Combining Event-Based and Functional Analysis in Municipal Risk Assessment: Capturing Cumulative Strain on Critical Societal Functions

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ABSTRACT

Municipal risk assessment is typically structured around event-based analyses. While widely used, such approaches may limit the ability to identify how multiple simultaneous pressures collectively affect critical societal functions. This study examines how municipal risk assessment can be further developed by combining event-based and functional perspectives through an analytical hybrid approach within existing governance practice. Based on participatory action research in a Norwegian municipality, functional load assessment was integrated into an established scenario analysis framework. Rather than introducing new models, the approach extends existing analysis by enabling assessment of aggregated impact on each and across scenarios. The findings indicate a shift towards evaluating functional system performance, making cumulative strain across scenarios more visible. The study provides practice-based insight into how existing analytical frameworks can be extended without methodological reform, with implications for municipal risk governance and more resilience-oriented understandings of risk.

Keywords

Municipal risk assessment, functional analysis, scenario-based analysis, risk governance, system resilience, critical societal functions, analytical hybridisation

INTRODUCTION

Municipalities face an increasingly complex risk landscape characterised by interdependencies among services, sectors, and societal functions. Municipal Risk Assessment (MRA) provides a cross-sectoral knowledge base to support the systematic prevention and management of adverse events. However, MRA is largely structured around scenario-based assessments of single events. While this approach provides structure and comparability, it can make it difficult to assess how multiple simultaneous pressures collectively affect critical societal functions. This raises the question of how existing risk assessment practices can be further developed to better capture overall functional burden and system vulnerability.

In this study, "functions" refer to operational societal capabilities required to maintain essential services, based on the Norwegian framework for critical societal functions (DSB, 2016), but locally adapted to reflect municipal service production and responsibilities.

In Norwegian emergency management, MRA is anchored in legislation and national guidelines and serves as a key tool for cross-sectoral preparedness. The national framework for critical societal functions (CSF) has further highlighted which 14 societal functions must be maintained to safeguard basic societal needs (DSB, 2016; DSB, 2021). However, experience from the COVID-19 pandemic (NOU 2021:6) indicates that such frameworks are often used for categorisation rather than as analytical tools for assessing cumulative functional load across

scenarios.

Despite growing attention to function-oriented approaches to societal security, there is limited empirical knowledge about how MRA can be developed to incorporate functional perspectives without replacing established scenario-based practices.

ANALYTICAL GAP AND RESEARCH QUESTION

The study addresses a tension between established scenario-based approaches in municipal risk assessment (MRA) and emerging system-oriented perspectives in risk governance and resilience research (Hollnagel, 2014; Aven, 2016; Woods, 2018; Renn, 2022). Scenario-based analysis provides structure, comparability, and strong institutional anchoring, but focuses on individual events assessed in terms of probability and consequences.

Recent research on systemic, compound, and cascading risks highlights how vulnerabilities arise from interactions and interdependencies across systems rather than isolated events (IRGC, 2018; Renn, 2022). However, such perspectives are primarily developed within quantitative modelling traditions, with limited attention to how they can be operationalised within existing municipal risk assessment practices. As a result, event-based approaches may have limited ability to reveal how multiple stresses collectively affect system performance.

In Norway, the CSF framework introduced by the Norwegian Directorate for Civil Protection (DSB) provides a system-oriented reference structure, shifting attention from infrastructure to the functions required to maintain societal stability (DSB, 2016; 2021). However, the framework is not designed as an analytical method and provides limited guidance on how functions can be used as units of analysis in MRA. In practice, functions are therefore often used for categorisation, while analyses remain event-based.

This creates a gap between the systemic ambition of function-oriented perspectives and their operational use in municipal risk assessment. In particular, there is a limited understanding of how functions can be used as analytical units to assess cumulative strain across scenarios within existing governance frameworks.

To address this gap, the study introduces the concept of functional load as an analytical lens for assessing the strain placed on critical functions in one and across scenarios. The research question is formulated as follows:

How can municipal risk assessment be further developed through analytical hybridisation of scenario-based analysis and function-based load assessment?

The study contributes by identifying functional load as an analytical bridge between scenario-based risk assessment and system-oriented perspectives on risk and resilience. Rather than proposing a new method, the study examines how existing practices can be extended through incremental analytical development within established governance frameworks.

METHODOLOGICAL APPROACH

The study is based on participatory action research (PAR), combining facilitation and analysis within an ongoing municipal process. PAR involves researchers and practitioners collaborating to identify challenges, develop solutions, and analyse the consequences of changes in practice. This approach is particularly suitable for investigating how existing practices can be further developed through iterative processes that combine action and reflection (Lewin, 1946; Reason & Bradbury, 2015; Coghlan & Brannick, 2014; Stringer, 2014).

The choice of PAR as the research method was guided by the study's research question, which focuses on how MRA can be further developed within existing frameworks rather than introducing new analytical models. Rather than treating practice as an external phenomenon, this approach enabled examination of how analytical changes occur through organisational processes and collective learning (Argyris & Schön, 1996).

The researcher actively participated as a facilitator in the municipality's development process, with responsibility for supporting reflection, structuring work processes, and contributing to progress. In parallel, the process was analysed with a research aim, where data from interactions, decisions, and development work formed the basis for systematic knowledge development. The study thus combines an intervention element, where practice is sought to be improved, with an analytical dimension aimed at theoretical understanding and learning (McIntyre, 2008; Bradbury & Reason, 2015; Stringer, 2014).

Case Context

The empirical context is the City of Oslo, Norway, which in 2024-2025 revised its MRA under the coordination of the Emergency Planning Agency. This process included all organisations across all sectors in the municipality, as well as collaboration with external cooperative actors. In the MRA process, the municipality reviewed all

scenario analyses and sub-analyses, and, as part of this work, a separate process was carried out to review and revise the CSF, to which this study is linked.

The participants included emergency-preparedness and technical managers at the enterprise level from agencies and districts responsible for emergency planning and follow-up for underlying service locations. The researcher served a dual role as facilitator and analyst, in line with the methodological tradition of action research (Coghlan & Brannick, 2014; Yin, 2018). The municipality's organisation and MRA work provided a "laboratory" where functional thinking and the integration of CSF into MRA face the same types of problems, needs, and solutions as in other cities and municipalities, even if these are larger or smaller in a local context than in Oslo. Common to all municipalities, however, is their proximity to citizens and their responsibility for citizens' safety and security through covering basic needs.

Before the research activity, the DSB's functional overview was incorporated into the MRA as a framework for categorising risk. At the same time, an initial review found that the concept of function was used only to a limited extent in analysis. The municipality had neither defined its own critical functions nor developed methodological approaches to analyse functional load across scenarios.

This starting point made the case even more relevant to the study, as it illustrated the gap between normative guidelines and actual practice.

Empirical Data

The empirical data consists of several types of material generated through the PAR process:

1. Document analysis of existing MRA and associated scenario analyses
2. Minutes and working documents from cross-sectoral working meetings
3. Overviews of critical functions developed throughout the process
4. Analytical matrices for functional load
5. Observations from facilitated workshops and work processes.

The document analysis aimed to map how the functional framework was used in existing MRA. The working meetings served both as a source of data and as an arena for developing new analytical practices.

Implementation of the PAR Process

The development process was carried out in several iterative phases that together constituted a single PAR cycle and involved representatives. The process involved approximately 45 participants across all municipal sectors, with 2 common workshops and analysis meetings and 1-1 meetings with each entity conducted over 11 months. This indicates the level of organisational resources required to implement the approach. Participants included emergency preparedness managers and coordinators responsible for planning and coordination for agencies, districts, and municipal undertakings.

Data were generated through multiple sources, including document analysis of existing risk assessments, observations, and documentation from workshops, meeting notes, draft templates, and iterative revisions of the MRA framework.

The research followed iterative cycles of planning, action, reflection, and revision. Each phase contributed to both problem identification and methodological development, allowing continuous refinement of analytical concepts and tools in collaboration with participants.

Phase 1: Mapping of existing practices

In the first phase, the municipality's existing MRA was analysed to identify how critical societal functions were integrated into the analysis. The scenarios were analysed individually, with a review of how critical societal functions were categorised and assessed.

This phase established a common basis of understanding for further work and clarified the need to develop a more function-oriented analysis.

Phase 2: Organisation-wide mapping and local adaptation

In the next phase, all municipal agencies and districts participated in facilitated workshops to identify their critical services and assess how these relate to DSB's functional structure. The process had both a competence-enhancing

and analytical purpose. Through the work, several functions and sub-functions were identified that were not included in the national overview. These included municipal services such as waste management, property management, education, cultural environment, and social services, which were not explicitly defined in the national framework but emerged as critical in the local context. These were integrated into a locally adapted functional structure. The result was not a replacement of the DSB framework, but a further development that reflected the municipality's organisation and service production.

Phase 3: Development of functional load as an analysis category

In this study, *functional load* refers to the degree of strain placed on a function's capacity to operate under a given scenario. It captures the relationship between increased demand and available operational capacity.

The third phase involved developing a method to assess the impact of scenarios on critical functions. Three levels of functional load were established:

1. Low load, manageable within existing capacity
2. Medium load, challenging but manageable through internal adaptations
3. High load, with a risk of cessation in the function or a need for assistance outside the function owner's area of responsibility.

The assessment levels were developed in collaboration with the Emergency Planning Agency and integrated into existing scenario analyses. In this study, assessment levels are not defined as numerical values but as qualitatively assessed capacity limits (e.g., low, medium, high), indicating when a function is likely to become critically strained.

Phase 4: Aggregate Load Analysis

In the final phase, a matrix was developed that linked scenarios and functions. This made it possible to analyse:

1. How does each scenario affect different functions
2. How each function is affected by multiple scenarios combined.

This analysis enabled the identification of functions with repeated high loads and provided a basis for assessing systemic vulnerability.

Analytical Approach

The analysis examines how the analytical perspective in MRA is developed throughout the process. The analysis is structured around the development and use of a scenario–function matrix, in which each scenario is systematically assessed for its impact on societal values and then critical functions. This enables identification of patterns of repeated strain across scenarios, strengthening the basis for analysing systemic vulnerability. Instead of evaluating the effect in the traditional sense, the study examines how the concept of function is operationalised and what analytical implications this has for understanding risk. The study thus analyses the development as a reconfiguration of existing practice, in which functions gradually shifted from classification to analysis points.

RESULTS

The results are not just a methodological adjustment; they represent a shift in the analytical point and, thus, in the understanding of risk.

A key finding of the study was that the CSF framework was initially used as a structuring category in MRA, rather than as an analytical point for assessing the overall burden. This helped to ensure that the analyses remained strongly linked to single scenarios, even when features were explicitly included in the analysis structure. It was only through the participatory process that the concept of function was gradually operationalised as an element of analysis, enabling assessment of how several scenarios collectively affected the same function.

Starting Point: Functions as a Classification Structure

The initial mapping of MRA showed that the CSF framework was formally integrated into the analysis. The functions were visible in the document structure and served as a reference to assess the consequences of different scenarios.

The scenarios were assessed individually, with a focus on probability and consequences, and the results were presented in separate overviews under relevant functional categories. There was no systematic assessment of how

several scenarios together affected the same function. The concept of function was thus present in the structure but not operationalised as an analytical tool.

This practice, established in 2017, has proven to be the first link between DSB's national framework for critical societal functions and municipal risk assessments in Norway. The approach was perceived by the municipality as satisfactory, given the lack of guidelines at the time of its implementation. At the same time, the mapping phase identified potential to use the functional concept more actively in analyses and the overall risk picture.

Local Definition and Expansion of Critical Functions

Through the organisation-wide mapping, all municipal agencies, districts and undertakings participated in identifying their own critical services and functions. The process served both awareness-raising and mapping purposes. The participants were introduced to DSB's definition of 14 critical societal functions and commonly discussed how these corresponded to the municipality's actual tasks and service production.

The work identified several functional areas that were not explicitly defined as critical in the national overview but emerged as critical in a local context. Five new functional areas were added, along with eleven sub-functions related to these, using the same criteria as the national CSF.

The five main functions included property management, social services, education, waste management, and the cultural environment. Several of these functions were considered critical during the COVID-19 pandemic, as noted in organisational inputs and evaluation reports.

The expansion of the functional structure did not mean that DSB's framework was rejected, but rather that it was supplemented and adapted to the municipality's organisational structure and service portfolio. The result was a more detailed, locally anchored overview of which functions are considered critical to the municipality's ability to maintain operations and emergency preparedness. In total, the municipality included 19 critical functions in the MRA: 14 from the national framework and 5 identified locally.

This phase contributed to a clearer link between the concept of function and the specific performance of activities. Functions were no longer perceived as abstract categories, but as specific services and responsibilities with defined risk owners.

Introduction of Functional Load as an Assessment Category

The next key development step was the establishment of functional load as an explicit category of analysis in MRA. Through dialogue in working groups, three levels were developed for assessing burden:

1. Low load: The function is affected, but the situation can be handled within existing capacity and ordinary operations.
2. Medium load: The function is significantly challenged and requires internal reprioritisation or customisation.
3. High load: The function is at risk of downtime or significant failure, and there is a need for assistance outside the function owner's own area of responsibility.

These assessment levels were developed through discussion of what, in practice, represents a critical influence on a function. The assessments were based on existing emergency preparedness experience and knowledge of organisational capacity.

The load levels were then integrated into the municipality's existing scenario analysis. For each of the 16 scenarios in the MRA, an assessment was made of how each scenario affected each critical function. This added an extra dimension to the scenario analyses. In addition to assessing probability and consequences, a systematic assessment of functional impact was conducted.

Development of Aggregate Load Matrix

A crucial step in the process was developing a matrix linking scenarios and functions to provide an overall overview. The matrix made it possible to visualise:

1. Which functions are affected by each scenario in MRA
2. What level of stress for each function is associated with scenario impact
3. How do all MRA scenarios impact all CSF

This matrix constitutes the core analytical output of the study, enabling cross-scenario comparisons and the identification of functions exposed to repeated high loads. The analysis thus moves beyond individual scenario

descriptions to reveal systemic patterns of vulnerability and can also contribute as insight into one scenario.

The matrix also enabled the identification of scenarios that collectively generated high load across multiple functions simultaneously. This provided a more comprehensive picture of how different events affect the municipality as a system.

The figure below shows all 16 scenarios in MRA and how each scenario burdens critical societal functions.

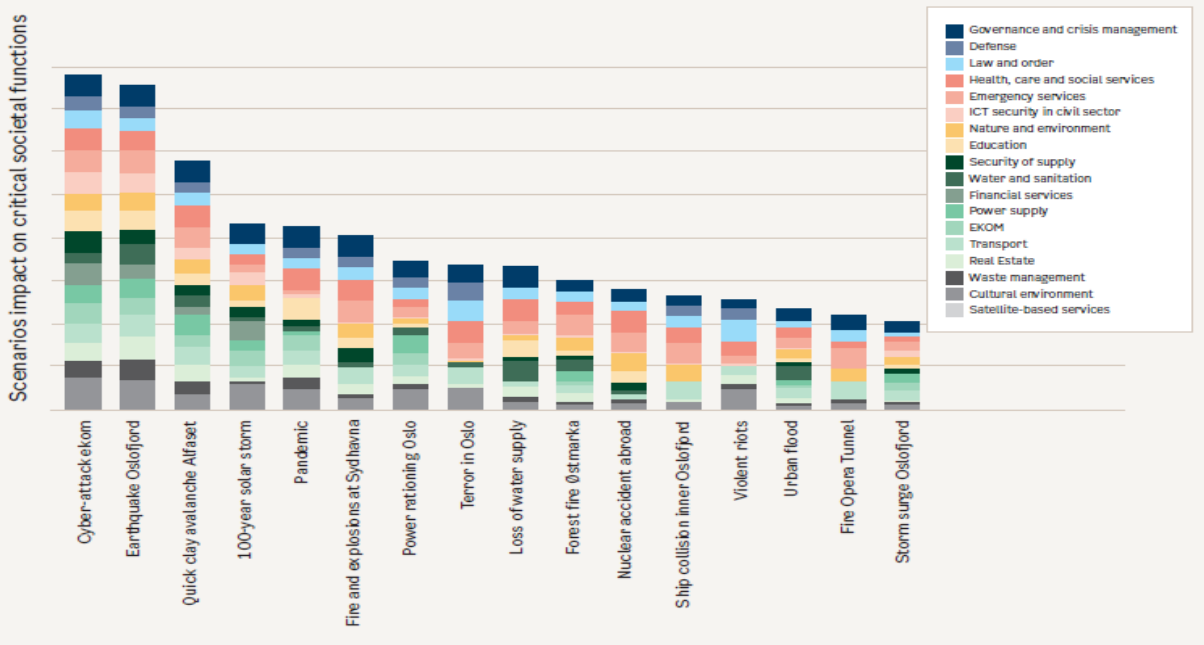

Figure 1: MRA - Analysis of scenario impact on critical societal functions

This overview provides insight into how the selected and conducted event-based scenario analyses in MRA affect the different CSFs. In this overview, we see a ranking from the left side, where the scenario involving cyber-attacks on ecom will have the greatest impact on critical societal functions, which is a change compared to the ranking of scenarios in MRA that are based on consequences for societal values (life and health, natural environment, economy, etc.), where the earthquake scenario was ranked highest.

Below, we see an overview of the overall load of the single critical societal function across scenarios in MRA. The results shown here also provide an overview of the mutual criticality between the CSF.

This overview also provides a comprehensive ranking of CSF, which has enabled systematic improvement of the municipality's emergency preparedness by identifying (1) which areas need attention (all CSF) and which of these need increased attention. The ranking of the top three, from left to right, shows governance and crisis management, health, care, and social services, and rescue services.

Another interpretation is that the results indicate that the municipality's holistic, systematic, and cross-sectoral management and cooperation are important to pay increased attention to in the future, and that health, care, and social services are not only linked to the out-of-hours clinic and ambulance service but also to all other primary care services for which the municipality is responsible. Then, as expected, emergency services address first responders through rescue services. This is an important "finding" and contribution from this study – precisely where, how, and why resilience needs to be strengthened, distributed, and gathered.

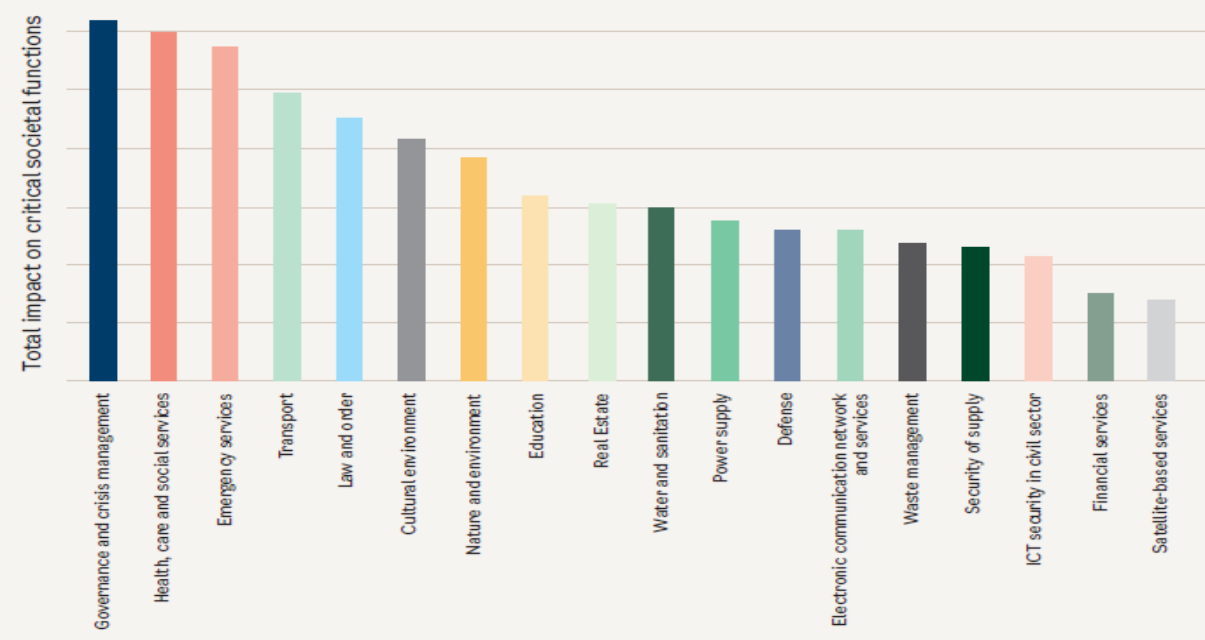

Figure 1: Total impact on each critical societal function from all 16 scenarios

Shifting Understanding of Overall Risk in the Organisation

The integration of functional load into MRA with a municipal perspective led to a change in how risk was discussed within the organisation. Whereas previously discussions were mainly focused on general discussions of single incidents, attention in workshops was more focused on which functions have limited resilience and where capacity challenges exist.

The work also highlighted the need for cross-sectoral coordination and which functions, when collectively, had the greatest impact on the municipal risk picture. When several scenarios showed a high load on the same function, it became clear that management of this could not be handled within a single sector. The functional load analysis thus helped link the scenario work to organisational discussions about capacity, resilience, responsibility, prioritisation, and cross-sectoral collaboration.

Integration into the Municipality's Overall Risk Picture

The function-based analysis was ultimately integrated into the municipality's overall risk picture as part of the MRA, which was published in December 2025 (Oslo municipality, 2025).

The result was that the municipality now has:

1. A locally adapted overview of critical societal functions
2. A structure for assessing functional load in scenarios
3. An overall view of total load patterns

This integration means that functional load does not appear as an add-on outside the risk analysis, but as part of the analysis basis adjusted to the local context.

DISCUSSION

The study did not aim to develop a quantitative risk model or estimate functional vulnerability as a function of event magnitude. Rather, it addresses a prior methodological challenge: how to systematically integrate CSF factors into MRA. Quantitative modelling of such relationships represents a relevant next step but presupposes an established analytical structure.

The development can be understood as a shift toward a hybrid analytical focus that combines events with functional system performance. Through a collective process, functions were established as a common reference point across sectors, enabling analysis of the overall load. This represents a practice-based link between traditional risk assessment, function-based system analysis, and resilience-oriented thinking.

The study does not primarily contribute a new method, but an analytical shift in perspective in MRA from single

events to functional system performance. Rather than providing a quantitative risk model, the contribution lies in introducing an analytical perspective that makes cumulative strain across scenarios visible within existing qualitative practices. In this sense, the approach complements quantitative risk assessment by focusing on functional capacity and system performance, which are often difficult to capture through event-based modelling. This represents a practice-oriented operationalisation of systemic risk perspectives (Renn, 2022; IRGC, 2018) and demonstrates how function-based analysis can be developed without introducing resource-intensive models, such as full functional modelling, after the Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012; Patriarca et al., 2020). Although the study is based on a single municipality, it offers analytical generalisation by identifying mechanisms for hybridising established forms of analysis that can be further investigated in other contexts (Yin, 2018).

The challenges that arose in the work can be understood as expressions of institutionalised forms of analysis in which scenario-based thinking dominates practice. Rather than treating these as implementation problems, the findings indicate how established forms of analysis shape what becomes visible as risk. The resulting hybridisation can therefore be understood as an analytical adaptation that enables a gradual shift in perspective within the existing management framework. Recent research on compound and cascading risks highlights how hazards interact across sectors and scales. While such approaches often rely on quantitative modelling, they similarly emphasise the need to understand how system functions are affected under combined stress to support decision-making (Huang et al., 2023). The present study complements this line of work by addressing how such perspectives can be integrated into municipal analytical practice.

From Event-based Analysis to Function-oriented System Risk Understanding

The results show that developing MRA towards a more system-oriented understanding of risk does not require introducing new analytical models. Instead, existing scenario-based analyses can be extended by adjusting the unit of analysis, shifting the focus from individual events to the collective effects of multiple scenarios on critical functions.

Traditional MRA practice has been characterised by an event-based understanding of risk, in which incidents are analysed in isolation in terms of probability and consequence (Aven, 2016). While this provides structure, it can contribute to a fragmented understanding of risk in complex systems. Systemic risk literature highlights how vulnerabilities arise from interactions among events, organisational structures, and functional dependencies (Renn, 2022; IRGC, 2018). The results illustrate how a function-based approach helps reveal such interdependencies.

By introducing functional load as an analysis category, it becomes possible to identify which functions are repeatedly exposed to high load across scenarios. This shifts the analytical focus from "which scenario is most severe?" to "which parts of the system are most exposed to cumulative pressures?", enabling a more system-oriented understanding of risk without replacing the established MRA structure. The qualitative nature of the analysis reflects the aim of developing and testing an analytical framework in practice rather than producing generalizable quantitative estimates.

Hybridisation Rather than Methodical Replacement

A key finding is that the development did not arise from implementing a new method but from the hybridisation of existing practices (Scott, 2014). Hybridisation is understood as the incremental integration of function-based analysis into existing scenario structures, in which established governance practices are extended rather than replaced. The analytical perspective is hybridised: scenario analysis is retained but expanded with a function-oriented dimension. This highlights the importance of incremental innovation in the public sector, where management tools are closely linked to organisational routines and regulatory frameworks.

The resulting model can be understood as a practical adaptation balancing innovation with stability and recognisability. This is particularly relevant in a municipal context, where resource constraints and the need for cross-sectoral coordination make extensive methodological reforms demanding. The study shows that function-based analysis can be developed through further refinement of existing practice rather than by introducing external models.

Functional Load as Operationalisation of Systemic Risk

Systemic risk is characterised by interdependencies and cascading effects that make it difficult to understand risk in isolation (Renn, 2025; IRGC, 2018). This reflects a broader shift in recent risk research towards understanding compound, cascading, and systemic effects across interconnected systems. It also aligns with research on

compound and cascading events, where interacting hazards and system interdependencies generate non-linear effects across sectors (Lee et al., 2024; Huang et al, 2023:2024; De Maio et al., 2023). While such dynamics are often explored through quantitative modelling, this study demonstrates how similar concerns can be addressed through an analytical reconfiguration of scenario-based practice. In the Oslo case, the functional load matrix served as a tool to highlight how several scenarios collectively affect the same function and how one scenario affects all CSF. Systemic vulnerability was thus understood as a pattern of cumulative burden.

This approach helps operationalise systemic risk in a municipal context. Instead of abstract discussions of complexity, the dimension of functional load introduces a concrete analytical approach that can be integrated into existing processes. The analysis showed that some functions served as load nodes across scenarios, indicating structural vulnerabilities within the organisation. This enables a shift in risk and crisis management from an incident-focused to a system-focused approach, without losing the structure provided by scenario-based analysis.

Connection to Resilience Engineering

Although the study did not explicitly use the Functional Resonance Analysis Method (FRAM), the development shows clear similarities to function-based systems analysis (Hollnagel, 2012). FRAM is based on the understanding of systems as networks of functions, in which variability can propagate and give rise to emergent properties, for example, when a municipal system develops patterns or behaviours that are not reducible to individual organisational units.

In this study, a similar logic emerges through the use of functions as analytical points, the assessment of aggregated impacts, and the analysis of systemic effects. This can be understood as a proto-FRAM approach, where key principles from resilience engineering are developed through the practice-based adaptation of existing tools (Hollnagel, 2012; Patriarca et al., 2020). The term proto emphasises that the analysis does not represent full functional modelling, but a step towards function-oriented systems analysis.

From a resilience engineering perspective, this involves a shift from focusing on failures and events to focusing on the system's ability to handle variation and load (Hollnagel, 2017). Functional load provides a concrete language for discussing resilience as an operational capacity rather than an abstract characteristic. Concepts such as brittleness, graceful extensibility, robustness, saturation, and adaptive capacity (Woods, 2018) became easier to understand, discuss, and contextualise in the working groups within the municipality's emergency preparedness system.

Implications for Public Governance

The results also point to implications for public governance. When critical functions are identified and analysed as units in analysis, the need for cross-sectoral coordination becomes more visible. Functions previously perceived as intra-sectoral appear more clearly dependent on interaction between organisational units.

This can strengthen integrated governance by shifting attention from sectoral risks to overarching systemic capacity risks, strengthening sectoral collaboration, responsibilities, prioritisation, and resource allocation.

Implications for Information Systems and Digital Decision Support

The developed functional load matrix also represents an information structure that can form the basis for digitalisation. Information systems research shows that digital decision-support systems require clear analytical units to support complex decision-making processes (Baskerville et al., 2020; Rai et al., 2019).

Defining functional load as a unit of analysis creates opportunities for digital solutions to visualise systemic load patterns, simulate scenario combinations, and support prioritisation processes. At the same time, the study shows that technological development should follow analytical development, not the other way around.

LIMITATIONS AND FURTHER WORK

The study has several limitations that should be considered when interpreting the findings. First, the analysis is based on a single municipality, and the results cannot be directly generalised to other contexts. Municipal organisation, resource base, and emergency preparedness culture vary considerably, and the development described here must therefore be understood as context dependent. At the same time, a case study provides in-depth insights into organisational processes and can contribute to analytical generalisation.

Second, the use of PAR means that the researcher has had an active role in the development process. This may have influenced both progress and learning. At the same time, the approach provides access to practice-oriented

reflections and decision-making processes that are often difficult to capture through more distanced research designs (Reason & Bradbury, 2015). The study addresses this challenge by being transparent about the researcher's role.

A third limitation concerns the analytical maturity of the approach. The function-based analysis represents a simplified operationalisation of system perspectives. It does not capture dynamic interactions at the same level of detail as more advanced methods in function-based systems analysis or resilience engineering. The term proto-FRAM is therefore used to indicate structural similarities with FRAM without implying full methodological equivalence (Hollnagel, 2012; Patriarca et al., 2020). The current analysis does not differentiate between variations in event magnitude or intensity, as scenarios are assessed as predefined cases rather than parameterised events. Similarly, compound or cascading interactions between scenarios are not explicitly simulated. These aspects are central in quantitative risk assessment and represent important directions for further development.

Furthermore, the implications for digital information systems in this study are primarily conceptual. Although the functional load model shows potential as a basis for digital decision support, such solutions have not been developed or tested in this case. Future research should therefore investigate how hybrid MRA, combining scenario- and function-based approaches, can be integrated into digital decision support platforms.

Finally, the study should be understood as a work in progress. It represents a first analytical step towards understanding how function-based systems analysis can emerge within existing polycentric municipal risk governance frameworks and in use in crisis management.

CONCLUSION

This study has investigated how municipal risk assessment (MRA) can be developed from an approach primarily based on single incidents towards a more function-oriented system analysis, enabling assessment of overall load and vulnerabilities in the municipal emergency preparedness system. Through a participatory action research process in a Norwegian municipality, the national framework for critical societal functions was further developed from a classification structure into an analytical basis for assessing functional impacts locally.

A key finding is that this development did not require the introduction of new analytical models. Instead, a hybrid approach emerged, combining scenario-based analysis with functional load assessment. This enabled the identification of systemic load patterns and vulnerabilities that remain difficult to detect through isolated incident analysis.

The study contributes to research on risk governance by showing how existing analytical frameworks can be extended to address systemic risk. It also contributes to the literature on system resilience by illustrating how function-oriented perspectives can be operationalised within established governance frameworks. At the same time, the study points to further theoretical development at the intersection of function-based systems analysis and resilience engineering.

Furthermore, the study shows that function-based analysis can provide a foundation for future digital decision support. By structuring risk as functional load, it becomes possible to develop information systems that visualise systemic effects and support more holistic decision-making. This highlights the need for further research on the integration of municipal risk management, information systems, and advanced analytics.

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