment, governance authorisation, operational activation, and public communication. Systemic gaps tend to cluster in the following areas:

- interoperability-related missing elements (shared conventions, interface visibility, minimum comparable datasets);
- semantic and procedural comparability of warning levels and alert lifecycle management (updates, downgrades/escalation, cancellation/stand-down);
- last-mile public warning variability and uneven documentation of minimum practices.

Context-specific gaps, by contrast, often relate to how governance functions are distributed across levels (national–regional–local), which is a legitimate feature of institutional design. These are treated as gaps only where they reduce operational clarity or comparability in the available evidence base, particularly for cross-border coordination.

6.2 EWS maturity is often an "interface maturity" issue

Across the analysed territories, differences in maturity are not primarily driven by whether EWS exist or whether monitoring/forecasting functions are operational. Instead, maturity differences are most visible in the clarity and robustness of interfaces, including:

- how decision rights are documented and exercised over time (issue, update, termination);
- how institutional notifications and public warning responsibilities connect (message approval chains, versioning coherence);
- how coordination structures and escalation pathways are triggered and recorded;
- how platform ecosystems exchange data and situational information with minimal friction.

This indicates that EWS maturity in the Programme Area can be interpreted as "end-to-end workflow maturity," where the strength of the system is determined by the continuity and traceability of the full warning lifecycle rather than by the performance of any single component.

6.3 Documentation completeness is itself a comparability and governance factor

A recurring cross-cutting issue is that the evidence base varies in granularity and completeness across partners. The WP1 mapping approach is explicitly evidence-based and avoids assumptions where information is not available. Where important elements are not specified (e.g., delegation rules, formal update/stand-down procedures, message approval steps), this is treated as a missing element for comparability and governance benchmarking, even if the practice may exist operationally. This has two implications, i.e., from a benchmarking perspective, uneven documentation reduces the ability to compare governance robustness and lifecycle management across territories using a uniform dataset. Moreover, from an operational perspective, incomplete specification of certain governance elements

(particularly those affecting updates, stand-down, and public warning authorisation) may indicate potential ambiguity under time pressure and therefore can be treated as a governance-relevant gap unless clarified through documented procedures.

6.4 Interdependencies between technical, governance, and communication gaps

The analysis confirms strong interdependencies between technical/data dimensions, governance arrangements, and public warning practices. Several gaps cannot be interpreted in isolation, because their operational impact emerges from how they combine:

- Interoperability and semantics**:** even with strong technical data exchange, misaligned alert terminology and warning-level semantics can undermine shared understanding. Conversely, semantic alignment is constrained if data and outputs are not exchanged in comparable formats.
- Governance and last-mile warning**:** decentralised last-mile communication models can be effective, but only if decision rights and public message approval chains (including updates and cancellations) are clear and traceable. Missing governance specification can therefore amplify communication risks.
- Update/stand-down governance and situational awareness: effective response depends on synchronised updates and coherent termination practices. Where versioning and update rules are not consistently documented, situational awareness and public messaging coherence may diverge across actors and territories.

These interdependencies explain why gaps related to lifecycle management (updates, escalation/downgrade, stand-down) appear as high-leverage issues across multiple dimensions.

6.5 Cross-border relevance: interoperability hinges on lifecycle coherence

A final cross-cutting observation concerns the cross-border dimension. The mapping deliverables show that EWS governance is primarily organised within national/regional systems, with cross-border cooperation occurring through a combination of EU platforms, institutional channels, and project-based collaboration.

In this context, interoperability is not limited to exchanging initial warnings. The governance baseline highlights that cross-border coherence depends on aligned decision points and message lifecycle management (Alert/Update/Cancel), including clear roles for authorising public-facing messages and ensuring version coherence.

Where these lifecycle elements are incompletely specified or not comparable across territories, the risk of asynchronous activation and inconsistent public communication increases during shared Adriatic hazard scenarios (as discussed in Chapter 5).

Conclusions

This deliverable (D.1.2.1) provides a structured, evidence-based diagnosis of gaps and missing elements in the current set-up of project partners' Early Warning Systems (EWS) across the Interreg Italy–Croatia Programme Area. Building on the consolidated baselines established through the WP1 mapping deliverables on existing EWS features and on governance/decision-making structures activated during an alert, the report moves from "what exists" to "what is missing or inconsistently specified" in ways that may affect operational effectiveness, comparability, and cross-border coherence.

Overall, the analysis confirms that core EWS functions are present across the Programme Area and that operational warning management follows comparable functional steps (detection, validation, classification, authorisation, dissemination, activation/escalation, and alert lifecycle management). At the same time, the gap analysis identifies recurring limitations concentrated at system interfaces and at points requiring inter-institutional and cross-territory alignment.

Key gap clusters can be summarised as follows:

- **Technical and data interoperability gaps**, characterised by heterogeneous tool ecosystems, limited consistent evidence of stable system-to-system interfaces, and missing common conventions for minimum interoperability datasets and metadata required for cross-territory exchange and benchmarking.
- **Procedural and semantic gaps** affecting comparability of warning levels and the operational meaning of alerts, including limited visibility of cross-territory crosswalks between warning levels and expected actions, and incomplete specification of warning lifecycle management (updates, downgrades/escalation, cancellation/stand-down, versioning).
- **Governance and decision-making gaps**, primarily related to uneven documentation and comparability of decision rights, sign-off pathways, delegation/replacement rules, escalation triggers, and traceability mechanisms (decision logging, versioning, audit trail practices), which are particularly relevant under time pressure and during evolving events.
- **Last-mile public warning and communication gaps**, reflecting variability in responsibilities and channel mixes, limited systematic visibility of minimum redundancy and accessibility practices, and limited evidence of structured feedback mechanisms to support learning and continuous improvement visibility.
- **Cross-border preparedness gaps**, linked to limited consistent evidence of institutionalised cross-border routines, shared situational awareness practices, and systematic joint exercising of full alert lifecycles across the Programme Area.

- **Coastal flood–specific missing elements**, particularly the unevenly documented integration of meteo-marine components within EWS operational chains and the limited availability, at Programme Area level, of a consistently described minimum baseline for coastal flood warning variables, thresholds, and operational outputs.

The risk analysis in Chapter 5 highlights that these gaps can translate into practical operational risks, including asynchronous activation across neighbouring territories, reduced shared situational awareness, misinterpretation of warning meaning, uneven public warning reach, and reduced coherence of alert updates and stand-down messaging. These risks are especially relevant for rapidly evolving coastal flood scenarios and compound events, where timing, message consistency, and cross-border coordination are critical.

Importantly, this report remains diagnostic by design. It identifies and characterises gaps and missing elements without defining improvement measures or recommendations. The findings provide a structured baseline for the subsequent deliverable D.1.2.2 – Joint analysis of improvement areas, which will build on the gap landscape presented here to support joint prioritisation of improvement domains and interoperability opportunities across the Adriatic Programme Area. In the table below (Tab. C.1) the correlation between gaps, risk areas, as well as cross-cutting dependencies is summarized, in order to provide a synoptic overview of main findings of this report.

Specific gap	Risk area(s) generated	Cross-dependencies
Lack of stable system-to-system interfaces for routine cross-border data/warning exchange	R B.1 (fragmented situational awareness), R D.1 (reduced preparedness), R D.2 (coordination mismatch)	Interoperability ↔ governance: if interfaces are ad hoc, update/version coherence becomes harder
Absence of an agreed minimum interoperability dataset (fields/metadata for alerts, zones, timing, versions)	R4, R6 (coastal baseline comparability), R3 (traceability/version drift)	Interoperability ↔ semantics: without common fields, semantic alignment can't be operationalised
Heterogeneous formats / legacy systems causing manual conversions	R B.1, R A.1 (asynchronous decisions), R A.2 (bottlenecks under pressure)	Technical ↔ operational: manual steps slow governance decisions and public messaging updates
Missing crosswalk "warning level → expected actions/activation posture" across territories	R B.2 (misinterpretation), R A.1 (asynchronous activation)	Semantics ↔ governance: same "colour" may imply different escalation/activation steps
Warning lifecycle Update / Cancel / Stand-down rules not consistently specified	R A.2 (update bottlenecks), R C.2 (message incoherence), R A.1 (asynchrony)	Governance ↔ communication: lifecycle ambiguity amplifies last-mile inconsistencies
Unclear decision rights / sign-off for issuance, escalation/downgrade, termination	R A.1, R A.2, R D.2	Governance ↔ interoperability: unclear "who decides" complicates cross-border synchronisation
Limited documentation of delegation / substitution / replacement rules for key roles	R A.2, R A.1	Governance ↔ resilience: continuity gaps worsen during prolonged events / staff turnover

Incomplete decision logging / versioning / audit trail practices	R A.3 (traceability), R C.2 (message coherence), R4 (situational awareness drift)	Governance ↔ interoperability: without versioning, different actors may act on different "truth"
Missing/unclear public message approval chain, especially for updates/cancellations	RC.2, R A.2, R C.1 (uneven reach)	Governance ↔ last-mile: message authority ambiguity leads to contradictory communications
Lack of defined channel-by-level rules (which channels mandatory at which severity)	R C.1 (uneven reach), R C.2	Communication ↔ governance: escalation without channel escalation reduces effectiveness
Accessibility / inclusiveness measures not consistently specified (vulnerable groups, multilingual, alternative channels)	R C.1 (uneven reach), R C.2 (misunderstanding), R C.3 (reduced learning)	Communication ↔ social vulnerability: last-mile variability amplifies inequality of protection
Weak/absent public feedback mechanisms after alerts	R C.3 (reduced learning), indirectly R C.1/R C.2 over time	Feedback ↔ improvement loop: lack of feedback prevents evidence-based refinement of messaging
Limited evidence of shared cross-border situational awareness routines (common dashboards/templates)	R B.1, R D.1, R D.2	Interoperability ↔ governance: without shared SA, cross-border coordination depends on informal channels
Joint exercises not systematic / not consistently documented	R D.1, R D.2, R A.1	Governance ↔ lifecycle: exercises are where update/stand-down coherence gets tested
Uneven documentation/embedding of meteo-marine/coastal components (storm surge/sea state) within EWS cycles	R6 (coastal baseline), R4 (SA), R5 (misinterpretation)	Technical ↔ semantics: if coastal drivers differ by territory, warnings may not be comparable
Lack of a shared baseline for coastal flood operational outputs (variables, thresholds, alert areas, update frequency)	R B.3, R B.2, R A.1	Coastal baseline ↔ lifecycle: rapid coastal evolution makes update/version coherence more critical
Cross-border cooperation often project-driven (not institutionalised protocols/routines)	R D.1, D.2	Governance ↔ sustainability: when projects end, routines may weaken, raising continuity risks

Table C.1: correspondence between specific gaps (Ch. 4), risk areas (Ch. 5) and cross dependencies (Ch. 6).

In the following table (Tab. C,2), the heatmap visualises the qualitative impact mapping between each gap identified in Chapter 4 and the analytical dimensions adopted in this deliverable. Ratings are assigned using a rule-based H/M/L scale (High/Medium/Low) reflecting the strength of the relationship between the gap and each dimension, considering: i) directness (gap intrinsically belonging to the dimension); ii) criticality along the alert lifecycle (issue–update–cancel/stand-down) and governance handovers, and iii) cross-dependency amplification effects. The matrix is diagnostic and evidence-bound: it supports interpretation

of cross-cutting patterns and interface-driven gaps without implying quantitative performance benchmarking or prescribing improvement measures.

The Gap × Dimension Matrix uses a qualitative, rule-based rating to represent the strength of the relationship between each *fine-grained gap* and each analytical dimension. The ratings are not derived from statistical computations or performance indicators; rather, they are assigned through a transparent and replicable procedure consistent with the project's evidence-based mapping approach and the functional governance model applied in WP1 deliverables. The following rating scale is used:

- **High (H)** indicates a *direct and determining* relationship between the gap and the dimension.
- **Medium (M)** indicates an *indirect but meaningful* relationship, where the gap acts as an *amplifier* or creates friction through interfaces.
- **Low (L)** indicates a *marginal or only contextual* relationship based on the available evidence base.

For each cell (Gap × Dimension), the rating was assigned using the following decision rules:

1. Directness criterion (primary rule)

   The rating is High (H) when the gap is intrinsically located within the dimension (e.g., a data interface gap within Technical/Data interoperability), or when it directly constrains a core function of that dimension.

2. Workflow criticality criterion (alert lifecycle rule)
   The rating is High (H) or Medium (M) when the gap affects a critical decision point or handover in the alert lifecycle (issue–update–cancel/stand-down), as defined by the functional "chain of command" governance model.
   - High (H) is applied when the lifecycle impact is direct and likely to influence operational coherence under time pressure (e.g., unclear update/termination rules affecting governance and public communication).
   - Medium (M) is applied when the effect is relevant but mediated (e.g., a technical fragmentation issue that indirectly delays governance actions via manual steps).
3. Amplification criterion (cross-dependency rule)
   The rating is Medium (M) when the gap is not the primary constraint within that dimension but is expected to amplify other gaps through cross-dependencies (e.g., semantic variability amplifying public communication inconsistency; limited versioning amplifying situational awareness drift).

4. Evidence-bound criterion (no-assumption rule)

The rating is Low (L) when the linkage is weak, indirect, or cannot be supported by the available evidence base without introducing assumptions. This is consistent with the mapping deliverables' explicit principle of avoiding inference where elements are "not consistently specified in available sources."

The matrix should be interpreted as an impact mapping tool that highlights:

- gaps that are domain-specific (concentrated "H" ratings in one dimension), and
- gaps that are interface-driven (clusters of "H" ratings across multiple dimensions), which typically indicate cross-dependencies affecting end-to-end warning workflows (e.g., update/versioning affecting semantics, governance, communication, cross-border coherence, and coastal-specific handling).

ID	T	S	G	C	F	X	Co
G1.1	H	M	M	L	L	M	M
G1.2	H	M	M	L	L	H	M
G1.3	H	H	M	M	L	H	H
G2.1	M	H	H	M	L	H	M
G2.2	M	H	H	M	L	H	M
G2.3	M	H	H	H	L	H	H
G2.4	M	M	M	L	M	M	M
G3.1	L	M	H	M	L	H	M
G3.2	L	L	H	L	L	M	L
G3.3	L	M	H	M	L	H	M
G3.4	M	H	H	H	L	H	H
G3.5	L	H	H	H	L	H	M
G4.1	L	M	M	H	L	M	M
G4.2	L	M	M	H	L	M	M
G4.3	L	M	M	H	L	M	M
G4.4	L	M	M	M	L	L	L
G5.1	L	L	L	L	H	M	H
G5.2	L	L	L	L	M	L	M
G5.3	M	H	M	L	H	M	H

ID	T	S	G	C	F	X	Co
G6.1	M	M	M	M	L	H	M
G6.2	H	M	M	L	M	H	H
G6.3	L	M	M	M	L	H	M
G7.1	M	M	M	L	H	M	H
G7.2	M	H	M	M	H	H	H
G7.3	M	H	H	H	L	H	H
Legend	**T:** Technical and data interoperability **S:** Semantics and procedures (warning meaning, lifecycle) **G:** Governance and decision-making **C:** communication and last-mile				**F:** Forecasting/Monitoring **X:** cross-border cooperation and preparedness **Co**: coastal specific		

Table C.2: impact mapping matrix