

Advancing the use of exposure and vulnerability data in Impact-based Warnings

Abstract

Impact-Based Forecasting and Warning (IBFW) aims to improve preparedness and decision-making by communicating the likely consequences of hazardous weather rather than the hazard alone. Central to this approach is the integration of hazard, exposure and vulnerability information to better understand who and what may be affected, and how severe impacts may be. However, approaches to incorporate exposure and vulnerability data vary, but could have substantial influence on warning provision. The HuT Project work has investigated the variability and role of these datasets to better inform their use in risk assessment and IBFW.

Key points

- Combining hazard, exposure & vulnerability information can better inform real world impacts.
- New global exposure and vulnerability datasets help address critical data gaps for impact-based warning systems.
- Methodological choices to integrate exposure and vulnerability can influence who might receive warnings and the warning severity level issued.

Evolving warnings to be impact-based

Impact-Based Forecasting and Warning (IBFW) has gained increasing international support through the United Nations' Early Warnings for All Initiative and guidance produced by the World Meteorological Organisation (WMO; WMO, 2021).

The underlying premise of IBFW is that impacts result from the interaction between the hazard itself, the people and assets exposed to that hazard, and the vulnerability of those exposed elements (Figure 1). As severe weather events become increasingly consequential under a changing climate, there is recognition that hazard information alone is insufficient to support effective preparedness and early action.

Potter et al. (2025) identify the importance of vulnerability and exposure data, while recognising persistent challenges around data availability, governance, evaluation, communication, uncertainty and the integration of dynamic risk information. Improving how exposure and vulnerability are represented within warning systems, alongside stronger partnerships and evaluation approaches, is seen as essential for developing effective, people-centred warnings that support early action and resilience.

What is vulnerability and exposure?

Exposure answers the question – what is in harm's way? These datasets describe the people, buildings, infrastructure, services, livelihoods and other assets that may be affected by a hazardous event. Examples include population datasets, building inventories, transport networks, schools, hospitals and critical infrastructure.

Vulnerability datasets describe the characteristics that influence how susceptible exposed people or assets are to harm. Vulnerability can be represented through physical, social, economic or environmental factors. For example, the age and construction type of buildings may influence their susceptibility to wind damage, while social factors such as income, health, mobility, access to resources or existing inequalities may influence how severely communities are affected by a hazard.

Using vulnerability and exposure data in IBFW

In practice, vulnerability and exposure can be incorporated into IBFW in several ways. Simpler approaches use hazard thresholds supported by expert judgement and stakeholder dialogue to infer likely impacts – where stakeholders and expert experience provide narratives around exposure and vulnerability. More advanced approaches integrate quantitative vulnerability and exposure datasets with hazard forecasts through impact or risk models. Between these two ends of the spectrum, operational systems use a combination of qualitative and quantitative methods, reflecting differences in available data, technical capacity, warning objectives and user needs (Robbins et al., 2022).

A global combined exposure and vulnerability dataset

It is difficult to obtain high-resolution exposure and vulnerability data. Most countries do not have open building registries, either because of a lack of political will or financial resources. Datasets that are available are often out-of-date and incomplete, since the building stock is constantly changing. As



Figure 1: Risk as the interaction of hazard, exposure and vulnerability, and the chain through which risk information leads to actions that reduce it.

part of the HuT project, a new global exposure model was developed. The model merges open data sources to create high-resolution information on building occupancy types, sizes and construction year, drawing for example on the crowd-sourced OpenStreetMap project and earth observation-derived datasets. The intermediate product is the fully open OpenBuildingMap (Oostwegel et al., 2025). This dataset was combined with local knowledge of building types to create the Global Dynamic Exposure model, in which not only the structural characteristics of buildings (i.e. physical vulnerability) are estimated, but also the population inside each building during night and day periods. The data also provides indicative information on the replacement costs of the buildings (Schorlemmer et al., 2026).

Advancing understanding of the role of vulnerability and exposure in risk analysis and IBFW

Within the HuT Project, researchers from the UK and New Zealand investigated how different methods of integrating hazard, exposure and vulnerability information influence the provision of impact-based warnings. Using severe wind case studies from New Zealand (Cyclone Cook) and the UK (Storm Eunice), three approaches were compared:

- a hazard-only method;
- a hazard-plus-exposure method (using population and building datasets), and
- a risk-based method that additionally incorporates building vulnerability through damage functions.

The study (Potter et al., 2026, under review) shows that the choice of methodology can substantially alter who receives a warning and the warning severity assigned, even when the underlying hazard is the same (Figure 2). For our case studies, hazard-based warnings tend to result in larger proportions of the population receiving warnings and with higher severity levels (orange and red). Including exposure data (either population or buildings) tends to increase the proportion of the population who may not receive a warning, while a full risk-based approach suppressed the severity of warnings (no orange and red).

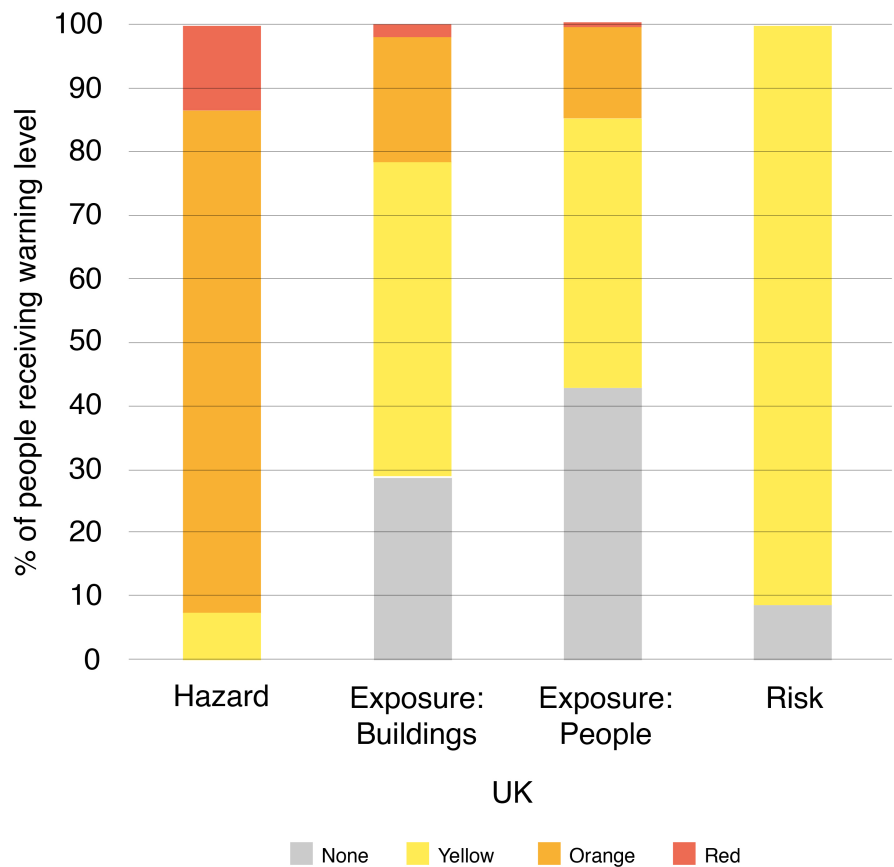


Figure 2: Percentage of people receiving each warning level in the UK case study under hazard-only, exposure-based and risk-based methods.

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