Improving Post-Disaster Damage Data Collection to Inform Decision-Making

Final Report

V. Silva, P. Kalakonas, M. Massabo, T. Bedrina, P. Campanella, A. Avagyan, J. Bevington, D. Farrier

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The Global Earthquake Model Foundation (GEM)
Via Ferrata 1, 27100
Italy

on behalf of the consortium involving the Global Earthquake Model Foundation, JBA Consulting, CIMA Foundation, and GeoCom Ltd.

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Authors: V. Silva, P. Kalakonas, M. Massabo, T. Bedrina, P. Campanella, A. Avagyan, J. Bevington, D. Farrier

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Executive summary

Collection of damage data following major disaster events is a fundamental exercise for a multitude of purposes, such as emergency management, resource allocation, fund mobilization and reconstruction planning. The processes involved, and scales of damage assessments vary by country, peril and context. Numerous sector-specific data collection activities provide an estimation of damage, loss and post-disaster needs in order to provide relief and facilitate the commencement of reconstruction and recovery efforts.

This project focused on the collection of data on physical damage to assets such as buildings (residential, commercial, industrial, public), infrastructure, and crops. The aim was to evaluate the current state-of-the-art in post-disaster damage collection – in protocols, tools and systems – in order to identify a suitable protocol and toolset that could be adopted by the Government of Armenia that would be generalisable and available, allowing adoption by other national government agencies or interested parties.

The project included identifying and reviewing tools for collecting data in the field as well as damage data aggregation and reporting tools. Of particular interest was the use case showing the requirement of a Ministry of Finance requiring national-level reporting of damage on a sub-national level in a transparent system that allows the user to store, retrieve and interrogate damage data down to the asset-level.

Review of existing protocols, tools and systems

To understand the requirements that various disaster practitioners have regarding the collection and analysis of damage data, several users and use cases were identified as part of a literature review and interviews with the local experts. Over 40 experts were interviewed, and more than 100 technical documents, guidelines and manuals were reviewed. Four protocols for disaster damage and loss collection were also reviewed in detail.

The review identified that currently, even in high-income nations, there is still duplication of data collection efforts due to lack of communication amongst stakeholders, which often leads to multiple systems to aggregate disaster data and the need to collect the same data repeatedly. The review identified several gaps in the current data collection protocols such as: insufficient collection of baseline data, weak regulatory framework, absence of protocols to train data surveyors, and lack of flexible and comprehensive IT solutions to support the collection and processing of disaster data. International procedures, such as the World Bank's Damage and Loss Assessment (DaLA) methodology, do not provide the necessary granularity (i.e. resolution), reliability and coverage necessary for all of the use cases of disaster data, in particular the provision of funding to householders for repair/reconstruction purposes. Other nationally derived systems (e.g. FONDEN, Mexico; DarmSys, Queensland) proved to be efficient systems to collect, store and report disaster damage and losses. However, such systems have been tailored to the reality of the respective regions, and the Australian system has not been extensively tested beyond meteorological hazards.

To understand the technologies used in collection and analysis of damage data, more than 15 data collection tools and analysis platforms were evaluated following a set of uniform criteria, covering their functionalities, technology, openness and types of hazards. The review identified several gaps in the existing tools such as: some of the tools have been developed for a particular hazard (e.g. ROVER for earthquakes, RISPOSTA for floods); they do not follow a consistent damage or asset taxonomy; they do not support asset-level data collection (i.e. granularity); and their development was often performed by researchers and/or academics with limited application. It is also worth mentioning that most of the systems to aggregate and report disaster data are country-specific platforms, which cannot be easily transferred elsewhere. On the contrary, the tools for field data collection are frequently region-independent. However, these are not efficiently connected to a data aggregation system, nor used within an operational framework.

In summary, the review found that there is no single protocol or toolset available that fully enables a user to collect damage data at the building level, track the progression of that building's repair or reconstruction (through repeat data collection), or understand how investments made to promote recovery are being allocated to specific reconstruction initiatives. Data are often siloed, with no easy method of aggregating, analysing or reporting data in the months after a disaster. Neither is there a suitable protocol available publicly that promotes a consistent, transparent manner of collecting data across the lifecycle of a disaster.

Design of a conceptual protocol and toolset

Given the findings of the protocol and tool review, a second phase of the project focused on developing a conceptual design of a protocol and toolset to enable rapid collection of damage data which can be reviewed, analysed and reported in a linked data aggregation and reporting system.

The toolset is designed in the context of a proposed conceptual framework for disaster data collection. An example protocol documents the types of activities undertaken across four phases of a disaster management cycle:

- **Prepare** – pre-event preparedness actions - covers the period of time before the occurrence of a disaster, when the preparation of the regulatory framework, establishment of the IT infrastructure, training of surveyors, and collection of baseline data should take place.
- **React** – rapid post-event damage data collection for emergency response - initiated by the declaration of a natural disaster, and covers the activities related with the immediate assistance of the affected communities, rapid assessment of the safety of the building stock and infrastructure, and initial estimation of the severity of the event. This phase should not exceed more than 2 weeks.
- **Act** – detailed damage data collection for detailed reconstruction and recovery planning - detailed damage and loss assessment is planned and performed, with the possibility of training additional surveyors depending on the magnitude of the event. The collected data is stored in the data aggregation and reporting system and shared amongst the different stakeholders depending on the use case. This phase is also marked by the initiation of the reconstruction, repair and recovery processes. This phase should be concluded within 7-10 weeks after the disaster event.
- **Monitor** – monitoring of long-term recovery and tracking of recovery investments – this phase consists of the monitoring of the recovery process, and in the use of the damage and loss data to improve risk models for the region.

It is expected that the proposed framework for disaster data collection and the associated activities described for each phase will reduce some of the limitations of current practices.

A detailed conceptual design was developed for an opensource toolset consisting of a handheld field data capture tool and data aggregation and reporting system. The tools were designed according to the following key principles:

- **Field data collection tool** – collect asset-level ('Exposed Element') data; expansible data collection forms using pre-defined taxonomies for attributes; geo-reference all data; allocate unique code to assets to trace data throughout the four phases; map interface with ability for users to load spatial data (map data and imagery); data collection in both online and offline modes; data synchronisation to central server.
- **Data aggregation and reporting system** – hosted system, with customisable interfaces depending on end-user; aggregation functions to spatial units (e.g. administrative boundaries); security and admin features; data exports to common formats; PDF reporting.

Application to the context of Armenia

An understanding of current processes in Armenia was gained from questionnaires, interviews, review of the current legislation and existing tools and forms. Currently, the disaster data collection and management is performed at the three administrative levels (community, regional and national), and regulated by the corresponding legislation and executive institutions.

The findings from this project identified a number of areas that could benefit from some improvements in order to increase the efficiency of the disaster data management in the country. The main gaps in the current system include:

- There is no single methodology for performing the damage data collection at the lower (community) levels, since they have difficulty aggregating and presenting the collected data to the government in a unified format.
- There is no single methodology for damage and loss assessment (especially for quantifying the damages and losses in monetary terms). Hence, the development of such methodology would increase the efficiency of the system.
- The current damage data collection and aggregation workflow is based on a paper format. The introduction of an automated damage data collection and aggregation system would allow all key players to use a single system for damage data collection and aggregation.
- There is no comprehensive database on disaster damage and losses. The MES has stressed the importance of having a single web-based platform for registration and sharing of damage and loss data collected by the communities, which could be verified by regional authorities, regional ARS departments and MES.
- There are organizational gaps stipulated by the flaws in current protocols and methodologies for damage data collection. For example, communities preparing the Loss Assessment Acts (LAAs) mentioned that there is no timeframe specified for collecting and submitting the LAAs to marzpetarans. This is specifically important for those settlements that are included in communities having more than one village.

The proposed conceptual toolset fills the gaps identified in the evaluation of the damage data collection in Armenia and would improve the efficiency of the government in responding to and coping with natural disasters. Applying the protocol and toolsets designed in this project will potentially improve the current post-disaster activities in the following ways:

- Decrease the data flow time from data collection to final decision on resource allocation.
- Increase the consistency, accuracy and objectivity of the obtained information.
- Increase the operational speed and transparency of data aggregation and reporting.

- Reduce the time for submitting critical information to international organizations for providing aid following natural disasters.

This has the potential to increase efficiency in resource allocation in the React, Act and Monitor stages.

Recommendations

A number of recommendations are proposed to build on this project:

- Initiate a follow-up project to develop an initial baseline prototype of both the data capture tool and data aggregation and reporting system. These prototypes could be developed to fit the requirements of Armenia or a number of countries interested in trialling the system and tailoring the protocols to their specific needs and context. This project should undertake a thorough review of the MAGE system as there are several components that can be used in the new system.
- Investigate options for hosting the toolset from a centrally-hosted location (e.g. GitHub, GEM), with locally-hosted installations by designated national entity.
- Additional development of the GED4ALL glossary to provide contextual help information within the tools.
- Source or develop additional damage taxonomies for flood, landslide and tropical cyclone perils.
- Investigate the feasibility of the Exposed Element code-tagging (e.g. QR codes).
- Explore options for developing a basic system allowing citizens to report damage to buildings through a crowdsourcing process.

Keywords: Disaster data, damage, loss, natural hazards, disaster risk reduction.

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1. Introduction

The impact of natural disasters can act as a serious impediment to sustainable development, creation of jobs and availability of funds for poverty reduction initiatives. This is particularly true in developing countries where the cost of natural disasters can exceed the nominal gross domestic product, cause thousands of fatalities and leave hundreds of thousands of families homeless. After the occurrence of large disasters, national governments or international agencies tend to organize campaigns to collect and curate data concerning the observed damage and loss. Depending on the magnitude of the event, this information can reflect the impact on buildings, infrastructure, agriculture and industry, and can be employed for a multitude of purposes, including the financial support to low-income families that cannot cope with the disaster without the support from the government. These grants can be one of the main catalyzers for the recovery process following the Build Back Better concept.

Despite the well-recognized need for reliable and accurate damage and loss information, there are currently several issues that prevent efficient collection, aggregation and reporting of disaster data. For example: 1) many countries rely on paper-based surveys to collect loss data, 2) there is a lack of baseline information regarding the distribution of the population and building stock, 3) different IT systems are used within a given nations, which makes the information sharing and flow complicated when a disaster hits several regions, 4) the distribution of roles and responsibilities concerning the damage data collection and authorization of funds is often unclear, and 5) most of the current technology does not use remote sensing or satellite imagery to assess and plan the damage extent, amongst other issues. On the other hand, some of the current tools or apps for data collection are either too detailed (and consequently inefficient for large scale data collection), tailored to a particular country (and thus not directly applicable to other nations), or specifically designed to fit the needs of a certain hazard (and therefore leaving out critical measurements required for other hazards). The storing of the data also lacks transparency, which often renders them unusable for disaster risk reduction due to aggregation, lack of information concerning the intensity of the event, or poor classification of the elements affected. Finally, it is also relevant to note the lack of standardization during the collection and processing stages leads to ambiguity and subjectivity concerning the magnitude of the event, and spatial distribution of the losses.

In response to these issues, the Global Earthquake Model Foundation, JBA Consulting, CIMA Foundation and Geocom Ltd. conducted a project titled **Improving Post-Disaster Damage Data Collection to Inform Decision Making**, supported by the Global Facility for Disaster Reduction and Recovery. This project is composed of two phases: 1) Revision of existing protocols and IT solutions for damage data collection and aggregation, and evaluation of the situation in Armenia; 2) Development of a conceptual design for a tool for field damage data collection and a platform to aggregate and report disaster data. Phase 2 also covers the customization of the conceptual design of both tools to the context of Armenia. The various findings from Phase 1 and 2 have been distributed across two sections as follows:

- **Section I** covers the generic solution proposed for the improved disaster data collection, aggregation and reporting.
- **Section II** covers the application of the solution to the context of Armenia.

Additional information related with each section is provided in the Appendixes (A to J). The contents of each chapter are briefly described below according to the Phase of the project:

Section I: Revision of existing protocols and IT solutions for damage data collection and aggregation, and presentation of the proposed solution.

- **Chapter 2 - Users and use cases for disaster data:** this chapter presented a description of all of the use cases that were identified within this project, along with the associated users.
- **Chapter 3 - Conceptual framework for disaster data collection**: this section presents an update of the different phases that comprise the conceptual framework for disaster data collection, aggregation and reporting.
- **Chapter 4 - Overview of damage collection protocols:** this part of the report presents a brief description of the protocols that were reviewed, and the main gaps that were identified.
- **Chapter 5 - Overview of existing IT solutions for disaster data collection and aggregation:** several tools and IT systems for data collection and aggregation were reviewed, and this section presents a summary of the main findings and existing gaps.
- **Chapter 6 - Conceptual design for a damage collection:** this chapter presents the main use cases, conceptual design principles and architecture for the field disaster data collection. Several mock-ups for the envisioned mobile tool are also presented.
- **Chapter 7 - Conceptual design for a damage aggregation and reporting system:** this chapter presents the main use cases, conceptual design principles and architecture for the disaster data aggregation and reporting system. Several mock-ups for the envisioned web-based graphical user interface are also presented.
- **Chapter 8 - Recommendations for future development:** this part of the report provides recommendations for the development of the IT solutions described in the preceding chapters.

Section II: Revision of the current situation in Armenia regarding disaster data collection and reporting and customization of the solution to the context of Armenia.

- **Chapter 9 - Overview of the disaster data collection situation in Armenia:** this part of the report covers the overview of the current situation on disaster data collection in Armenia, including the existing gaps.
- **Chapter 10 - Customization of the conceptual design to the context of Armenia**: this chapter analysis each component of the proposed conceptual design, and defines the necessary modifications to fit the needs of the Armenian disaster data collection system.

Although it is evident that this deliverable provides critical information for the development of a reliable, efficient and useful framework for the collection of disaster data, we anticipate that some of the documents mentioned in this deliverable and the key experts that were interviewed will have to be involved once again during the actual development of the framework. This will ensure that the outcome is fit-for-purpose and that issues that might have been overlooked during this stage are properly addressed.

The partners of this consortium would like to express their gratitude for the over 40 experts that contributed with their knowledge and past experiences to this report. As requested no particular quotes or names were included in this deliverable, but their feedback has been incorporated in the explanations, lessons learnt and final remarks.

Section I

Revision of existing protocols and IT solutions for damage data collection and aggregation, and presentation of the proposed solution.

2. Users and use cases for disaster data

The collection of damage and loss data in the aftermath of disastrous event is the fundamental step to inform decision-making during the emergency stage, for funding and resource allocation, and for reconstruction planning and compensation schemes. The latter category has special importance for the purposes of the current project. Also, this type of information is essential for disaster risk management and mitigation, calibration of damage models used for cost-benefit analysis, and development of insurance policies. The requirements of the various use cases vary considerably in terms of type of information, accuracy, reliability, granularity, and temporal dimension for their collection. Within this project several users and use cases have been identified, both during the literature review, and more importantly, as part of the interviews with the local experts. The sections below summarize these use cases, as well as the stakeholders involved in each category. **These users will be linked to the identification of the gaps** presented in the following two chapters.

2.1. Emergency management and immediate relief measures

Upon the occurrence of a natural disaster, the responsible authorities for emergency management and rescue operations are activated. The emergency planners are in need of reliable information regarding the severity of the direct damage and casualties in the affected area. Information related to the spatial and temporal evolution of the physical event is essential for planning the rescue operations and preventing further human and economic losses. In the current practice, various tools are used to provide such information, including remote sensing techniques, satellite imagery, and existing exposure and vulnerability indicators.

During the emergency response phase, data are collected regarding the overall direct impacts of the disaster, usually involving the estimated total number of partially and completely damaged buildings, damaged essential services, affected population, and people left homeless. These data are utilized to prioritize the restoration of essential services, design of temporary countermeasures, and plan the immediate relief activities and resource allocation, such as the establishment of temporary shelters and provision of services and goods to the affected population.

- **Data requirements**: Aggregated statistics regarding the direct effects of the disaster, including the total number of damaged and collapsed buildings, affected population, fatalities, injuries, and homeless people. Hazard footprint and list of affected areas.
- **End users**: Emergency management authorities, governmental agencies, humanitarian NGOs, and local authorities responsible for emergency operations.

2.2. Evaluation of safety and usability of buildings

Among post-disaster activities, the usability and safety evaluation of buildings is one of the most common and important tasks. After the emergency management phase, rapid damage assessment surveys and tagging of buildings often take place in order to inform the population regarding the safety of their homes and public buildings. Also, it informs decision-makers in the transition phase from the temporary shelters to temporary houses, and provides recommendations for the application of short-term safety countermeasures. An illustrative example of such guidelines is the post-earthquake damage assessment forms AeDES (Agibilità e Danno nell'Emergenza Sismica) implemented in Italy since 2011, where the outcome of the assessments is a building usability evaluation classified into 6 categories.

- **Data requirements**: Asset level damage classification according to a broad system and immediate occupancy evaluation, including short-term safety countermeasures recommendations, with particular importance on public buildings, residential building stock and essential services.
- **End users**: Civil protection authorities, local governments, affected communities and individuals, post-emergency relief decision makers.

2.3. Funding mobilization

The damage and loss assessment determines the extent of damage sustained by buildings and infrastructure, and quantifies related funding needs. Depending on the disaster funding mechanisms of each country, the data requirements and end users may vary significantly. The Queensland Reconstruction Authority (QRA) and the FONDEN Program for Reconstruction consist two state of the art examples of usage of detailed georeferenced damage data for financial compensation. The former introduced an innovative IT system where the real-time damage data are used directly for damage compensation applications, while the latter introduced a damage assessment committee that evaluates the damage data based on pre-defined criteria in order to access the reconstruction funds.

Most developed countries maintain national budget accounts for disaster recovery, whist developing nations usually rely on international organizations (e.g. World Bank, UNDP), and other sources of funding to support the recovery efforts. It is also common to use the international re-insurance market to partially fund the reconstruction process (this was observed in the earthquake sequence in New Zealand in 2011 and Italy in 2016). This use case is usually the one that requires the most detailed damage data. Regardless of the end users, having access to accurate and transparent disaster loss data that track the extent of damage are fundamental for funding mobilization.

- **Data requirements**: Detailed georeferenced damage and loss data of each affected asset including photographic evidence that covers structural and non-structural components, adequate to estimate the funding needs based on a loss estimation formula.

- **End users**: Governmental organizations (responsible for the funding allocation – e.g. FONDEN in Mexico), ministry of finance, (re)insurance companies, and policyholders involved in natural catastrophe insurance schemes.

2.4. Reconstruction planning

The repair, recovery and reconstruction of damaged buildings and infrastructure in the aftermath of natural disasters is a time consuming task that requires detailed planning, and protocols to define the process and actors of decision making. Reconstruction is a process that requires a considerable amount of funds, and therefore the decision makers must have access to accurate and transparent damage data in order to avoid biased damage assessments. Whist the previous use case is focused on residential buildings and businesses, this use case covers the entire built environment, and its outcomes are used to plan the reconstruction of the region, as opposed to release funds for house or business owners.

Nepal’s experience after the 2015 Gorkha earthquake sequence highlights the importance of an established national reconstruction authority before the occurrence of a disaster, capable of managing the reconstruction process. It also highlights the need for a damage/loss estimation methodology to efficiently mobilize funds either for repair or reconstruction. Furthermore, prioritizing the financing of reconstruction activities of public assets and infrastructure is fundamental for national and local governments, and other NGOs that may be involved in the reconstruction process.

- **Data requirements**: Georeferenced damage data of each affected building, infrastructure, and environmental asset, including a classification of the reported damage to inform decision-makers for either reconstruction or repair, and prioritize such activities.
- **End users**: National reconstruction authorities, ministry of finance, ministries of public works, urban planners, international NGOs funding the reconstruction and recovery, and private entities involved in the reconstruction process.

2.5. Development of disaster risk reduction measures

Disaster data are useful for a range of applications related to disaster risk management and reduction. Understanding the causes of damage and losses due to excessive exposure in hazardous areas and high levels of vulnerability can support the development of risk reduction measures and policies in areas similar to the ones that have been affected. Corbane et al. (2015) proposed a conceptual framework for loss data recording for disaster risk reduction purposes, which highlighted four main application areas of disaster loss data (see Figure 1), namely **loss compensation**, **loss accounting**, **forensic analysis** and **disaster risk modelling**. The first application was described previously as a unique use case, and thus it will not be explored in this section.

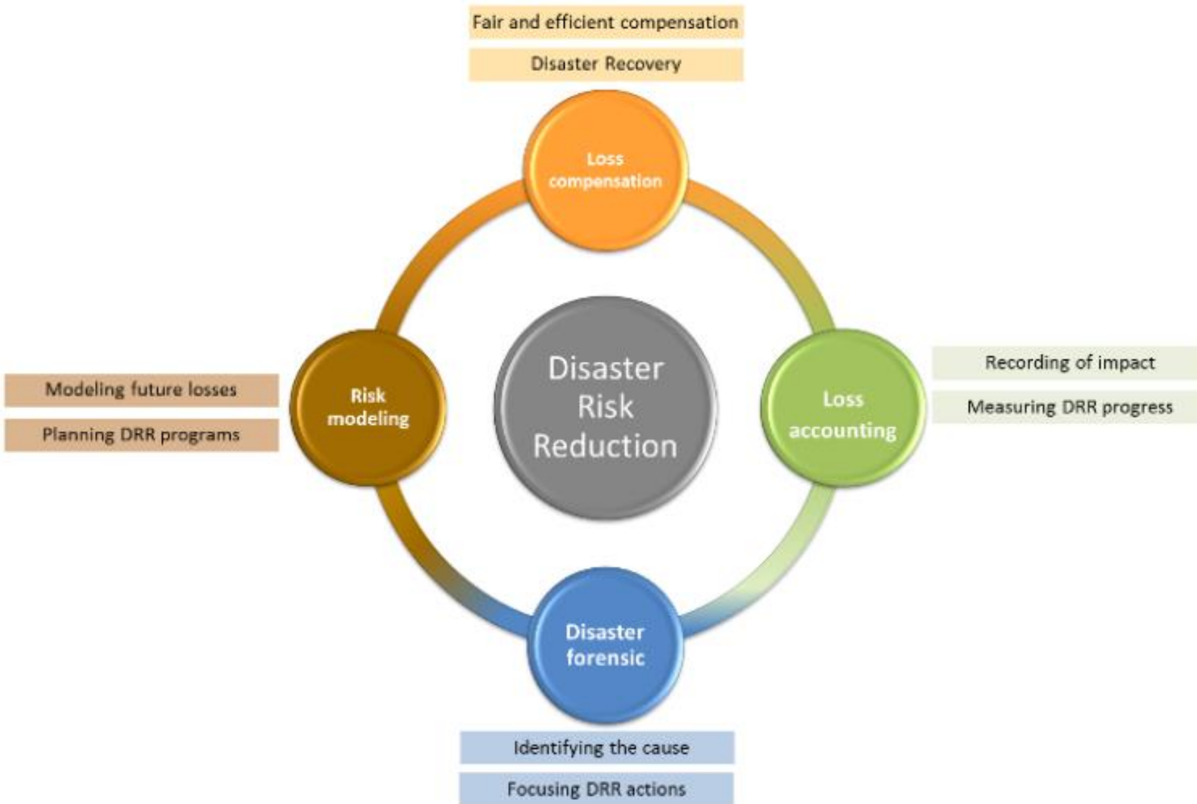

Figure 1 - The four application areas of disaster loss data within a disaster risk reduction scope. Reproduced from Corbane et al. 2015.

Disaster loss accounting is necessary to monitor the impact of disasters in each country (or region). The Sendai Framework for Disaster Risk Reduction (2015-2030) calls for the collection of disaster damage data, as a mechanism to measure the progress towards the agreed targets of the framework.

- **Data requirements**: Transparent and accurate data regarding the overall effects of a disaster, covering the physical damage and human casualties (direct and indirect losses).
- **End users**: National and international organizations (e.g. UNISDR) involved in disaster risk reduction and mitigation, scientific and humanitarian institutions involved in disaster resilience studies.

Disaster forensics allows identifying the drivers of loss by measuring the relative contribution of exposure, vulnerability and coping capacity. The integrated information provides valuable lessons for improving disaster management, or to inform the development of risk reduction measures.

- **Data requirements**: Detailed data that incorporate hazard-specific intensity measures, information about the exposure indicators and physical vulnerability, occurred damage and extent of damage to structural and non-structural components.
- **End users**: Building code committees, physical vulnerability experts, natural catastrophe exposure modelers, disaster prevention and management decision makers.

Disaster risk modeling is used to make predictive forecasts of potential impacts from future events. Probabilistic or deterministic approaches are widely used in various scales in the (re)insurance industry and from various private and governmental organizations. Disaster risk models typically comprise three main components (exposure, hazard and vulnerability), which much be verified, calibrated and improved using disaster damage and loss data.

- **Data requirements**: Physical event footprint and spatial distribution of hazard intensities, quantified damage and losses in physical units and monetary losses.
- **End users**: Natural catastrophe and disaster risk modelers, (re)insurance companies, scientific institutions and organizations involved in risk reduction and mitigation, research institutions and academia.

2.6. Exploration of benefit-cost analysis (BCA)

Several countries have explored benefit-cost analysis (BCA) in order to understand which risk reduction measures would be more advantageous from an economic perspective. The relevant activities may involve retrofitting of existing buildings, design of early warning systems and disaster countermeasures. For example, in 2009 several benefit-cost analyses were performed in Colombia for school buildings, resulting in either the retrofitting of the structures, or in the demolition and construction of new facilities. This particular process requires information about damage functions from past events, as well as estimates of repair costs.

- **Data requirements**: Detailed damage data in physical units, accurate repair and reconstruction costs.
- **End users**: Structural engineers, ministries of public works, urban planners, and disaster risk reduction organizations.

2.7. Long-term investment planning

The planning of long-term risk investment must be informed by probabilistic risk models, as well as disaster data from past events. For example, in 2012 the Italian government decided to invest almost 1 billion EUR in earthquake risk reduction measures. The distribution of these funds across the country was performed considering the expected annual losses in each region and the observed damage from previous events. Other long-term investments can include the development of insurance pools or the modification of the land use regulations (e.g. regions frequently flooded can be classified as inhabitable). All of these activities are frequently informed by data from previous disasters.

- **Data requirements**: Transparent and accurate data regarding the overall effects of a disaster, covering all the physical damage and human casualties, direct and indirect losses.

- **End users**: Governmental agencies, ministries of public works, ministry of finances, and private sector involved in long-term investment.

3. Conceptual framework for disaster data collection

Considering the information from the review of the data collection protocols, tools and IT systems, and the lessons learnt from the case studies, an updated version of the conceptual framework is presented herein. It builds upon the version proposed in the inception report and includes the requirements set by the project partners and GFDRR. Nevertheless, the authors acknowledge the possible limitations in the application of such framework, as it is strongly dependent on the capacity of local experts and pre-existing disaster management. The conceptual framework consists of four main phases: **disaster preparedness**, **emergency response**, **detailed damage assessment**, and **reconstruction/recovery monitoring**. The schematic representation of the framework is presented in Figure 2.

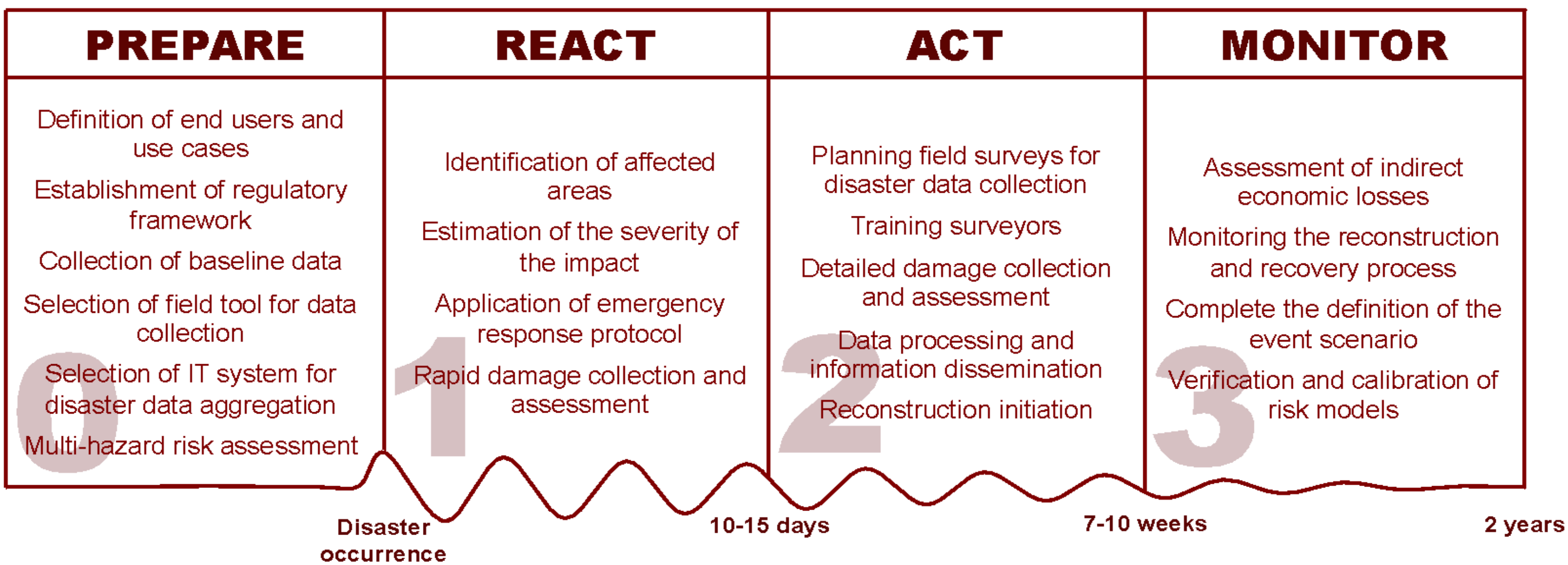

Figure 2 - Schematic representation of the proposed conceptual framework.

3.1. Phase 0: Disaster preparedness

- **Identification of end users and definition of damage/loss indicators**
  - Identification of all the end users (e.g. governmental agencies, public authorities, international organizations, private entities) and use cases for the disaster data within the national context, throughout all the phases of a post-disaster situation, including short-term and long-term objectives. This step will allow the definition of the requirements for the disaster data collection as described in Chapter 2.
  - A comprehensive and transparent definition of the damage and loss indicators that must be collected based on the identified use cases (e.g. fatalities, injuries, damaged and destroyed buildings, direct and indirect losses – see Chapter 4). These indicators should be reviewed by the end users to ensure that it fits the needs of all stakeholders.
  - The information compiled in the previous two steps will set the requirements for the damage assessment guideline, data collection tools and IT systems for reporting and aggregation.

- **Establishment of a regulatory framework**
  - Definition of a central governmental authorized body responsible for the coordination and application of all the post-disaster activities (as established within the disaster data collection protocol in Mexico and Queensland, Australia). The disaster coordinator role as a central decision-making body should be supported by technical and scientific institutions (as practiced in Italy), and the only stakeholder in close communication with the government for political guidance.
  - Definition of the legal owner(s) of the disaster data, potentially organized according to the sector (e.g. residential, commercial, industrial, governmental, education, healthcare, infrastructure, energy, transportation).
  - Establishment of a common disaster management protocol throughout all the regions of the country, in accordance with the local governments. The decision-making and coordination should be centralized, while the local authorities will apply the post-disaster activities, and representatives of the disaster coordinator will manage the process.
  - Clear role definition of the area of responsibility (AOR) of each stakeholder, in particular for the damage/loss data collection and assessment, in order to avoid duplication of efforts (as seen in Nepal after the 2015 Gorkha earthquake).
  - Appointment and training of key individual(s) within central disaster management authority in a data coordination role. They will have prime responsibility for coordinating data collection from various sources and liaise with the relevant lead authorities in each sector. They will also be responsible for organizing pre-event training on use of the tools and setting up the aggregation and reporting tool at each lead authority.
  - Establishment of protocols and policies that define how, when, and what type of data can be shared amongst the involved stakeholders and the disaster coordinator, during the post-disaster activities.

- **Collection of baseline data**
  - Introduction of a section related to building characteristics in the national census survey questionnaires, such as material of construction, year of construction and/or retrofitting, number of floors, type of roof and type of dwelling (several census surveys around the world already endorse this practice, e.g. Japan, Portugal, Greece, India). This information is essential for the estimation of the damage immediately after a disaster, enabling multi-hazard risk assessments, but also for monitoring and evaluating risk mitigation and reduction activities in the future.
  - Data gathering from the existing census and cadastral databases about the physical assets of each exposed sector (e.g. residential, commercial, industrial, governmental, education, healthcare, infrastructure) at the lowest administrative level available (e.g. municipality, district, county).
  - Data gathering regarding house ownership, land use and possible existing of insurance policies, including potential georeferenced data from the responsible governmental departments (as practiced in New Zealand). This information should be available to the reconstruction authority prior to the occurrence of a disaster, to enable efficient and rapid reconstruction decision-making.
  - Collation of data and targeted data capture initiatives in high-hazard regions – development of inventories of buildings, critical facilities, infrastructure, agriculture. Data may have been developed from previous donor investment on projects relating to disaster risk (e.g. GFDRR Africa R5 programme in Africa). These data should be collated and reviewed for use in post-disaster context. Where possible, target campaigns for new inventory data capture on high hazard regions and utilise existing resources from universities through initiatives like Missing Maps or Humanitarian OpenStreetMap. For detailed information capture, a number of tools and protocols exist for collection of data according to taxonomies that would be interoperable with the proposed site data collection tool.

- **Establishment of guidelines for damage/loss collection and assessment**
  - Definition of the damage criteria and guideline for the rapid and detailed damage assessment. The former should be focused towards an immediate occupancy/usability assessment, while the latter should incorporate all the damage and loss indicators defined in the first step of the framework (this approach was successfully adopted in Italy after the 2016 earthquake sequence).
  - Creation of field investigation forms (standard templates) for the damage assessment of the exposed assets according to the sector. The information captured by the forms should be in agreement with the identified use cases, include quantitative metrics, and avoid qualitative individual judgments. A possible template was developed within Phase 2 of this project.
  - The damage assessment guideline and field forms should to be shared amongst all stakeholders involved in the damage data collection, ensuring that the data are collected

in a uniform manner, and allowing the identification of parameters that might be missing for specific uses.

- The training of surveyors for the damage assessment should be carried out at two levels: 1) training personnel without necessarily an engineering background, in order to rapidly assess the safety of the damaged buildings; 2) at a more rigorous level, training technical experts for the detailed damage assessment.
- The training programs should include full-time staff involved in the emergency response and detailed damage assessment phase, who will be capable of training volunteers in a demanding post-disaster scenario, and leading the field surveys as well. The training of these key members should take place both at central and local level, and identify local engineers and technical experts, who can potentially lead the data collection at the local level. It is fundamental to support these activities prior to the occurrence of natural disasters, as practiced in Italy.
- Scenarios – training is only effective if people get to apply their knowledge in realistic circumstances. Running scenario events in accelerated or real-time or as part of multi-day workshops is an effective way of reinforcing training and troubleshooting issues during the preparedness Phase. These scenarios can be run on fictitious events (they can be produced from model event-sets – such as for reinsurance reporting against Lloyd's Realistic Disaster Scenarios[1]), or historic events. They can be used to identify inter- and intra-agency strengths and weaknesses in knowledge, coordination, hierarchies and protocol.

- **Selection of a disaster data collection tool**
  - The entire disaster data collection process should be supported by a field tool, as an alternative to the use of paper forms. These tools can serve as a first verification/validation step of the collected data, as explained in Chapter 4. This project also covered the conceptual design of such tool (see Chapter 6).
  - The data collection tool should preferably be an application installable to any mobile device, such as smartphones and tablets. It should incorporate the damage assessment guideline and field forms (as described previously) in a user-friendly interface, be able to collect the required data (damage and loss indicators, hazard-specific intensity measures) using the appropriate format and type of information (e.g. photographs and measurements), and include a georeferenced system for mapping the location of the inspected assets.
  - The application should be open-source and adjustable based on the use case (e.g. rapid versus detailed damage assessment). Moreover, the tool should be capable of deployment GIS layers of the affected area and real-time updates accessible by all surveyors, including the basic damage information of the surveyed assets.
  - Additionally, the tool should be able to collect basic building characteristics, such as structural type, material of construction, occupancy, year of construction, number of

[1] https://www.lloyds.com/market-resources/underwriting/realistic-disaster-scenarios-rds

storeys, plan area, and possible insurance policies. A basic building taxonomy has been recently developed as part of the GFDRR-DFID Challenge Fund.

- The data collection tool should be directly linked to a GIS disaster database for data uploading, storage and post-processing, and an integrated web portal for data management and visualization. It should be able to operate in an online mode to support real-time data sharing, and offline mode in case of limited access to mobile or wireless networks.
- The training programs of the full-time personnel for the damage assessment should include sessions regarding the use of the field data collection tool.
- The data aggregation and reporting system could be linked to an online repository for disaster data, such as the GEM Global Consequences Database. Users of the tool (it is primarily designed for a national or regional disaster management authority) should have the explicit option to share data with this repository, set the level of aggregation in which to report the data and set the onward licensing/use restrictions for the data.

- **Selection of an IT system for the aggregation and reporting of disaster data**
  - The disaster loss database should be designed to accommodate the collected data in a consistent and homogeneous manner, enable data validation, post-processing and aggregation, while preserving the initial granularity, and promoting information sharing using an open-data policy. In addition, the database and IT system should be centralized, owned and administrated by the disaster coordinator. This project also covered the conceptual design of such IT system (see Chapter 7).
  - Establishment of a data verification mechanism, both automatic and by technical experts. Once the damage data are uploaded from the field data collection tools (or manually should paper forms be used), data verification/validation should take place prior to the sharing amongst the stakeholders.
  - The disaster database should be connected to a framework (if available) for funding compensation and reconstruction activities, as established in Mexico (FONDEN). This is a fundamental step and one of the main drivers of rapid recovery after the occurrence of disasters.

- **Multi-hazard risk assessment**
  - Acquisition of pre-existing multi-hazard risk assessment knowledge, disastrous past events, and existing probabilistic models.
  - Collection of exposure and vulnerability modeling by utilizing the baseline data, pre-existed empirical damage data and analytical engineering tools.
  - Performing multi-hazard risk assessment, producing illustrative relative risk metrics able to indicate the high-risk areas, and disaggregating the results per hazard.
- **Hazard and loss forecasting**
  - In the preparedness Phase, disaster authorities should establish close relationships with authorities on perils that some level of forecast can be achieved. For example, the local meteorological and hydrological authorities may have set up or have access to systems

that provide forecasts of rainfall, flood inundation, storm surge, windstorm, or forecast loss estimates up to days ahead.

- Forecast data can be used effectively for a number of pre-event activities ranging from staging of temporary shelters in local warehouses, tasking of satellite image acquisition, communicating with the public about preparedness actions, communication with NGOs and first responders to identify responsibilities and avoid duplicated efforts, to forecast-based financing or parametric insurance products. Understanding if the Emergency will have multiple Events (e.g. monsoon flooding on major rivers will come in multiple 'waves'), will help communication across all stakeholders.
- Linking forecast-based hazard data to catastrophe loss models will allow for forecast-based loss assessment – allowing for the development of parametric products suited to the local context and needs of the Ministry of Finance (MoF). This will also help decision-making within the MoF prior to and during in the React Phase as to the amount of capital to be allocated to immediate relief efforts, or play a coordinating role amongst international donors.

3.2. Phase 1: Emergency response

- **Declaration of an Emergency**
  - The Conceptual Framework and tools developed in this project have a common boundary between the Prepare and React Phases, demarked by the formal declaration of an emergency by the disaster management authority. It is this declaration that defines the Emergency and Event parameters in the data collection and aggregation system, whereby damage is attributed to one or multiple event(s) within a single Emergency (see Appendix H for more details).
  - In this Phase, the damage data collection and aggregation systems would be set up to allow for hazard mapping and early damage estimation using pre-loaded baseline data on population, assets and exposure.
  - Capacity and responsibilities for managing data can be confirmed once the availability of the local data management team is confirmed – there may be damage to office facilities, equipment, servers, etc. or the team members may be personally affected by the event.

- **Identification of hazard event and affected areas (within the first few hours)**
  - Identification of the affected areas using remote sensing techniques (e.g. UAVs), real-time satellite imagery and first response data. Information regarding the state of essential services is collected at this stage. This approach is currently being explored in Queensland, Australia and has become commonplace after natural disasters in the last decade. There are numerous initiatives that exist to provide interpreted products derived from satellite imagery in the hours and days after a disaster. However, often, particularly outside of Europe and North America, these sources of data are not widely known to emergency responders, and are still underutilized, as was the case in the 2015 Nepal earthquakes. Making connections to these organizations and understanding the types of data outputs and how to receive the data needs to be undertaken in the Prepare Phase. It

is possible for the affected authorities to capture and process their own imagery data to extract damage or hazard information from a range of sensor platforms.

- Estimation of the severity of the event, including prediction of casualties, damaged buildings, and monetary losses using scenario-based damage assessment and loss estimation tools (granted that the baseline information described previously is available).
- When and if the government declares the event as a natural disaster, the event is uniquely characterized within the disaster database, along with its main features (e.g. hazard footprint, expected impact).

- **Application of the emergency response protocol (72 hours)**
  - Based on the information from the previous step, the responsive authorities and agencies carry out emergency operations to ensure the safety of the public. Preliminary countermeasures are applied to ensure that no life-threatening situations exist or arise.
  - The activities of this phase are focused on the immediate assistance to the affected population and the data collection is limited to the estimation of the human impact (e.g. number of fatalities, injuries, and missing people).
  - A potential crowdsourcing protocol is suggested in the specification document for the damage data collection tool (Appendix H). It is now that the national or regional authority would commence the protocol, sending short message service (SMS) prompts to those areas thought to be affected and receiving basic damage information and locations in return, assuming a cellular data connection is operational.

- **Rapid damage assessment (7-10 days)**
  - Vehicle-based (windshield) assessments are carried out in the affected areas by the responsible organizations and authorities within their AOR. The affected areas and essential damaged buildings are mapped using a georeferenced system, in order to use this information for the planning of the detailed damage assessment.
  - The rapid damage assessment in initiated to evaluate the safety and immediate usability of the damaged buildings and infrastructure. Assets deemed unsafe are flagged for the detailed damage assessment (see next Phase).
  - The data collection is limited to the estimation of the number of partially and completely damaged assets, homeless and affected population. The objective is to inform decision-makers regarding the immediate relief activities, such as temporary shelters, temporary assistance to affected people, and resource allocation.
  - The rapid damage assessment phase is concluded when all the affected areas have been investigated and mapped, and preliminary statistics per administrative area have been compiled.

3.3. Phase 2: Detailed damage assessment

- **Planning field surveys (2-3 days)**

- Information from the previous phase is utilized to plan the activities of this phase, by defining specific areas where damage assessment at the asset level will be conducted, while the detailed damage assessment of the essential buildings and services is continued.
- Meetings are held at the central premises of the disaster coordinator where all the stakeholders, agencies and organizations responsible for the data collection participate (e.g. this was the protocol followed after the first seismic event that hit the Italian town of Amatrice in 2016). The respective local authorities and agencies of the affected areas are contacted. Depending on the severity of the event and number of available trained surveyors, an ad-hoc time schedule is created and decisions are made regarding the training of additional personnel and volunteers. Damage assessment coordination centers are set up in the affected areas, administrated by representatives of the disaster coordinator, where the planning and monitoring of the daily surveys and potential training will take place.
- The damage assessment teams are created, including full-time trained surveyors, sector specialists, GIS experts, local engineers and architects, and volunteers. The core of experts and specialists of each team should not be altered until the end of this phase, and no team should be formed without full-time personnel, in order not to compromise the quality of the damage assessment.
- The affected areas are divided in sub-regions and assigned to the investigation teams, while the surveyors are equipped with the data collection tools, which incorporates the GIS layers (i.e. maps) and the daily tasks to be completed.

- **Field surveys expedition (5-8 weeks)**
  - Daily asset-by-asset detailed damage assessments are performed, and all the impacted buildings and infrastructure are investigated. This is particularly important to initiate the release of funding required for the reconstruction/recovery activities. Undamaged buildings should also be accounted for in order to use the data for vulnerability modeling.
  - The collected georeferenced data are uploaded directly in the central disaster database using a wireless or mobile network, and real-time updates of the affected areas are provided. All the assets where the indirect losses will be assessed in the next phase are explicitly indicated, such as commercial, industrial and agricultural assets.
  - At the end of each day, a meeting is held in each coordination center where all the assessment teams participate, in order to address possible issues during the data collection, finalize uncompleted surveys, and plan the tasks for the next day, including re-inspections, whenever necessary. In addition, the collected data that were not uploaded due to limited access to mobile networks are uploaded to the central database.

- **Data processing and information dissemination (in parallel)**
  - The collected data are stored and organized into the IT system (see Phase 0) following the pre-defined formats. Data verification takes place by technical experts.

- Spatial and sectorial data aggregation is conducted, based on the needs of each end user (the asset-level granularity is preserved in this process). Different damage and loss indicators at different resolutions are required for decision-making, and the sectorial loss estimation considering the interdependency of the affected sectors is an essential tool for resource allocation (such outputs were fundamental for the recovery activities in the Philippines after the Yolanda Typhoon in 2013).
- The collected and processed information is shared with all the involved stakeholders and decision-makers. The type, format and granularity of the shared data varies among the multiple end uses, which are defined in regulatory framework defined during the disaster preparedness phase.

- **Reconstruction initiation (in parallel)**
  - The reconstruction phase is initiated in parallel with the field surveys and is managed by the reconstruction authority.
  - The reconstruction and retrofitting of essential buildings and services is prioritized, while the reconstruction authority is in close collaboration with the respective governmental departments.
  - The individual applicants access the web-portal of the reconstruction authority to provide additional information that may be required to access additional funding for the reconstruction or retrofitting measures, such as house ownership, annual income, and potential existing of an insurance policy.
  - The activities of the detailed assessment phase continue until all the damaged buildings and infrastructure of the affected areas are surveyed, while the reconstruction and recovery activities carry on.

3.4. Phase 3: Reconstruction and recovery monitoring

- **Assessment of indirect losses (1-2 weeks)**
  - A few months after the completion of the detailed damage assessment phase the identified assets for the estimation of the indirect losses due to business interruption are re-inspected. The estimated monetary losses are uploaded to the IT system, to complement the already collected/estimated direct damage/loss metrics.

- **Monitoring the reconstruction process (every 2-3 months)**
  - Technical experts of the reconstruction authority in conjunction with the disaster coordinator perform periodic field visits on the damaged assets under reconstruction and retrofitting. The objective is to provide systematic feedback on the recovery and reconstruction progress, based on the collected damage data from the detailed damage assessment phase.
  - The collected information is uploaded directly to the IT system and is compared to the damage data collected in the previous phase, in order to benchmark the progress and level of completeness of the reconstruction process. The reconstruction and retrofitting

process should follow the 'Build Back Better' concept. Therefore, a technical expert committee of the reconstruction authority should evaluate the progress and guide the reconstruction efforts towards that direction.

- The monitoring and evaluation of the reconstruction efforts is an ongoing process, and the inspection of the damaged assets is carried out systematically until the reconstruction is sufficiently completed.

- **Complete event scenario (2-3 months)**
  - The disaster coordinator gathers the post-processed data from all stakeholders, organizations, and scientific institutions. These include the total number of partially and completely damaged buildings, direct and indirect monetary losses, direct and indirect affected population, and hazard footprints. The disaster database is updated and the event characterization is completed, including its physical attributes and overall consequences to the affected area (this is one of the strengths of the RISPOSTA system, see Chapter 4).
  - Based on the experience of the involved personnel in the different phases, each stakeholder submits an evaluation report to the disaster coordinator, regarding the performance of each component. The feedback from these reports is used to improve the damage assessment guideline, timeframe of activities, field data collection tool, and IT system.
  - The disaster coordinator in collaboration with scientific organizations and institutions integrate all the collected data, in order to update the baseline information (see Phase 0), and probabilistic risk models. The existing vulnerability functions are calibrated and additional functions are derived. Furthermore, multi-hazard assessment is performed and the information is disseminated to the organizations and governmental agencies responsible for emergency response and disaster management.

The satellite and remote sensing data are cross-referenced with field observations. This will improve the tools used to identify the affected areas immediately after the occurrence of an event, which can support the rapid prediction of total damage as well.

4. Overview of damage collection protocols

Four protocols for disaster damage and loss collection were reviewed in detail in this project, one with a global applicability (DaLA), and three developed specifically considering the context of the associated region or country (RISPOSTA – Umbria, Italy; FONDEN – Mexico; DARMsys – Queensland, Australia). This section provides an overview of this review, while additional details can be found in Chapter 11.

The **DaLA** protocol has the advantage of being a multi-hazard methodology, which can be applied in any country regardless of its domestic protocols and level of socioeconomic development. It covers a wide range of sectors, thus leading to a comprehensive view of the impact of the disaster. It has been applied mostly in developing countries where a dedicated national framework did not exist or was insufficient to assess the disaster needs. Despite the recognized value of such protocol, it relies heavily on the availability of baseline (pre-disaster) data regarding the state of the building stock, infrastructure, agriculture, livestock, forestry, amongst other elements, and **it does not compile information at the asset level, which hinders the use of the disaster data for a multitude of other purposes**. For example, as described in the case study for Nepal, the process for data collection proposed by NSET allowed the development of vulnerability models that could be used in the improvement of risk models for the country, or in the rapid estimation of the impact of future earthquakes. In Australia, the detailed loss assessment allowed the improvement of the current DARMsys framework two times since its first implementation. Moreover, the damage data in Queensland is used directly to support the affected population with financial support, without the need for another data collection process. It is also relevant to note that the application of a protocol that has not been explored previously in a given country will likely lead to institutional challenges, where the roles of the existing organizations in the country are not clear. We do not claim that such aspects are necessarily a limitation of the DaLA protocol, as it was not developed for detailed damage data collection, but simply to assess sectorial needs after a disaster and to inform the recovery process.

The **RISPOSTA** protocol has been developed specifically for the region of Umbria in Italy, though its platform seems to be easily applicable to future flood events for other regions in the country. It features IT tools to support the data collection and management process, and the data collection is carried out at the asset level in a sector-by-sector basis, which allows for further data analysis and disaggregation. Despite the pioneering character of this approach, its performance in collecting damage and loss data from other natural hazards (e.g. earthquakes, landslides, storms) is yet to be explored. Moreover, it should also be noted that the events in Umbria were relatively localized, and thus the performance of the protocol could prove to be insufficient in capturing damage in events with a widespread geographical extension.

The **FONDEN** and **DARMsys** systems from Mexico and Queensland, respectively, represent examples of systems that have been developed specifically for a given country or region, and that are currently operational. Both systems, and in particular FONDEN, have been tested for several natural disasters, and proved to be efficient and meet the needs of the end users. The former system relies on technical experts (or individuals with some level of training) to perform the damage and loss estimation/collection, while the latter also contemplates the participation of volunteers, which can download the necessary mobile device app (Survey123 – see Chapter 12). One of the reasons for such difference could be related with the requirements to assess damage from floods (in the DARMsys protocol) and other more structurally damaging hazards (e.g. earthquakes, landslides). Another strong aspect observed in both protocols is the clear definition of the roles and responsibilities throughout the entire process. The FONDEN system in particular also has a clear timeframe, with specific deadlines for each part of the process, which starts with the declaration of a natural disaster by the central government. This is particularly important to ensure that all stakeholders understand when they should contribute to the damage estimation or collection process.

From the review of the existing methodologies (see Appendix A), case studies (see Appendix D) and interviews with the key experts, this consortium identified a number of gaps in the current practice of disaster damage and loss data collection, as listed below. Along with these gaps we also provide a few possible solutions that should be considered in the development of the conceptual framework, along with successful examples from the case studies.

- **Lack of protocols to collect baseline information**: a common point of agreement across all key experts and protocols is related with the important of baseline (or pre-disaster) data. This is a fundamental component in some disaster data collection protocols, and a critical tool for the planning and management of all disaster recovery phases. Every protocol should envision pre-disaster activities to collect detailed information concerning the location, structural attributes (e.g. number of storeys, main material of construction, age of construction, main use) and socio-economic parameters (e.g. number of occupants, workers) of public and private buildings. The same approach should be adopted for the collection of information concerning the infrastructure (e.g. hospitals, schools, energy generation facilities), lifelines (e.g. road network, power grid, water supply system), crops, livestock, fisheries and forestry. This information should be stored in a platform that allows overlapping the pre-disaster built environment with the collected or estimated damage in the affected region.

- **Lack of a plan to establish damage assessment teams**: the lack of trained staff to perform the damage and loss assessment can delay considerably the recovery process, even when a reliable protocol supported by an IT system exists, as observed in the 2016 Central Italy earthquake sequence. Once a methodology for the damage assessment has been established, each country should seek to train a large number of experts, and to establish a program that enables the training of additional volunteers rapidly. Unfortunately, these activities are usually performed after the disaster strikes, and within a time span that might not be sufficient to properly train surveyors. This gap was indicated by experts from the Civil Protection Authorities.

- **Unclear timeframe:** the activities comprised by the damage assessment protocols often do not have a specific timeframe. The plan for the activities should start from the declaration of a natural disaster by the central government, to the final provision of the financial support to the affected population. Clearly a universal timeframe is not possible as each country will have different requirements and challenges (e.g. due to the governing system or disruption that may be caused by the disaster), but a general timeframe should be defined. This timeframe must be in agreement with the available resources and be adjustable based on the specific challenges of the disaster. In this context, it is worth learning from the FONDEN framework which has clear deadlines for the different phases required to issue the financial support. This was one of the current issues reported by the experts interviewed in Armenia (see Chapter 9).

- **Unclear definition of the roles of each organization:** the evaluation of the four case studies highlighted the need to have a clear distribution of responsibilities across all stakeholders, and well-defined protocols to share the data. In the Umbria region (Italy) there difficulties in reaching a formal agreement on data sharing, even though most of the data were shared during meetings prior to the disaster. Similarly, during the Central Italy earthquakes the Italian Civil Protection had to establish agreements with the local authorities in the fours affected regions. These agreements should be established prior to the disaster and with the support from the central government. Experts from the reconstruction authority and civil protection authorities stressed this issue.

- **Lack of a set of parameters to be collected:** each country or protocol currently features different sets of parameters, which are collected during the field missions (e.g. damage on the building, expected loss, level of income), and usually adjusted after the occurrence of a disaster. The definition of these parameters is often not discussed with all of the stakeholders, which creates situations in which the data collected is not sufficient for all of the use cases. In order to avoid multiple data collection efforts (as observed in Nepal), a comprehensive list of the parameters that will be collected for the various purposes (e.g. usability assessment, strengthening campaigns, financial compensation) should be define. However, in order to ensure that the data collection process is still efficient, this list of parameters should be adjustable depending on the final use. For example, the FAST system was developed during the 2016 Central Italy earthquake sequence in order to improve the efficiency of the usability assessment of regular houses. This system required less parameters, which could be extended to the usual method if the building was deemed unsafe. Finally, when available, the set of parameters should also cover the hazard intensity at the location of the collected data. These data can be used to create risk models for the region, or to improve existing ones. This issue was indicated by all of the experts interviewed in this project (e.g. governmental officials, urban planners, local authorities, reconstruction authority, researchers, risk modelers (and in particular vulnerability engineers from the private sector).

- **Lack of a validation process:** the damage and loss assessment procedure must feature verification and validation procedures, which ensure that the collected data is reliable, realistic, useful and usable. For example, from the data collection in the 2013 floods in Umbria, around 23% of the submitted forms were unusable due to lack of fundamental information. This issue can be partially solved by the incorporation of a collection/estimation method using tools for mobile devices, which can automatically provide a first level of verification and validation. This issue was indicated by technical experts (e.g. Politecnico di Milano, Eucentre, NSET) supporting decision makers, and members of the civil protection authorities.

- **Lack of robust IT solutions**: still nowadays most of the data is collected using paper forms, which are frequently lost, damaged and leave room for ambiguity. The collected data in the field should be aggregated using a centralized system that allows further analysis. The system must be capable of keeping all of the collected data separated, and extracting only specific portions of the results (depending on the end use). This system should also allow overlapping the damage and loss data with the baseline information (when available) and/or maps with the hazard intensities (e.g. spatial distribution of water depths, ground shaking in the region, areas where landslides occurred). Multiple stakeholders should have access to the system (or parts of it) in order to be able to plan and adjust the recovery plan and financial compensations in near-real time. The lack of a centralized system (such as the one currently used in Queensland (Australia) or Mexico) is one of the major limitations to the efficient management of disaster damage and loss data. This was a problem indicated by all of the experts interviewed from less developed nations. These experts were part of international NGOs, members of the reconstruction authorities, members of the government in charge of monitoring the reconstruction or the assessment of the needs shortly after the disaster.

- **Disregard of space, aerial or drone technologies**: the use of advanced technologies to capture hazard and damage in the built environment has been entirely neglected in disaster data collection activities, and mostly explored only in academic exercises. However, this technology has reached a level of maturity which justifies its use in damage assessment, mainly in the first days after the disaster when rapid, but yet reliable, information is required to plan the damage assessment missions. Such technologies can also support the collection of damage data in remote areas of difficult access, or in communities that have been isolated due to the disruption of the road network. The former problem was faced during the 2010-2011 Queensland floods whilst the latter was reported by the experts from Nepal after the 2015 Gorkha earthquake. This issue was highlighted by technical experts involved directly in the data collection and aggregation process.

The findings from the overview of the data collection protocols have been incorporated in the conceptual framework presented in Chapter 3.

5. Overview of existing IT solutions for disaster data collection and aggregation

In this component of the project several tools for the collection and aggregation of disaster damage and loss data were reviewed. This section provides an overview of this review, while additional details regarding tools for in-field data collection can be found in Appendix B, and an in-depth review of IT systems for disaster data aggregation is presented in Appendix C.

5.1. IT Solutions for disaster data collection`

The reviewed **tools for the field disaster data collection** serve mainly to two main purposes:

- Post-disaster in-field data collection on physical damages by various survey teams, individual professionals, or citizens.
- Data transmission to an aggregation system for long-term data storage, analysis and estimation of loss.

Furthermore, the tools can be organized in two main groups:

- The **first group** of tools is based on specific methodologies and directional data collection for further use in the assessment of losses. Examples of such tools are **DARMsys**[2], **FONDEN and RISPOSTA**. These systems are based on three architectural components: a methodology, a database, and tools for in-field data collection.
- The **second group** of tools are usually in the public domain, developed for mobile devices, and can be downloaded from a dedicated website or common App Stores. Single users or various groups of users can use these applications for their own professional or amateur purposes.

First Group

The procedures of data collection within this group strictly follow a specific methodology on accounting damage and losses, the information is sent to an institutional database developed for the purposes of loss data collection, and the data is mostly collected by trained survey teams. These IT tools are developed for internal use by governmental authorities in post-event assessment phase and coupled with central aggregation system for data storage. This group of tools performs in-field data collection and data transmission to an aggregation system.

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[2] In the framework of DARMSys monitoring the IT solution Survey123 ArcGIS for form-centric data gathering was integrated. This ArcGIS solution was originally developed for general public in the line of related ArcGIS applications with purpose of creating, sharing, and analyzing of surveys.

The **FONDEN** is a robust inter-institutional framework strongly oriented on post-multi-hazard assessment and funds allocation to affected infrastructures in key sectors (education, health, roads, and low-income housing). The **FONDEN** system consists of official governmental methodology, infrastructure inventory database and IT field tool for data collection, but there is no sufficient information on IT field application and database functionalities. The **DARMSys** is an effective system of Queensland Reconstruction Authority for the post-floods damage assessment and reconstruction monitoring, which establishes a productive collaboration among post-disaster recovery organizations and authorities. For in-field data collection in **DARMSys** was adapted the Survey123 mobile application.

RISPOSTA pilot project is based on three components: methodology, in-field data collection tool and web-portal for data storage and analysis. **RASOR** tools are designed for development of risk scenarios. The disaster loss data collection is an optional functionality of the RASOR system and can be applied rather as an additional secondary procedure. The in-field tools of **DARMSys, FONDEN,** and **RISPOSTA** systems are coupled with central official databases where the data are stored after a gathering.

Second group

The IT tools from this group can be used by entities of engineers, architects, teams of professionals, brigades of volunteers, as well as by individual professionals, or citizen scientists. Basically, the applications allow enhancing current risk management capabilities and providing state-of-the-art solutions for post-disaster data collection. Examples of such tools are **ROVER**, **GEM Android App**, **I-React** or **MAGE**. These tools are cover case of physical damage data collection by survey teams, individual professionals or citizen-scientists. This group of tools perform only in-field data collection. It is not coupled with a system for long-term data storage or data analysis.

These solutions are state-of-the-art applications with smart interfaces and user friendly. These applications are supported by technical documentation, manuals and supporting chats. The **MAGE**, **GEM Android App** and **Survey123** applications can be installed on GPS enabled common devices (like a smartphone) and after some easy settings can be used by survey teams. **MAGE** and **Survey123** applications allow data collection for multi-hazard events. The **GEM Android App** is designed for data collection after earthquakes. The **I-REACT** project is under development and currently does not offer ready solutions for in-filed data collection.

The IT in-field tools are commonly designed for affordable smartphones, which are equipped by widespread Operational Systems, digital cameras, GPS functionalities and sufficient memory for conduction of in-field data survey. The basic information collected usually includes: georeferenced pictures, video, textual information, and voice recordings. The **DARMSys** (Survey123); **FONDEN** in-field tool; **RISPOSTA**; **GEM Android** application, and **ROVER** are collecting pictures and textual information. **MAGE** application allows also voice recording. The georeferencing is usually an automatic function during a data capture at asset level. **MAGE**, **ROVER** and **FiDAT** IT tools transmit gathered data on a local server (or smartphone memory). This IT tools developed for small survey teams, or for individual professionals, are relied on a storage of data on a local server.

Almost all the use cases listed in the Task 1.2. can be applied to **DARMSys** and **FONDEN** systems, which incorporate robust methodologies related to Emergency management; Reconstruction planning; Resource allocation; Fund mobilization activities; and Long term investment planning. The **RISPOSTA** procedures are also recording information on monetary losses, for further provision of information to responsible authorities for Resource allocation. The **MAGE, ROVER, Survey123, GEM Android** in-field tools are designed basically for data collection related to Emergency management.

The review of the existing tools for disaster data collection allowed the identification of the following gaps and recommendations:

- **Lack of basic functionalities**: most of the tools did not support some basic capabilities such as:
  - Support for static geospatial layers: buildings, public places, industry, infrastructure, etc.
  - Option to display already checked/visited objects (assets).
  - Visualization of the status of completeness of the assessment.
  - Support for a shared chat between team members.
  - Control over the location of team members.

  This gap has been identified by emergency management authorities, structural engineers and other experts (some of them volunteers) involved in field post-disaster data collection.

- **Lack of flexibility to cover multiple hazards:** Often the IT tools are designed for data collection for one specific disaster, for example flood (e.g. **RISPOSTA**) or earthquakes (e.g. **ROVER**). The functionality on multi-hazard data collection by one tool would provide a wide coverage of disaster events and will be more functional for use in application to different situations. The multi-hazard approach would be an effective solution from an economic and functional point of view. **Survey123** and **MAGE** are designed following a multi-hazard approach. These issues were indicated by members of civil protection authorities, representatives of local governments, and post-emergency relief decision makers.

- **Lack of a centralized storage system**: The tools developed for data gathering by small teams or a single person rely mostly on storing the data on a local server (or device's memory card). A robust database is fundamental for systematic loss data collection, storage and further data use. An official data collection system at national level should rely on a centralized aggregation system. A reliable solution is a joint design of an IT tool with an aggregation system, similar to what has been followed in the development of the **DARMSys, FONDEN** and **RISPOSTA** systems. This gap was mentioned by members of civil protection authorities, local authorities and governmental organizations (responsible for the damage and loss data collection and storage).

- **Inadequate data form**: The data forms should insure accurate and consistent data recording. The main gaps of predefined forms in the reviewed tools were:
  - Excessive complexity: data forms are too complicated for users.
  - Mandatory questions are not related to a real situation.
  - Impossibility of digital checking if an object/asset was already assessed during a survey operation.
  - The data collection form is the same for volunteers unfamiliar with the procedure and professionals with experience in data collection.

  The data form should be accompanied by instructions on data filling and be extensible allowing possibility to add extra fields (see also recommendation on the Conceptual Framework – Chapter 3).

- **Lack of a damage/asset taxonomy:** The lack of indication of a standard/taxonomy for the description of the affected assets, set of physical damages, categories of vulnerable objects for assessment, scale or magnitude of an event, etc. Standard specifications of affected assets are used for example by **RASOR** and **GEM Android** tools. **GEM Android Building Data Capture** application is based on the GEM building taxonomy. In **ROVER**, two international standards of seismic safety screening procedures (FEMA P-154 and ATC-20) are applied. **RASOR** building categories are characterized through a series of physical attributes, in accordance with GEM and HAZUS taxonomies. Some of these problems were mentioned by emergency management authorities, structural engineers and other experts (some of them volunteers) involved in field post-disaster data collection. This was a common issue expressed by the majority of the experts (emergency management authorities, governmental agencies, local authorities responsible for damage and loss data collection; professionals, volunteers, and individuals involved in post-disaster data collection; national reconstruction authorities, ministries of public works, urban planners).

- **Insufficient documentation**: There is a lack of manuals and technical notes designed for different groups of users. Usually FAQs sessions (if available) are not well-supported by developers of tools. For the users it becomes an issue to find some information on functionalities of the tools and specifications. At the initial stage of design the definition of groups of end-users is fundamental, so different types of documentation can be developed. For example: field inspectors – for principal data collection and preliminary assessment; volunteers - for additional data collection such as pictures, video, clarifications on affected objects; and for affected citizens – for property damage declaration; requirement of funds, or insurance claim. As a good example, the **Survey123**, **GEM Android** and **RICS** tools are accompanied by detailed manuals and instructions. Some of the experts that indicated this issue include field inspectors responsible for data collection and preliminary assessment, volunteers involved in additional data collection such as pictures, video, clarifications on affected objects; and householders that had to provide additional damage information for the purposes of funding compensation and/or pursue insurance claims.

5.2. IT tools for disaster data aggregation and reporting

Almost all of the reviewed systems for **disaster data aggregation and reporting** are used by official authorities for institutional data collection. The **AJDA** (Slovenia), **NDOIS** (Moldova), **CDTE** (Spain), and **FloodCat** (Italy) are official national loss data collection systems based on national legislation and well-defined methodologies on loss data accounting. The **DesInventar** accounting system is also used by governments of many countries as official aggregation systems of disaster damages and losses.

These databases are not intended for sharing of collected data with the general public and do not provide open access to the data. For example, the official national disaster databases such as **AJDA**, **NDOIS** and **FloodCat** are internal databases, and summaries of data are provided to stakeholders in form of statistical analysis and reports. **Desinventar** allows access to the data of different countries by an analysis module, with prior official consent from associated country.

The specific mobile applications and devices are not used for in-field data collection for these aggregation systems. The disaster loss data is collected mainly by official trained survey commissions using as a rule paper forms (**AJDA**, **NDOIS**, **FloodCat**), call centers (**NDOIS**), and automatic telephone interviews (**HOWAS21**). The instruments for statistical data analysis and mapping tools are embedded in some systems (e.g. **DesInventar**, **AJDA**).
The aggregation systems are commonly *SQL*-based, typically *PostgreSQL* using *PostGIS* support for geographic objects. One particular advantage of SQL is its simple and powerful *JOIN* clause, which allows developers to retrieve related data stored across multiple tables with a single command. *PostgreSQL* generally shows advantages in complex data models. It is *SQL*-compliant and open-source Relational Database Management System.

The 5th Global Platform for Disaster Risk Reduction (5th GP-DRR) working session on "Risk Information and Loss Databases for Effective Disaster Risk Reduction" (Mexico, 22-26 May 2017) highlighted the importance of standard methodologies and guidelines for the collection of data in creating and maintaining national loss databases and risk assessments. The compliance with worldwide accepted standards and methodologies in loss data collection is important for further analysis of trends, comparison among different countries. In addition, it is important to acquire data in a standardized format to enable effective data sharing. The European and worldwide standards currently in use by reviewed aggregation systems are:

- Sendai Framework for Disaster Risk Reduction (indicators to monitor progress and achievement against global Targets A, B, C, D). The UN General Assembly (December, 2017) has defined 38 indicators for monitoring the targets of the Sendai framework, on which participating countries are required to report.
- Floods Directive 2007/60/EU (categories which can be affected by potential adverse consequences of floods: human health, environment, cultural heritage and economic activity).
- EU JRC minimum set of damage and loss indicators (human loss; physical damage; direct economic loss to different economic sectors and infrastructure).

DesInventar DataCard is recently updated in conformity with the SENDAI Framework indicators A, B, C and D. The FloodCat catalogue is designed in line with EU Floods Directive 2007/60/EC provisions and JRC minimum requirements for data recording and sharing by EU Member States.

AJDA (Slovenia), **NDOIS** (Moldova) databases implement data recording in accordance with national legislation standards. This fact together with positive aspects creates also some difficulties in transferring and adaptation of procedures on data collection to other systems.

The concept of open source software is important for design of new or improvement of existing IT tools. Open source software supports open exchange, collaborative participation, rapid prototyping, and transparency. The **FloodCat** database was developed following an open source approach, which can be used with authorized permission from the Italian Department of Civil Protection for development of IT solutions. The **NDOIS** database of the Moldova Civil Protection Service is based on the GISCUIT software. GISCUIT is a web-mapping platform with an open source code, provided under various software licenses (or packages) with the possibility of purchasing additional modules. The **HOWAS21** is system for flood loss data collection. It is managed by GFZ University of Potsdam and provides access to collaborators who contribute with data. Other stakeholders have limited access to data after registration and official permission from GFZ. The **CDTE/CNIH** systems are not open source. Databases are populated by official authorities. Systems were developed following the same methodology and provide access to the general public through web-portals. The **DesInventar** system is a unique inventory system following an open source approach for multi-hazard data aggregation in line with the Sendai Framework for Disaster Risk Reduction. **DesInventar** is provides various statistical and mapping tools for data visualization and preparation of tables. The software can be configured for specific needs of risk managers and other users.

According to the JRC report (2013)[3] the three main application areas for loss data aggregation systems are:

- Disaster loss accounting to document the trends and aggregate statistics informing disaster risk reduction programs.
- Disasters forensics, which identifies the causes of the disaster, with the aim to improve disaster management from lessons learnt.
- Disaster risk modeling, for improvement of risk assessment and forecast methods, for which loss data are needed, for calibrating and validating model results in particular to infer vulnerabilities.

The **DesInventar, AJDA, NDOIS, HOWAS21, FloodCat, CDTE/CNIH** cover these three application areas, and are also suitable with some of the use cases listed in Chapter 2:

- Emergency management.
- Resource allocation.

[3] T.De Groeve, Recording Disaster Losses, EC JRC, 2013

- Reconstruction planning.
- Risk reduction targeting.
- Long term investment planning.

The review of the existing IT solutions for disaster data aggregation allowed the identification of the following gaps:

- **Insufficient documentation and transparency:** The three basic components for loss data collection, identified previously in the Inception Report, include: methodology – in-field data collection tool – aggregation system. Some of reviewed aggregation systems do not provide a description of a methodology on which loss and damage data collection was performed. The methodology is a basic component defining the process, types, indicators, categories, etc. of loss data collection. The systems **FONDEN, DARMSys, RISPOSTA, DesInventar, FloodCat, NDOIS,** and **AJDA** are based on well-described methodologies and can serve as an example of robust data collection systems. The central aggregation system is fundamental for systematic and robust loss data collection at national level. This gap can be filled by existing solutions such as **DesInventar**, **AJDA, NDOIS, FloodCat,** and **CDTE/CNIH**. These are examples of institutional systems for data collection and storage. The lack of documentation has been indicated by governmental organizations, civil protection authorities, and national/international organizations involved in disaster risk reduction and mitigation.

- **Disregard of economic losses**: The data collection focuses mostly on physical damage, and often neglects the assessment of the economic impact. The automatic calculation of direct (and indirect) monetary losses of different industrial assets, infrastructure, economic sectors, disruption of services, etc. could add value to an aggregation system. This gap was highlighted by governmental organizations (responsible for the funding), representatives of the ministry of finance, experts from (re)insurance companies, and policyholders involved in natural catastrophe insurance schemes.

- **Lack of post-processing functionalities**: In order to analyze and process disaster data a set of additional (or external) tools is often necessary. As highlighted by the end-users, several external modules are used for the preparation of reports. The statistical functions, graphical visualization, designation of charts and thematic maps are useful tools for data processing that should be part of the aggregation system. This gap has been partially resolved within the **DesInventar** accounting system, which provides a multi-functional analysis module equipped by various tools for data processing: querying tables, statistical analysis, thematic maps, graphics, charts, and cross tables. The **AJDA** (Slovenia) database and **HOWAS21** database provide functionalities for basic statistical processing of data. The **FloodCat** catalogue and **NDOIS** (Moldova) systems have functionalities for preparation of official reports in a predefined format. The lack of functionalities is a problem that was indicated by Governmental organizations and local authorities during the preparation of official reports; natural catastrophe exposure modelers, disaster prevention and management decision makers, natural catastrophe and disaster risk modelers, research institutions, academia and organizations involved in disaster risk reduction.

Insufficient granularity: The loss and damage data collection at asset level plays a decisive role for the further accuracy of the aggregated data. Often aggregation systems provide data collection at the level of an event, such as **DesInventar** or **FloodCat**. The scale of disaster data collection provides an indication of the precision of the measurement of losses. There cannot be precise statistics on disaster losses if there is no detailed loss data collection. In the JRC Guideline "Recording Disaster Losses" (2013) the importance of asset level scale is emphasized. The asset level refers to measurement of the damages performed at the building level. The aggregation of the data by an aggregation system can be at national level, but precision, or scale, still remain at the asset level. The insurance companies are usually use asset scale for claims. The aggregation system should insure data collection at the level of an asset. For example, the **AJDA** system is based on national cadastre. The loss data assessment is conducted on the base of the real value of constructions. In the **NDOIS** system the data collection is performed at the level of an asset by an assessment commission. Representatives from local governments, national reconstruction authorities, ministries of public works, urban planners, ministry of finance, and disaster risk modelers.

- **Lack of standards for the definition of disaster data:** The lack of standards during data collection, as well as reporting tools in accordance to international and national standards, is a significant gap in aggregation systems. These functionalities are important for data collection for national DRR purposes and international data sharing. An official aggregation system should rely on standards. For example, the data accounted by the **DesInventar** system is automatically reported to SENDAI Framework Monitoring System and Sustainable Development Goals (SDG) portal. **FloodCat** catalogue generates official reports for reporting on floods in line with the EU Floods Directive, meeting the requirements of European Commission. The national databases **AJDA** and **NDOIS** provide standard reports in accordance with governmental prescriptions. This was a common issue amongst most of the end users, apart from regions where an IT system for the disaster data aggregation was well established.

- **Need to improve event Data Cards**: One of the principal components of an aggregation system is the definition of an event Data Card. The main gaps related to Data Cards include:
  - Inflexibility when additional fields are not provided for complementary data.
  - Complexity of Data Cards, which hampers the correct entry of data.
  - Ambiguity of field titles leading to double interpretation of the damage criteria.
  - Inadequate operator's skills.

The event characteristics, damage and loss indicators, affected sectors, and level of disaggregation of parameters should be defined in a DataCard. **DesInventar** and **FloodCat** rely on detailed DataCards in accordance with specific methodologies. The operators performing the data entry should be familiar with a methodology for loss data collection, and should be well instructed on mandatory data; extensible fields; damage and loss indicators, etc. This was a problem identified by operators of emergency management authorities, civil protection authorities, and local authorities involved in disaster damage and loss data registering.

Lack of open-source IT solutions: In general, aggregation systems are designed as governmental tools or provided for use on a commercial basis. The further configuration or adaptation for specific needs of such systems is not possible. In order to design an IT system that can be transferable in future to another context, a new system software should be based on the open-source code principles. This concept is followed by: **DesInventar, FloodCat** (with the official permission of Civil Protection Department), and RASOR (provided upon request). This issue was recognized by emergency management authorities, civil protection authorities, researchers, academic and representatives from governmental agencies.

6. Conceptual design for a damage collection tool

This section describes the development of a conceptual design for a site data collection tool suitable for collecting variables on Exposed Elements to enable *in-situ* data collection through each of the four phases of the conceptual framework. Although the tool is primarily designed for collection of basic and detailed damage information, the data entry forms can be configured to collect information on building safety or recovery.

A standalone document with a full description of the functional and non-functional requirements in the conceptual design can be found in Appendix A.

Data collection is carried out using site-based data entry forms loaded onto widely available smartphone or tablet mobile devices using a mobile application sourced via an Application (App) Store (e.g. Google Play). The mobile application will leverage several components of the mobile device hardware to assist and evidence data collection as illustrated in Figure 3.

Figure 3 – Site data collection tool components

A pervasive theme within the conceptual design is the notion of an expansible system, that can be extended by the system users, or more precisely a trained system administration team which would include the stakeholder country emergency response coordinators. As such, the conceptual design does not seek to define a fixed taxonomy, but feasibly allows for any developed or future taxonomy to be adopted within the system. Therefore, the conceptual design seeks to work alongside the developed taxonomies identified in the Phase 1 report and more specifically the GED4ALL – the Global Exposure Database for Multi-Hazard Risk Analysis (developed within the GFDRR-DFID Challenge Fund – Silva et al[4]. 2018) with links into established taxonomies, RASOR, Hazus, ICC and IUCN with implied linkage to the Sendai framework.

The conceptual design provides a transparent and low-cost solution for adoption by users in low- to middle-income countries and will hence seek to use open source components by choice. In-built expansibility of data collection forms will enable country and language variations to the 'core' data collection process which will be very closely aligned to the conceptual framework phases.

The site collected data will be synchronised with a centralized server, which will accept new data edits from a user and pass back changes from other users. The synchronised data will then be available to a web-based application that will allow the viewing, editing, review, aggregation and reporting of the collected data. The data aggregation and reporting system is described in Chapter 7.

6.1. **Use cases**

A number of use cases were defined in Phase I of the project (see Chapter 2). These were used to verify that the design of the conceptual system would be fit for purpose for a variety of users and purposes. Those use cases are summarized below:

- Emergency management and immediate relief measures
- Evaluation of safety and usability of buildings
- Funding mobilization
- Reconstruction planning
- Development of disaster risk reduction measures
- Exploration of benefit-cost analysis (BCA)
- Long-term investment planning.

These use cases were expanded to take into account historic disaster events and their technological contexts – i.e. to consider the access to technology and tools for low to middle-income countries as well as higher income countries. This was important to test the expansibility and generalisablility of the tools to a variety of stakeholders, experience levels and access to technology.

6.1.1. Use of the proposed solutions within the conceptual framework

The use cases span a range of activities across the four phases of the conceptual framework. The site data collection tool and data aggregation and reporting system can support each of these activities in different ways. Figure 4 describes the use of each of the tools as well as external tools, models and

[4] V. Silva, C. Yepes-Estrada, J. Dabbeek, L. Martins (2018). GED4ALL - Global Exposure Database for Multi-Hazard Risk Analysis - Inception Report. GEM Technical Report 2017-01, GEM Foundation, Pavia, Italy.

data. Additional information about the relation between the data collection tool and other resources can be found in Appendix C.

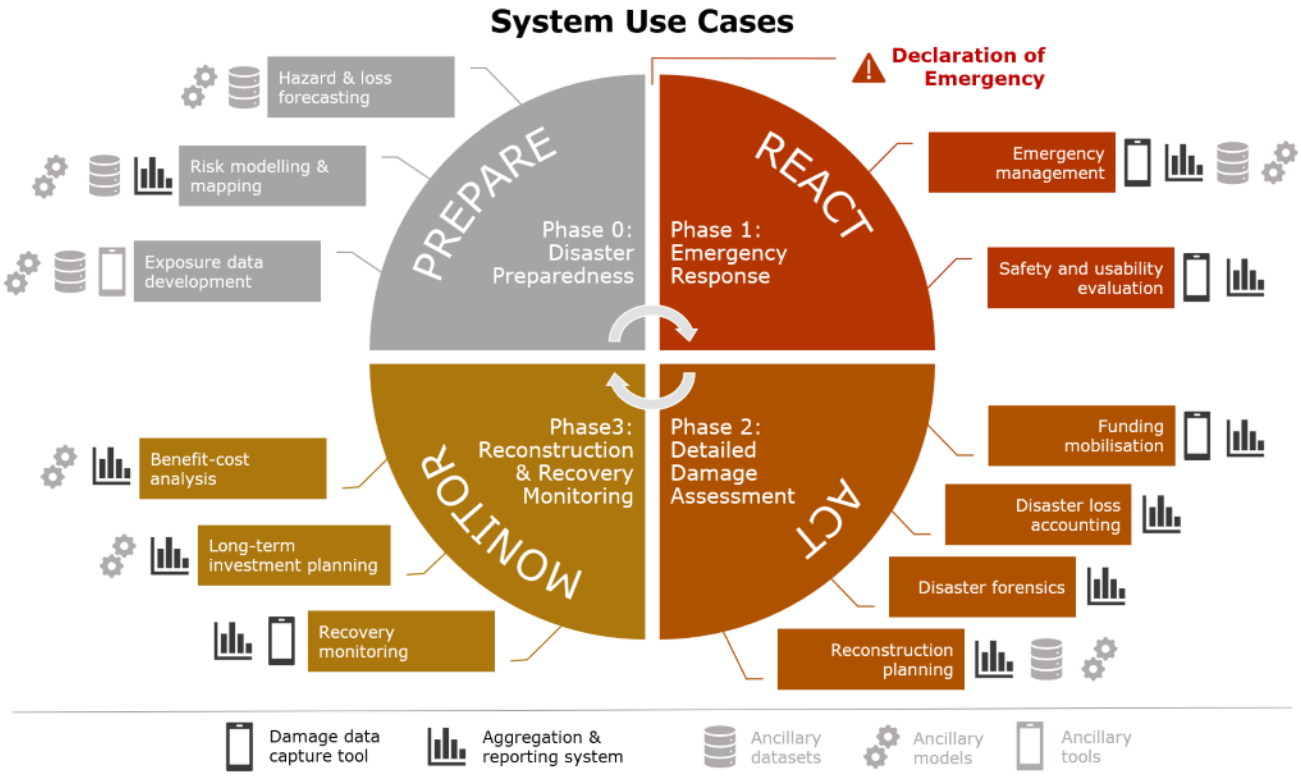

Figure 4 - The use of the damage data collection tool and data aggregation and reporting system to meet the use cases in each phase of the conceptual framework.

6.2. Design influences from existing systems

There are a variety of methods for post-disaster data collection as listed and discussed in Chapter 4. With respect to site damage data collection, each country has their own methodology and systems to collect data. This can vary from summary estimates, paper-based surveys to structured data collection methods.

The functionality defined in the FRDs in Appendix H and I leverage the learning on best practice, structure and products outlined in Chapter 4 and 5, extracting the strengths of the products presented and provide a coherent design from these strengths taking in current technologies.

For the site data collection tool the following influences can be observed:

- **DARMSys**: Cross-platform customisable data collection tool
- **FONDEN**: Geo-referenced photographs and data verification
- **RASOR**: Multi-hazard taxonomy and Sendai framework output
- **GEM Inventory Data Capture Tools (IDCT)** Android App: Taxonomy, map interface, visual taxonomy support and open source data collection tool
- **MAGE**: Open source dual-platform customisable data collection tool using a NoSQL Database

Adopting best practice from existing systems is included in the conceptual design in other ways. For example, the design adopts the contextual help system developed within the Global Earthquake Model (GEM) Inventory Data Capture Tools (IDCT) Android tool. This has been used widely by GEM users for collection of exposure data around the world and has been a particularly useful feature – even being used for education and training of engineers and surveyors.

It should be noted that **none of the above systems was considered to be suitable for direct adoption as a single application without modification** due to limitations inherent with each system. However, although the data model, form templating, taxonomy, reporting and general user interface design used with MAGE may require modification, the technology stack and design philosophy used within the product along with the open source Apache licensing mean the product could provide a suitable, and substantial starting point for any future system development work. **The feasibility of using of MAGE as a base application to build upon should be further investigated on this basis.**

6.3. Tool architecture

6.3.1. Conceptual design principles

The general philosophy of the conceptual design is to attempt to simplify to the end-user a complex series of data collection objectives to achieve an efficient data collection. This will shift the system complexities to the system developer to provide an expansible and dynamic method of data collection, limiting user options presenting only information required for/of a user in a specific scenario.

The expansibility of the system will be achieved through two fundamental principles:

- Configurable data form 'templates' that can be changed by a system administration and support team.
- Flexible database design.

The aim of these principles is to provide system adaptation without the requirement for code development and system updates. These principles are well established within:

- Asset management systems, such as IBM Maximo[5] or ABB Ellipse[6].
- Open source MAGE[7] system reviewed in the Phase 1 report.
- commercial data collection products, such as ArcGIS including Survery123[8] or JBA's GISmapp®[9]/GISmo[10] products.

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[5] https://www.ibm.com/products/maximo
[6] https://new.abb.com/enterprise-software/asset-optimization-management/ellipse-eam
[7]http://eofsac.org/sites/default/files/2018-02/Wasko_%20Field-based%20data%20collection%20methods%20%28MAGE%20app%29_0.pdf
[8] https://survey123.arcgis.com

Technologies such as eXtensible Markup Language (XML) and JavaScript Object Notation (JSON) are enablers to this methodology and provide documents or partial documents of structured data for interpretation by an application.

The flexibility of these technologies and methodologies is appealing to commercial products due to the rapid adaption for differing clients, but within the context of the post-disaster data collection the stakeholder countries could be regarded as clients and a similar appeal exists. However, it should be noted commercial products are generally not open sourced code to clients and maintain a tie-in to the products. Open source products still have a cost generally as a higher upfront development and implementation cost and require a clear support and maintenance path but can provide a lower lifecycle cost and more importantly here a lower client cost and an increased community interaction and participation.

A core data model with corresponding database, mandatory data collection attributes and templates will be provided as a base to a country's implementation which can then be expanded to their requirements via management user interfaces within the data aggregation and reporting system.

Central to all the data collected within the system will be a spatial representation of a record which can be viewed on a map. Geographical Information Systems (GIS) are at the core of the technology for providing spatial data storage and viewing within a map. This GIS and location technology, used to generate mapping user interfaces, combined with Global Positioning System (GPS) hardware will be a fundamental feature of the system to visualise, manage, and assist survey of the exposed element data.

The conceptual framework described in Chapter 3 using the **Prepare**, **React**, **Act** and **Monitor** phases forms the basis for the construct and layout of the conceptual design. A simplified taxonomy will be implemented under the React phase, aimed at a fast turnaround of site data for post-disaster evaluation. The taxonomies developed under separate projects such as GED4ALL (Silva *et al*., 2018) and RASOR (RASOR, 2017) will form the basis for the more detailed Act Phase data collection.

6.3.2. Conceptual data design

An entity relationship describes interrelated items of interest within an area of knowledge, resulting in a data model. At a conceptual level the data model establishes the overall scope of what is to be included within the model set. Figure 5 represents the 'Core' conceptual entity relationship diagram for the post-disaster data collection.

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[9] https://www.jbaconsulting.com/knowledge-hub/asset-data-collection-tool-gismapp/
[10] https://www.jbaconsulting.com/knowledge-hub/gismo-network-rail/

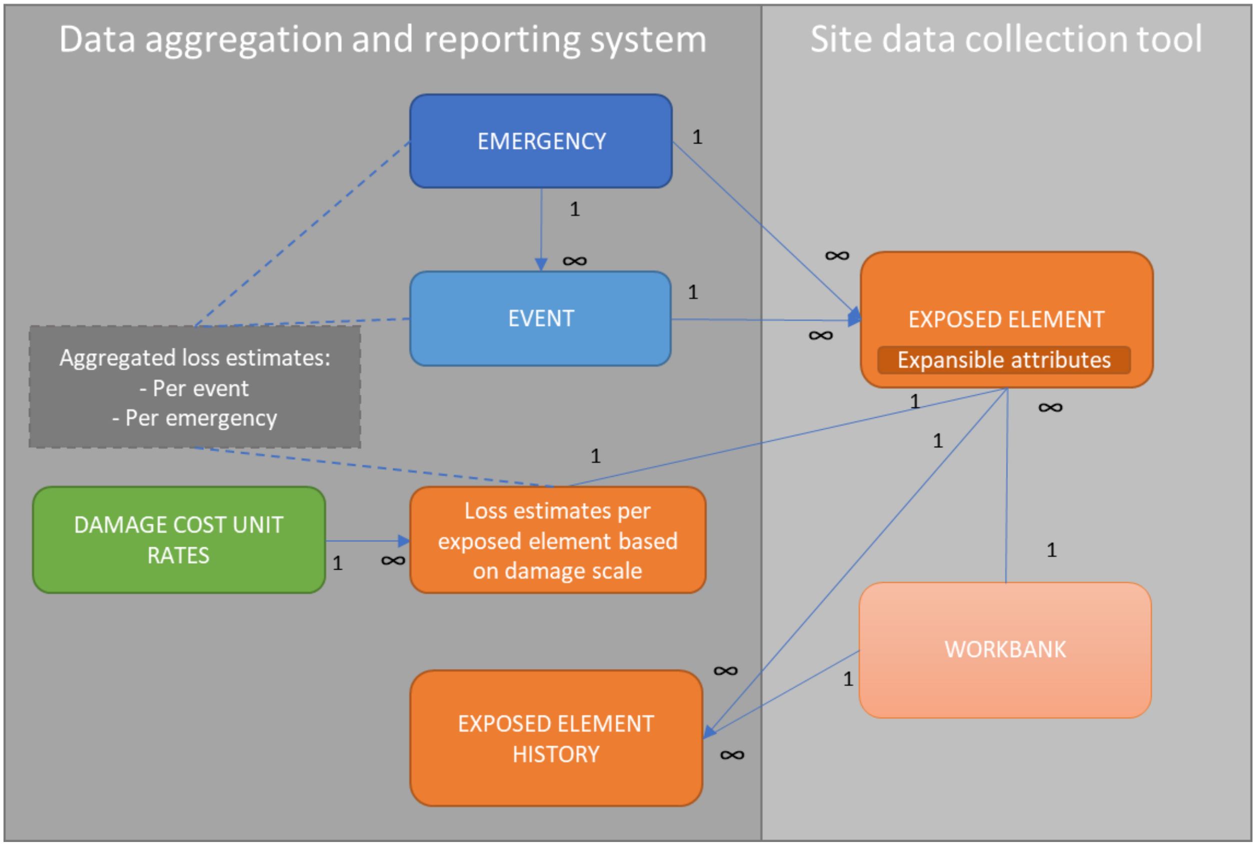

Figure 5 - Conceptual 'Core' entity relationship diagram.

The post-disaster data model should be designed to include the concept of 'Emergency' and 'Event' entities. These parameters will be used to define the context within which data on exposed element entities (buildings, roads, rail, critical facilities, agricultural crops, etc.) are collected.

The conceptual data model will consider a 'Core' data model required to collect post-disaster damage loss only. However, the system features seek to make the system extensible from this core data model as required by the responsible party at the time of implementation based on any additional or localised data collection requirements.

Emergency

An Emergency is defined when a state of emergency is declared by the responsible public authority in the affected country. It is intended that although the physical cause of an emergency may affect multiple countries, that an emergency will always relate to the declaration of a state of emergency which is linked to a singular government and country. The emergency entity forms the high level 'parent' entity to which all data will be related to.

A set of core attributes has been proposed for each Emergency Entity, as described in Table 3-1 of the Site Data Collection Tool Functional Requirements Document (Appendix H).

Event

Within an Emergency, an Event will be defined for a single cause of damage, such as earthquake, flood or landslide events and links to the Disaster Loss Data (DATA) family classification proposed under the Integrated Research on Disaster Risk (IRDR) programme (UNISDR, 2018)[11] 'Main Event' as represented in Appendix I

The event entity forms the main aggregation entity to summarize the collected data in a format compatible with the Sendai Framework and the DesInventar Sendai Disaster Information Management System described in the Phase I report.

Structuring the data in this form will meet the requirement to capture damage data following clustered events such as the New Zealand or Central Italy earthquake sequences, or from cascading events, such as earthquake-induced landslides. In addition, it also allows for data to be captured by multiple affected authorities, each with independent requirements to quantify losses, allocate funds for relief and recovery and manage/control their own damage and loss data.

A set of core attributes has been proposed for each Event Entity, as described in Table 3-2 of the Site Data Collection Tool Functional Requirements Document (Appendix H).

Exposed Element

The Exposed Element entity forms the mechanism for the site data collection and the 'core' mandatory data to be collected on site. An Exposed Element is the generic term for the following categories of elements that may be affected by a disaster as defined within GED4ALL (Silva *et al*., 2018):

- Buildings
- Lifelines
- Crops, Livestock and Forestry
- Socio-economic.

The latter category is not considered a part of the 'core' data model as they do not represent a physical damage loss, but the data model could be extended to include these in the future.

Each Exposed Element will have a generic set of data to be collected. Variance will exist based on the Exposed Element category and the event or hazard type which will form a matrix of required data templates around the data model.

A set of core attributes has been proposed for each Exposed Element, as described in Table 3-3 and 3-4 of the Site Data Collection Tool Functional Requirements Document (Appendix H).

[11] UNISDR (2018). DesInventar Sendai - Disaster Classification. https://www.desinventar.net/disasterclassification.html

To enable monitoring of Exposed Elements over time a secondary table containing all edits to an exposed element record will be stored on the server. Each historic record will be created on edit upload from site or via a webs form entry. The Exposed Element historic entity should contain both the current exposed element record and the full history of edited records across events. The Exposed Element entity will remain as the vehicle for editing data and site data delivery, and as such no direct editing of the exposed element history entity will occur. A record of Emergency and Event phase change will also be kept for reference.

The Exposed Element data, representing the physical damage in an event, forms the primary data collection. The data collection will be required to pass through a data cycle illustrated in Figure 6 and further described in Appendix I.

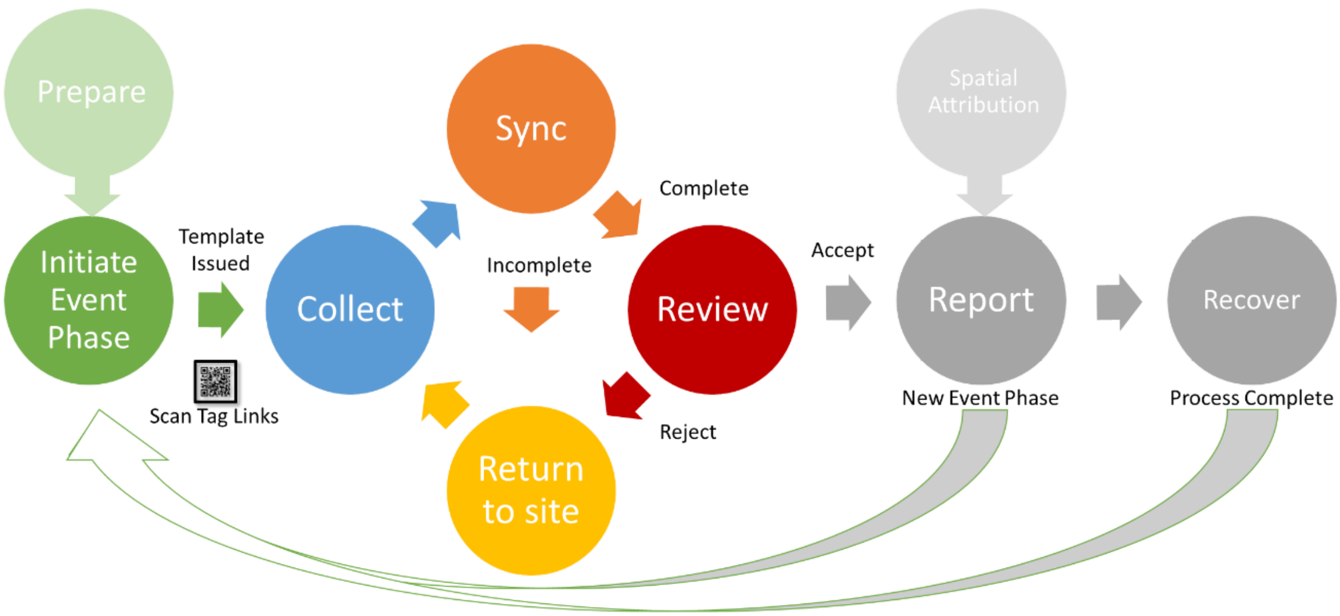

Figure 6 - Exposed Element Data Cycle

The data cycle begins with a phase initiation linked to the conceptual framework protocol, including the emergency declaration, definition of Emergency and Event and eventual return to the Prepare phase after the process completion. On initiating a phase, the appropriate data form template will be issued to users assigned to data collection and data reset and downloaded on availability.

Unit rates / replacement costs

A table of unit rates or replacement costs for damage costs related to the Exposed Element type could be provided to enable a rapid loss estimate, with a lower confidence of accuracy. Unit rates would be applied in the aggregation and reporting system based on the Exposed Element attributes. As a minimum, the average unit rate would be provided based on the Exposed Element category and the damage scale with suggested units based on:

- Point: Buildings (occupancy)
- Linear: Lifelines (per length of linear section)
- Area: Crops, Livestock, Forestry (per tonne of produce or per hectare of land).

The unit rates would need to be expansible for a more detailed unit rate which would be based on the extended attributes of each individual Exposed Element category, using more accurate unit rates. It is intended any modelling of unit rates would occur outside the system and the unit rate entity will be used to apply derived unit rates to Exposed Elements to produce a dynamic estimation.

At the end of an event, the established recovery costs collected in the Monitor phase should be used to review and refine unit rates for future estimation. Unit rates should also be periodically reviewed to adjust for any inflation/deflation affects.

6.3.3. System architecture

Operating system
Android has by far the greater market share of operating system (OS) globally and generally provides a lower cost device. Of greater importance for site-based usage, Android is open source and can be installed on a variety of hardware, including ruggedized devices. Rugged devices are specifically designed to withstand a higher range of operating temperatures, ingress (e.g. from water, dust or sand) and protection. **As such, we recommend Android as a target OS for development.**

Hardware architecture
The conceptual architecture for the site data collection application is based on the use of mobile devices, smartphones and tablets, synchronising to a central server over an intermittent data connection. Figure 7 provides a conceptual view of the overall recommended hardware architecture.

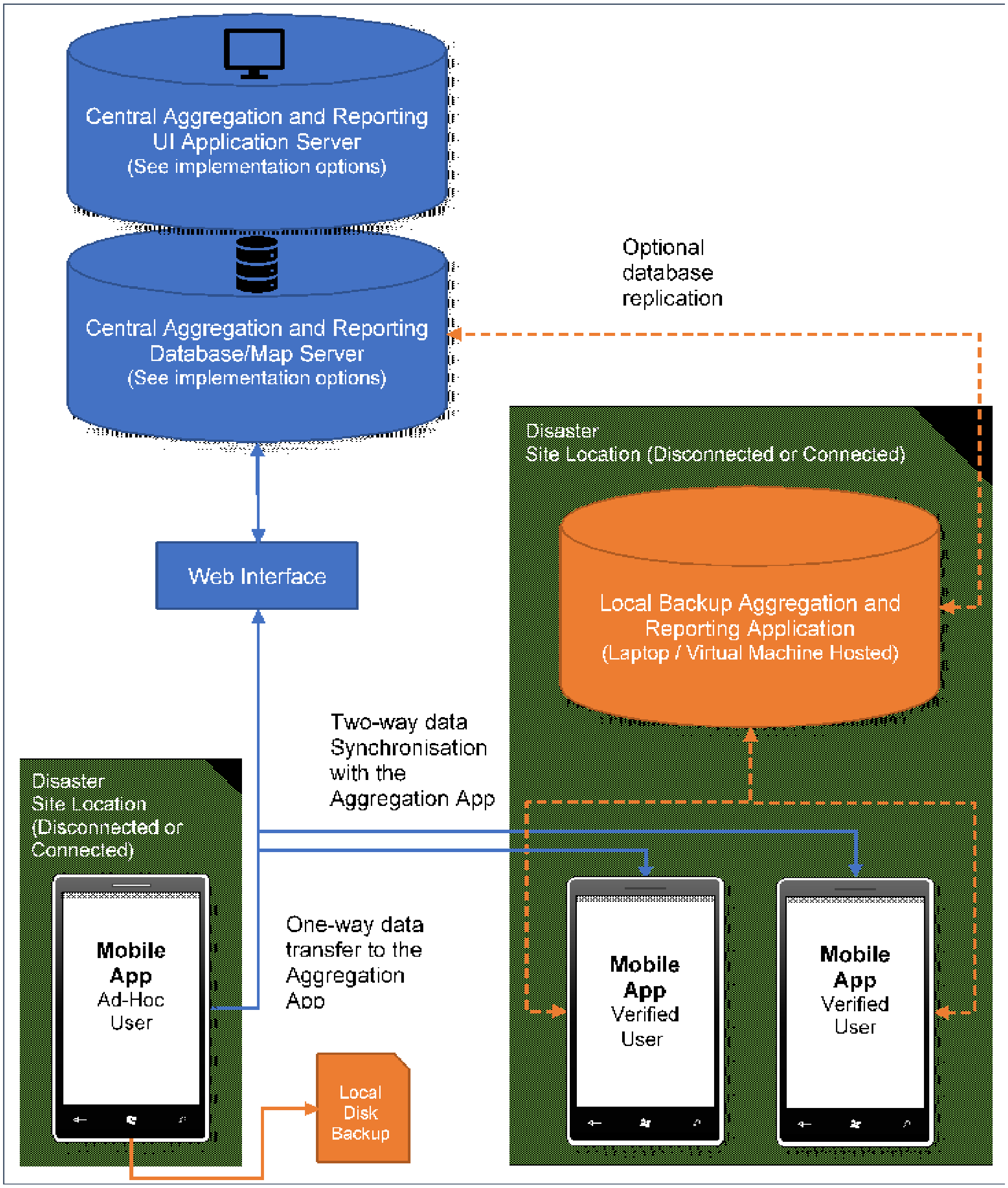

Figure 7 - Conceptual Hardware Architecture.

There is hence a definitive interface and interaction occurring between the site data collection tool and a centralized server that will be hosted alongside and integral with the proposed data aggregation and reporting system to be implemented as a web application. For the purposes of local site backups and possibly off-line data aggregation the server can be hosted on a local computer/laptop using a virtual machine to encapsulate a server instance.

In Phase I, we learned that in Australia (see Section 14.1), surveyors using the Trimble devices had to return to a docking station to upload the collected data back to a local computer. This was a major setback (time consuming), which resulted into people delivering USB drives across South-East Queensland and created issues with data duplication. The introduction of real-time data upload capability tackled these issues – a key consideration in this design.

The site data collection tool will interface directly with the proposed aggregation and reporting system – a web application - as illustrated in Figure 8. This will be the only intended interface for the site data collection tool.

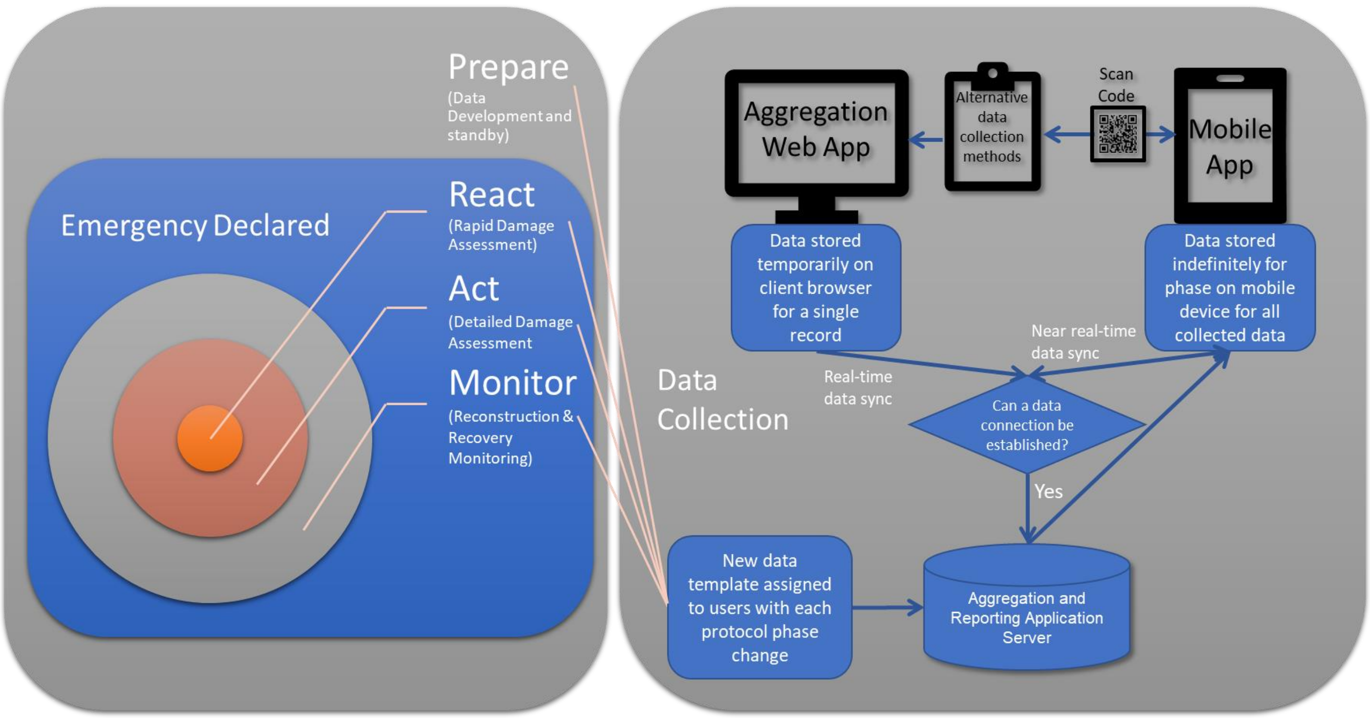

Figure 8 - Interaction between site data collection and aggregation tools using the conceptual framework.

The software interface to the aggregation and reporting web application will be used for a number of purposes:

- Definition of a new 'emergency' or 'event', for which data will need to be captured using the site data collection tools.
- Selection and customisation of the data entry screens to be used in-field, linked to the protocol phases, Prepare, React, Act, and Monitor.
- Synchronisation of data to/from multiple site data collection tools.
- Load any offline background maps, satellite images into the site data collection tools;
- Load any ancillary data layers (e.g. sample point locations, ground shaking maps, flood inundation footprints) into the site data collection tools.
- Send the latest data collected in the event to the site tools.
- Receive any new data from the site tools.

Data templates

As a fundamental part of this interaction, data form templates will be issued to site users at each phase focused on the data collection task in hand. The envisaged data form templates include:

- **React**: Generic
  - Single simplified generic template for multi-hazard and multi-exposed element data.
- **Act:** Event linked with country specified modifications
  - **Earthquake template**
  - **Flood template**
  - **Landslide template**
  - **Tropical cyclone template**
- **Monitor:** Event linked with country specified modifications
  - **Earthquake template**
  - **Flood template**
  - **Landslide template**
  - **Tropical cyclone template**
- **Prepare:** Exposed Element Data Development

To expand on this for clarity, using Armenia as an example, once country adaptation and adoption has taken place the available templates listed within a country for assignment to a user might look like:

- React
- Act: Earthquake (Armenia)
- Act: Flood (Armenia)
- Act: Landslide (Armenia)
- Act: Tropical cyclone (Armenia)
- Monitor: Earthquake (Armenia)
- Monitor: Flood (Armenia)
- Monitor: Landslide (Armenia)
- Monitor: Tropical cyclone (Armenia)
- Prepare (Armenia).

The Exposed Element types and data variances therein are managed within the template and managed on site by the selection of an exposed element type and sub-type and subsequent toggling of data visibility on a form.

The adaption of the core data templates for implementation within a country could also afford a language translation to the countries native language or even multiple language translation such as for local language variations and an English version for international users.

Quick Response codes

To tie together the physical exposed element e.g. a building, field etc., and the Exposed Element data in the system, it is proposed a scan tag such as a Quick Response (QR) code or barcode be used. This would:

- Simplify mobile application usage for return surveys,
- Link any externally collected data such as from crowdsourcing, and
- Form the ID linking all exposed element historic data over time irrespective of emergency or event.

6.3.4. User interface workflow

The mobile application will be used by a wide variety of users with differing experience and skills in the use of mobile technology or collection of damage data. Therefore, the user interface (UI) is required to be simple and clear to use, and the collection process should be as efficient as practical. There is a range of use cases for data collection in the different phases of the disaster, each with the purpose of collecting damage or safety data. Any more advanced features should be hidden away from the general user.

To achieve this, UIs consistent with the operating system implemented should be used where possible to provide a familiar look and feel. Displayed information will need to be focused on the task in hand with any supplemental information and questions visible only when required. The envisaged application will have the core user interfaces described in Table 1.

Table 1 - Summary of mobile application screens.

Screens	Description
Login screen(s)	One-off verification(s) of the device and user
Map screen	Central application screen and opening screen displaying location
Search screen	Data attribute filtering/search screen
Scan tag screen	Scan a physical code to identify a data record in the exposed element data
Data collection screen	Data entry form(s)

Figure 9 illustrates the conceptual workflow for the mobile application screens and connectivity for the proceeding wireframes, which are depicted from Figure 10 to Figure 15.

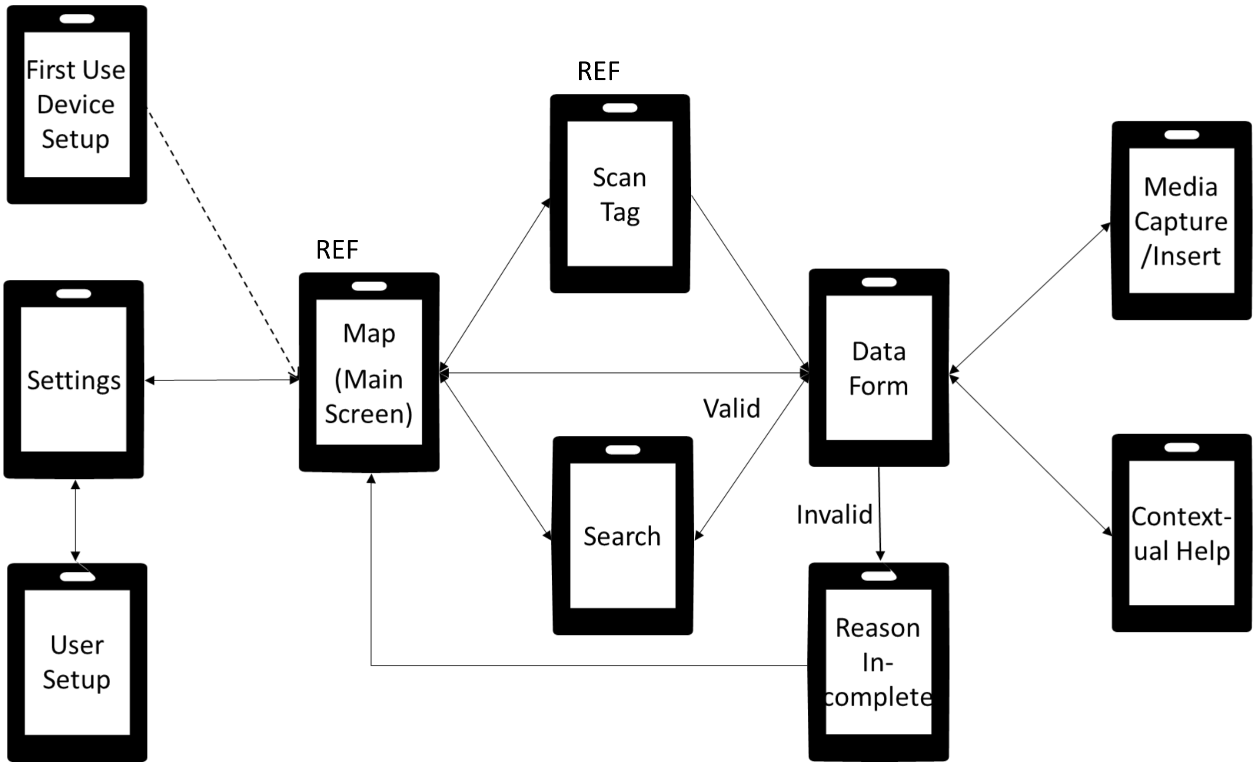

Figure 9 - Conceptual Mobile Application Workflow.

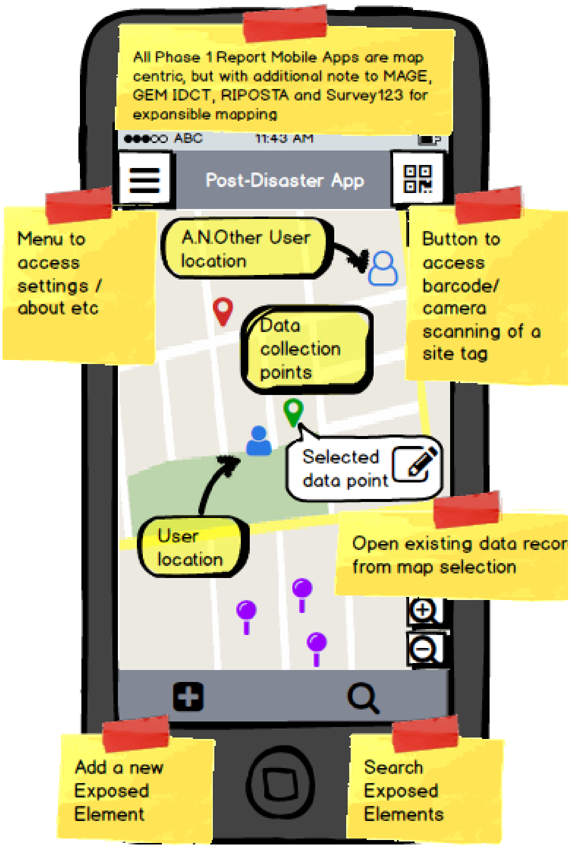

Figure 10 - Map (Main screen) wireframe

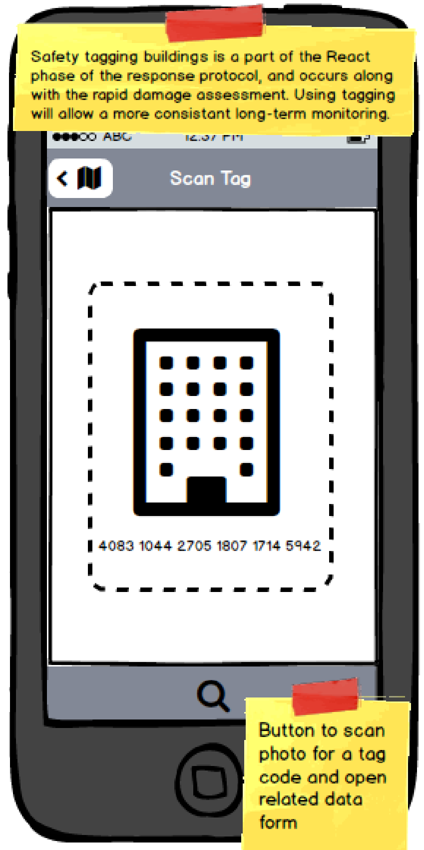

Figure 12 - Scan tag wireframe

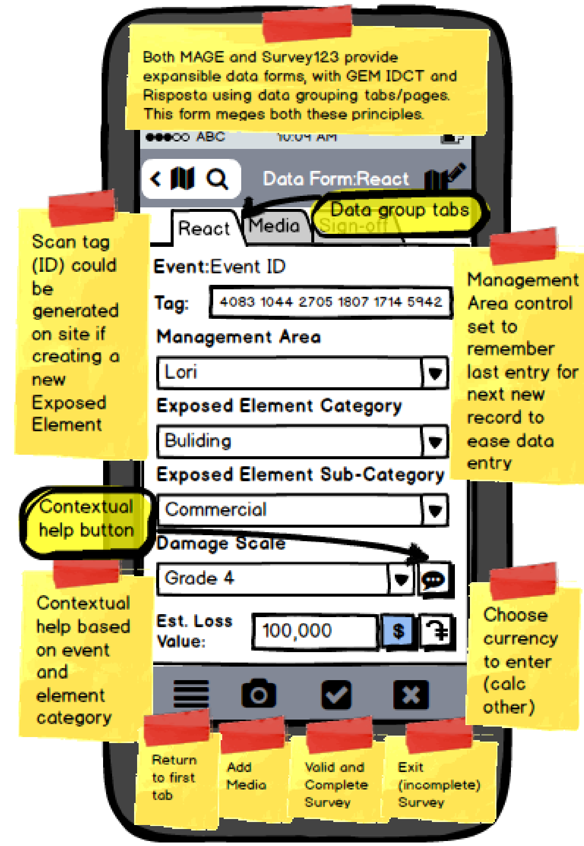

Figure 11 - Data form: React wireframe

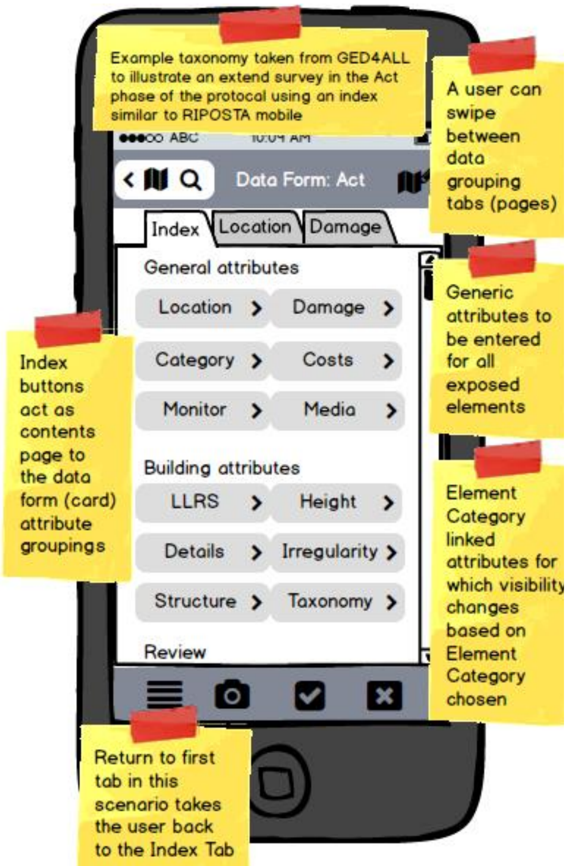

Figure 14 - Data form: Act: index wireframe

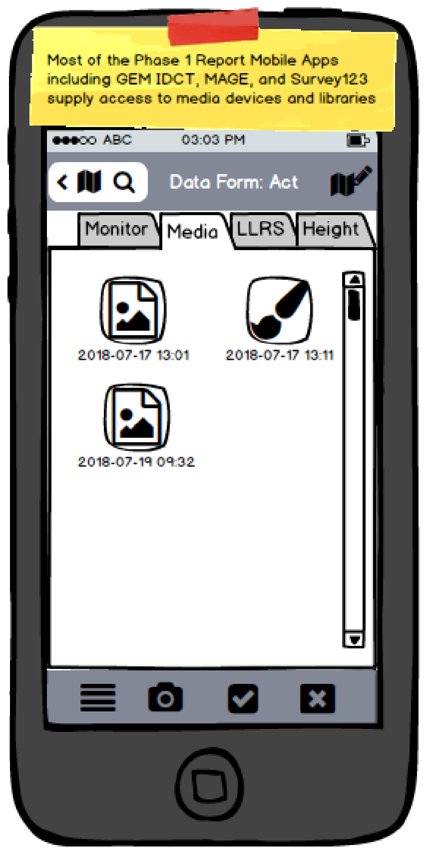

Figure 13 - Data form: Act: media example wireframe

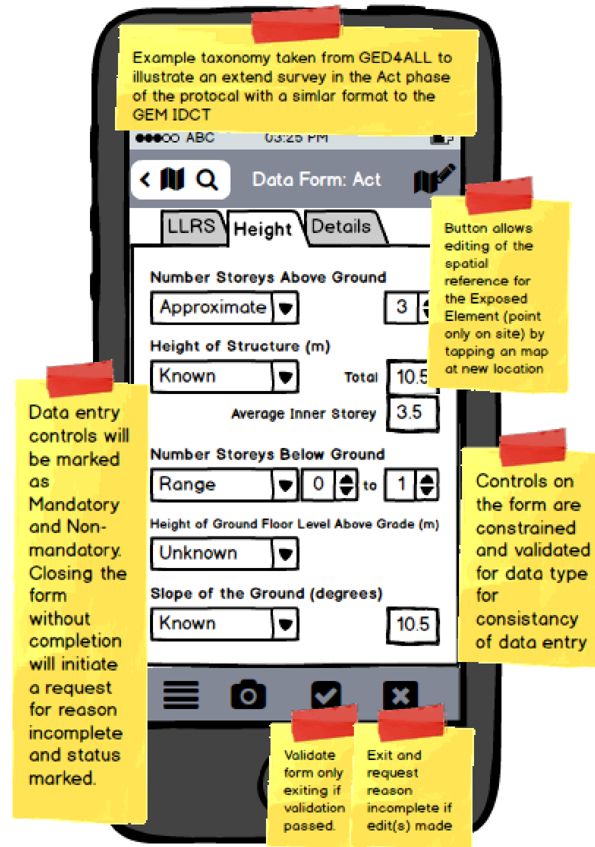

Figure 15 - Data form: Act: element category example wireframe

6.4. Supporting documentation

The site data collection tool will need to be provided with supporting documentation detailing how to access, setup and use the tools. These can be provided to users during detailed training sessions to occur in the Prepare phase of the conceptual framework.

In addition to tool-specific documentation, guidelines and checklists should be developed describing the appropriate use and care of any hardware or personal protection equipment (PPE) that is used or brought into the field. These guidelines and checklists can greatly help during deployments due to the pressures experienced by the survey teams due to working in hazardous and stressful conditions. Guidelines and checklists may cover:

- Appropriate and proportional health and safety protocols and dynamic risk assessments, including checklists for PPE
- Use and maintenance of data collection hardware – i.e. setup, installation, management of battery life
- Supplementary hardware – i.e. external battery packs allowing for USB charging of hardware in the field, external hard drives for *in-situ* data backup, device holders and covers to reduce glare or ingress of water/dirt.

6.5. Final remarks

A conceptual design for a site data collection tool for use across the phases of the conceptual framework, including damage, loss and recovery assessment was described in this chapter. In summary, the major functions of the site data collection tool are:

- Clear easy to use and customisable and expansible data collection forms
- Concise, consistent, restricted and validated data entry
- Provide visual support to relevant pick lists generated from pre-defined taxonomies
- Geo-reference all collected data and media
- Allow physical identification of exposed elements via a scan code (e.g. QR code)
- Map interface to display collected data and user location against street level background mapping or user-input imagery
- Allow for user loading of simple spatial datasets to be overlaid on the map interface
- Collect data in a mobile connected and disconnected environment
- Minimise battery usage
- Collect data in variable weather conditions
- Data to be synchronised with a central location as a multi-user environment
- User login.

A detailed documentation of the functional features and requirements is presented in Appendix I. A supplementary prioritization of the key features is also provided in the same Appendix using the

Must have, Should have, Could have, Won’t have (MoSCoW) nomenclature. An estimate of effort using a High Medium, Low scale is also provided based on a new code development.

7. Conceptual design for a damage aggregation and reporting system

A standalone document with a full description of the functional and non-functional requirements in the conceptual design can be found in Appendix B.

7.1. Use cases

The use cases for the data aggregation and reporting system were the same as those used in the site data collection tool, as described in Chapter 2. The use cases span a range of activities across the four phases of the conceptual framework. The site data collection tool and data aggregation and reporting system can support each of these activities in different ways. Figure 4 illustrates the use of each of the tools as well as external tools, models and data.

7.2. Design influences from existing systems

There are a variety of methods for aggregating site-level post-disaster data and reporting on the damage and loss generated by natural hazards as listed and discussed within the project Phase I report. With respect to reporting of data, each country has their own methodology and reporting requirements within their governmental and administration hierarchy.

The functionality defined in the FRDs in Appendix A and B leverage the learning on best practice, structure and products outlined in Phase I, extracting the strengths of the products presented and provide a coherent design from these strengths taking in current technologies.

For the data aggregation and reporting system the following influences can be observed:

- **AJDA**: Evidence based multi-hazard damage and loss data aggregation, spatially defined events, data review and country specific legislation.
- **NDOIS**: Country legislated reporting formats.
- **FloodCat**: Modern interface and architecture, geospatial representation and event data management.
- **DesInventar**: Sendai framework repository.
- **RASOR**: Multi-hazard taxonomy and Sendai framework output.
- **Global Exposure Database (GED)**: Taxonomy, visual taxonomy support.
- **MAGE**: Open source dual-platform customisable web aggregation tool using a NoSQL Database.

As with the site data collection tool, it should be noted that **none of the above systems are considered to be suitable for direct adoption as a single application without modification** due to limitations within each system. However, although the data model, form templating, taxonomy and reporting used with MAGE will require modification, the technology stack used within the product and open source Apache licensing mean that **MAGE could provide a suitable and substantial starting point for any future data collection application development work**.

7.3. Tool architecture

A summary of the architecture and design principles follows. More detail can be found in the full Functional Requirements Document in Appendix H.

7.3.1. Conceptual design principles

The same principles and philosophy outlined for the site data collection tool (Section 6.3) are reflected in the data aggregation and reporting system, with a continuation of usage of the data form templating and flexible database design.

The general philosophy of the conceptual design is to attempt to simplify to the end-user a complex series of data collection objectives to achieve an efficient aggregation of collected data and focused reporting. This will shift the system complexities to the system developer to provide an expansible and dynamic method of data aggregation, limiting user options presenting only information required for/of a user in a specific scenario.

As discussed in Section 6.3, GIS and mapping will be a central feature of the system. Within the web application, management of the map layers contained in the system will be enabled. There will be a core of data related to the emergency data collection, to spatially represent emergencies, events, exposed elements and provide a background mapping context to the data as supplied by the OpenStreetMap (OSM), administrative boundaries and high-level mapping. Further to this core though additional layers will be supported to either:

1. Import into the system as secondary data,
2. Provide a direct and dynamic data feed into the system from an external source,
3. Signpost as a hyperlink to external data.

As such it is intended hazard mapping, forecasting and near real-time data feeds can be overlaid by the emergency data collection data. The Phase 1 report tool RASOR is permanently linked to the USGS ShakeMap Library, and this principle will be used within the system and extended to both localised and global data feeds. It is also possible data stored in the system could be fed to other systems, but this would be optional for the country of implementation and would need to take account of any data security issues.

7.3.2. Conceptual data design

The conceptual data design for the site data collection tool, as outlined in section 6.3.2, is also integral to the aggregation and reporting tool.

An additional data feature to be defined exclusively within the aggregation and reporting system is a function to enable spatial attribution of data. This function would allow the upload of a spatial dataset containing attributed boundary areas (polygons). The Exposed Element data can then be intersected with the uploaded dataset to assign the contained attributes to any Exposed Element record. Data update would occur on upload and then be maintained during dynamic data synchronisation and update of individual Exposed Element data. A specific example would be to assign administrative boundary information, which can infrequently change over time, but is definitively spatially defined. The principle though could be extended to hazard intensity mapping (e.g. assigning locations with ground shaking, flood depth or slope values) or other polygon data.

7.3.3. Architecture

As a browser-based web application there are no specific hardware requirements for the user's 'client' hardware other than a modern standards compatible web browser is used.

The aggregation and reporting system will need to run using a server or machine capable of serving web pages. The system is designed to be platform agnostic, but with the intention of using an open-source web server platform based on a Linux operating system and Apache web server to reduce running costs. This would also allow the use of container technology such as Docker. There would be separate servers for the web application and the database hosting unless the hardware is fully hosted within an individual country, and potentially a further separation for a mapping server.

The location, ownership and responsibility of a server is discussed in Chapter 8 as part of a potential implementation strategy framework.

The interaction with the site data collection tool, as a key feature of the solution, is discussed in Section 6.3.3 with the site data collection tool architecture. The aggregation and reporting system manages the template interaction with both site and web users. The expansible data template and database principles of the site data collection tool permeate into the web application. As such the web application will access and present the same data as the site data collection tool, for viewing and editing of data. This will include the ability to create exposed element data off-site within the web application and at the other end of the process, review and validate exposed element data with a record 'sign-off'.

The main output of the web application will be the aggregated reporting as summarised in Table 2. Further detail on reporting is provided in the Aggregation and Reporting Tool Functional Requirements Document presented in Appendix I.

7.3.4. User interface workflow

The aggregation and reporting system is designed as a web application. The application is envisaged to be available on the internet behind a user security layer but could also be installed across an intranet or indeed locally as a virtual machine. Users are to be verified as a part of an emergency team but could extend to government departments and partner organizations, but potentially sections of the web application could be opened up for public access for crowdsourcing data in the future. As such the application will need to be clear, but able to provide a complex set of tools for managing the system to more advanced users. Therefore, users will be provided levels of access only showing the required components of the web application to user interface for the specified user.

The user interface design for the web application will continue the theme of the site data collection tool with an expansible and templated approach to data presentation. The envisaged application will have the user interfaces or screens available from the main web page header menu described in Table 2.

Table 2 - Summary of web application screens.

Screens	Description
Login screen	User verification and authentication
Dashboard screen	User assigned summary of key aggregated data attributes
Map screen	Map screen to visualise, spatially overlay data, edit spatial representations and access to data form(s)
Search screen	Data attribute filtering/search screen and access to data form(s)
Manage screen	Manage interaction between users, templates and data
Report screen	Provision of data aggregation reports for both system defined, and user defined reports

Figure 16 illustrates the conceptual workflow for the aggregation and reporting tool and connectivity for the proceeding wireframes, Figure 17 to Figure 22.

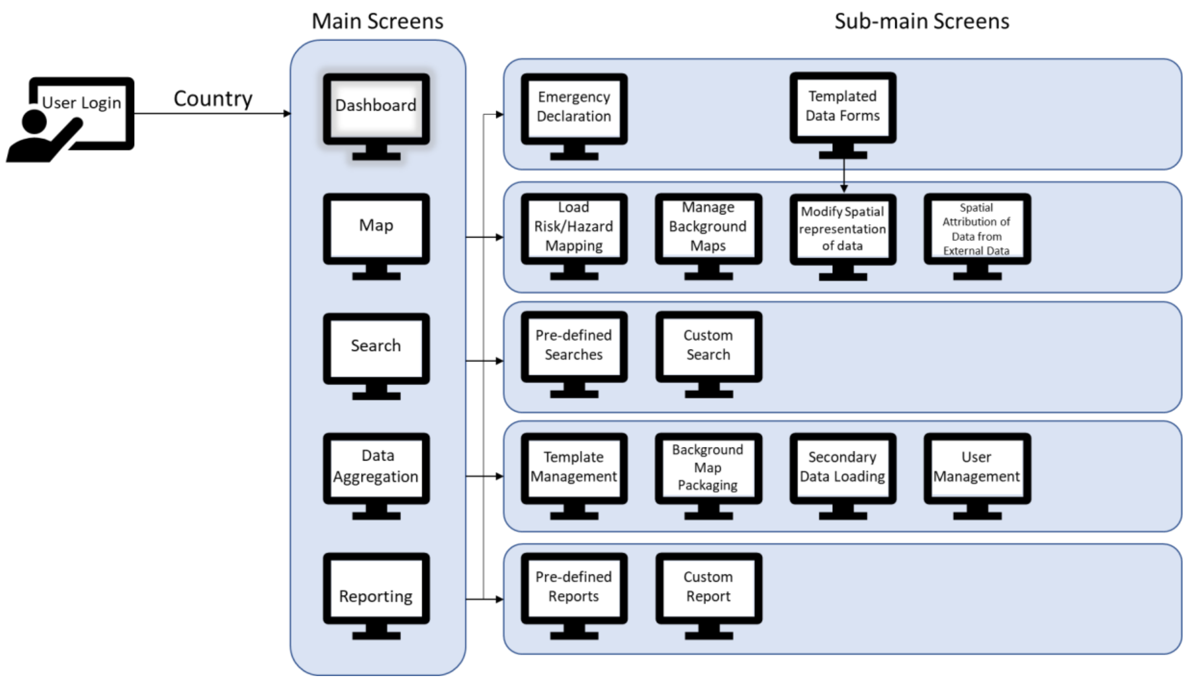

Figure 16 - Conceptual Mobile Application Workflow.

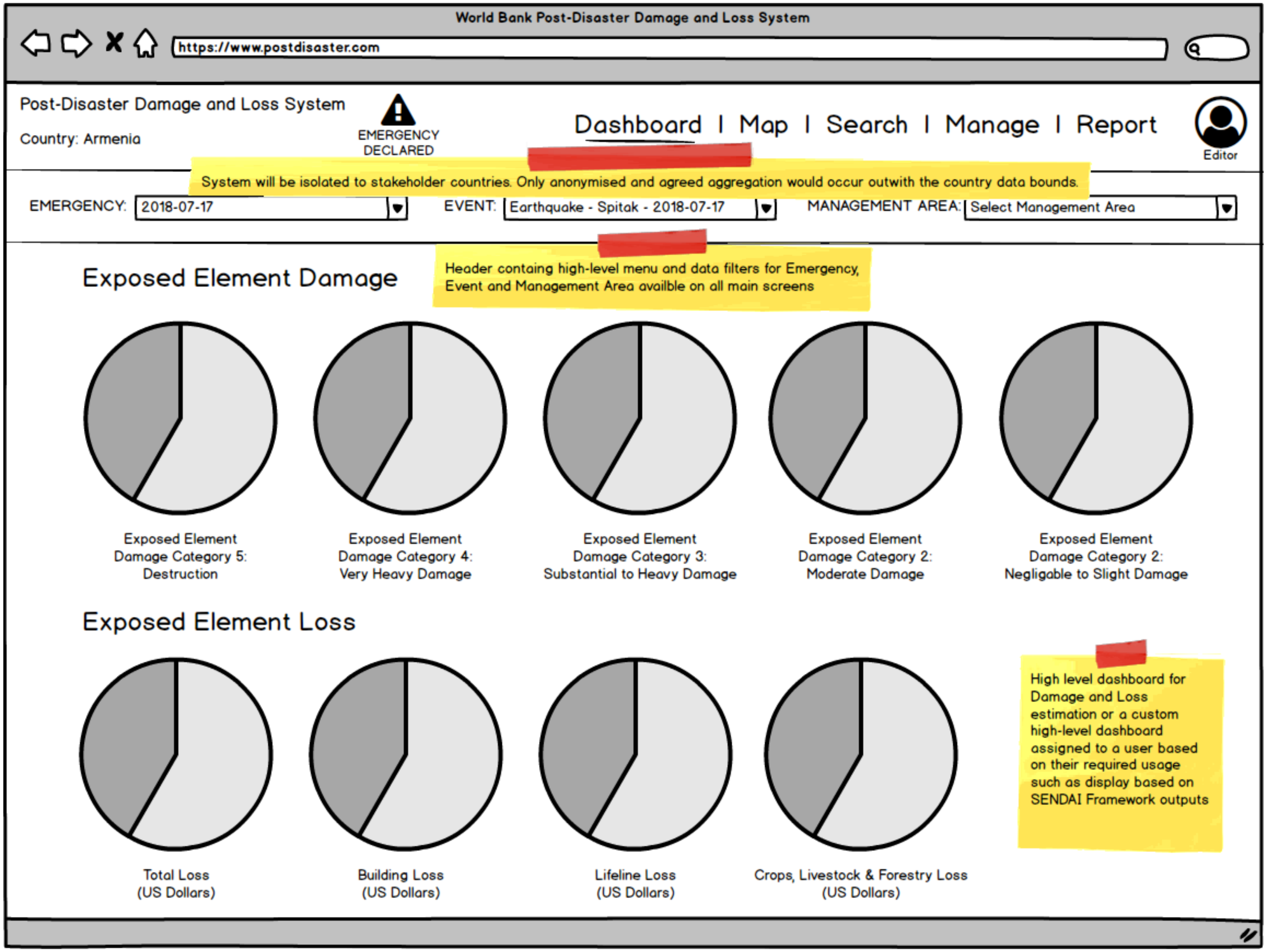

Figure 17 - Dashboard wireframe.

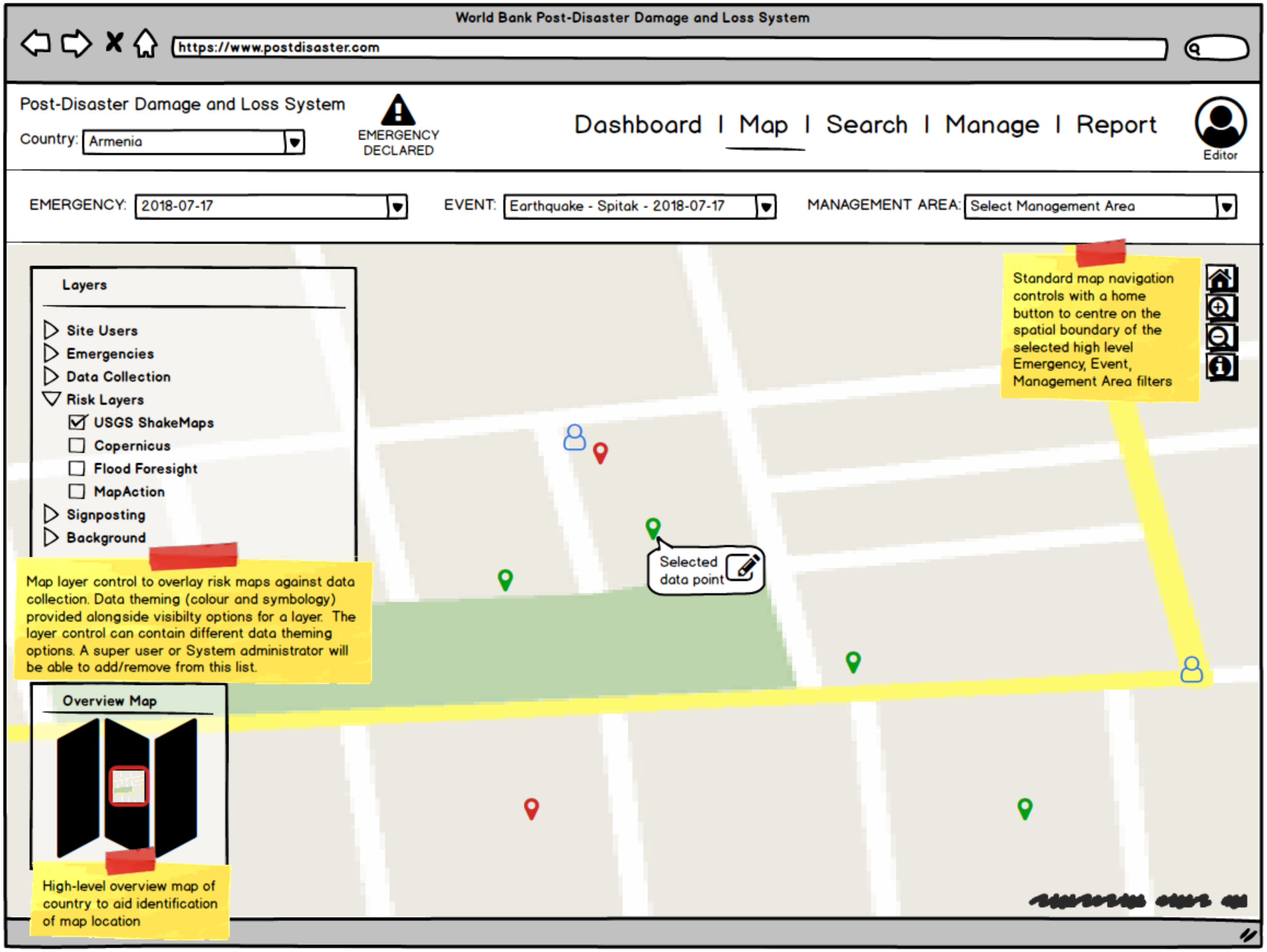

Figure 18 - Map wireframe.

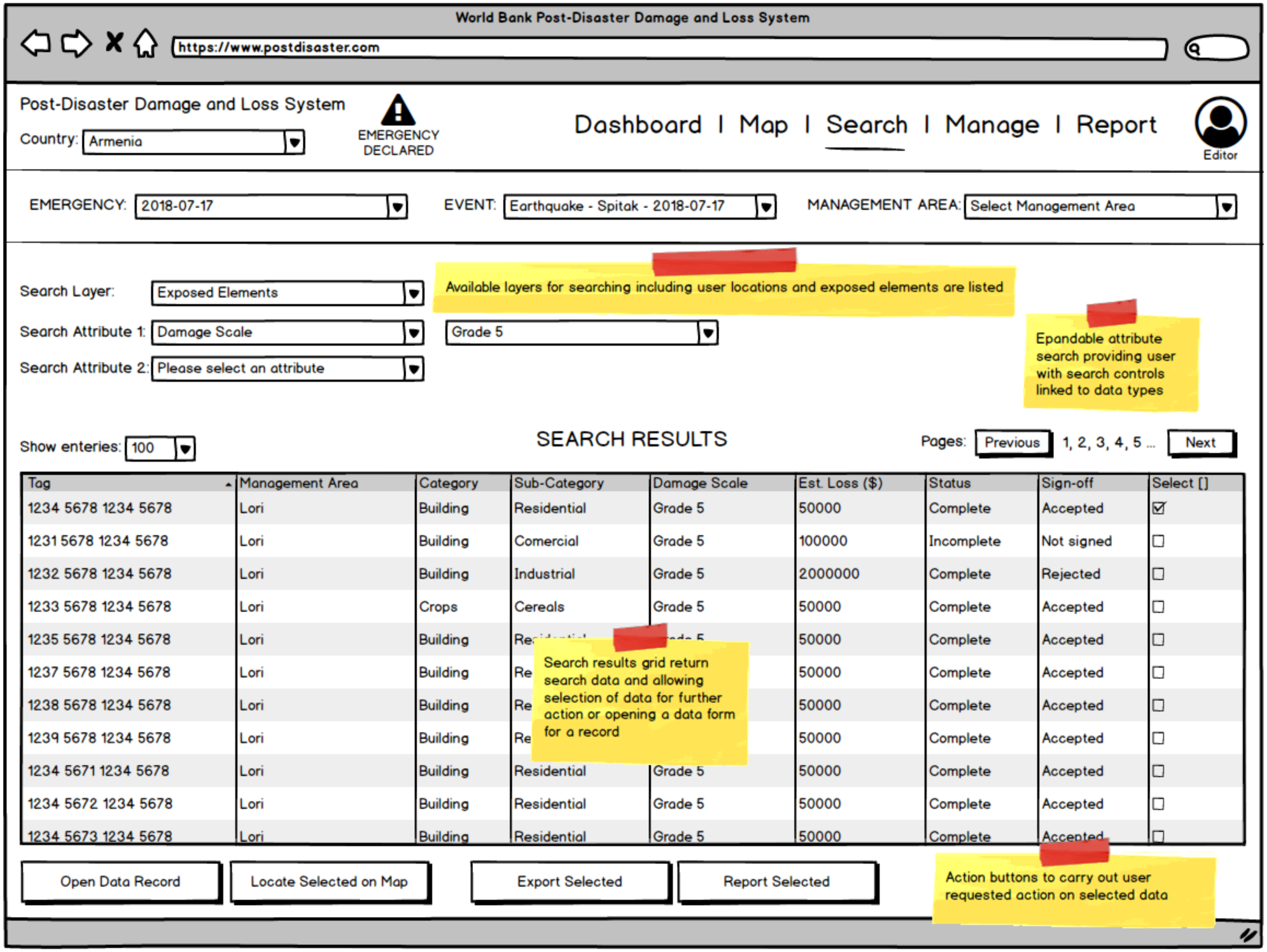

Figure 19 - Search wireframe.

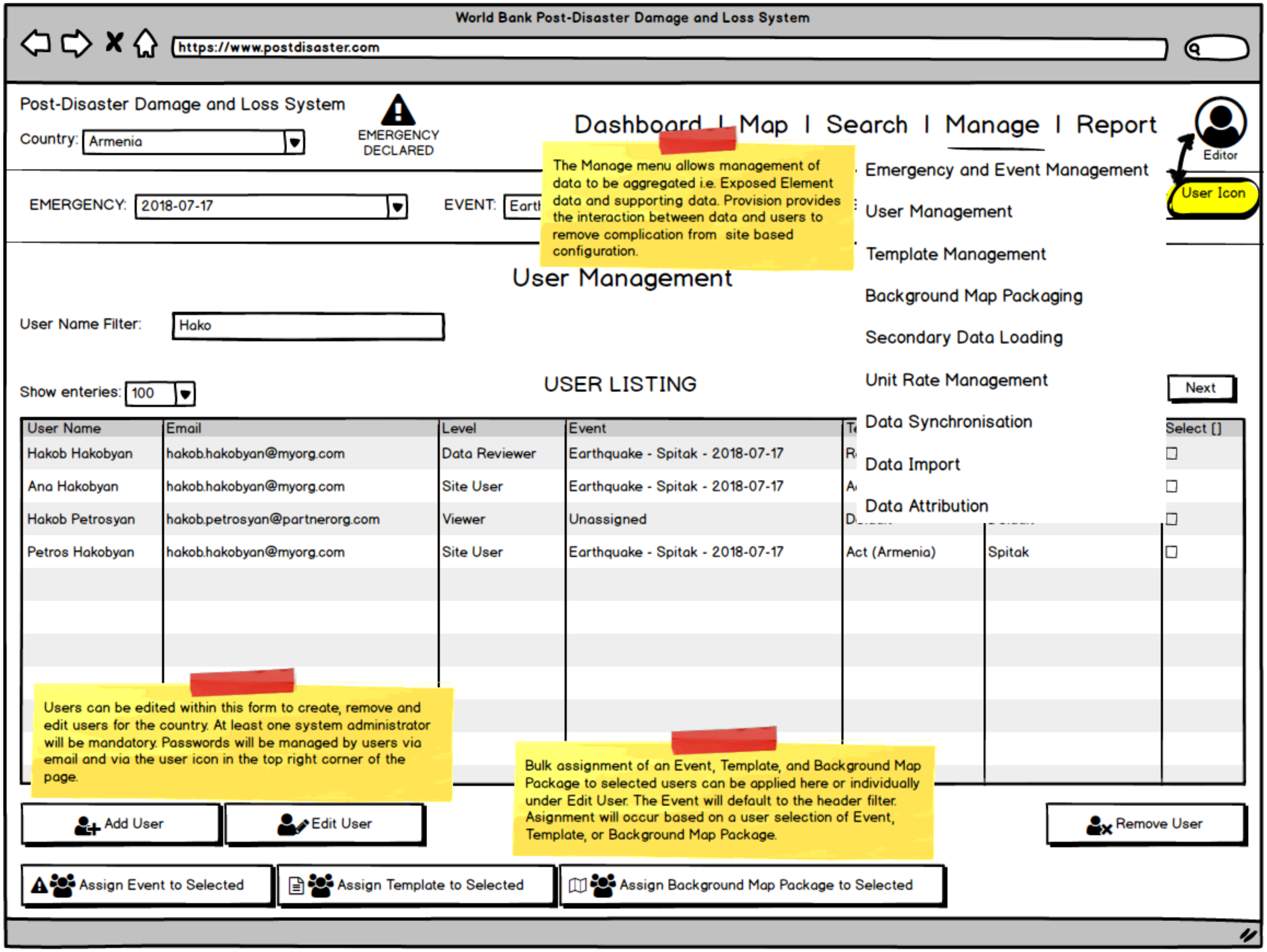

Figure 20 - Manage wireframe.

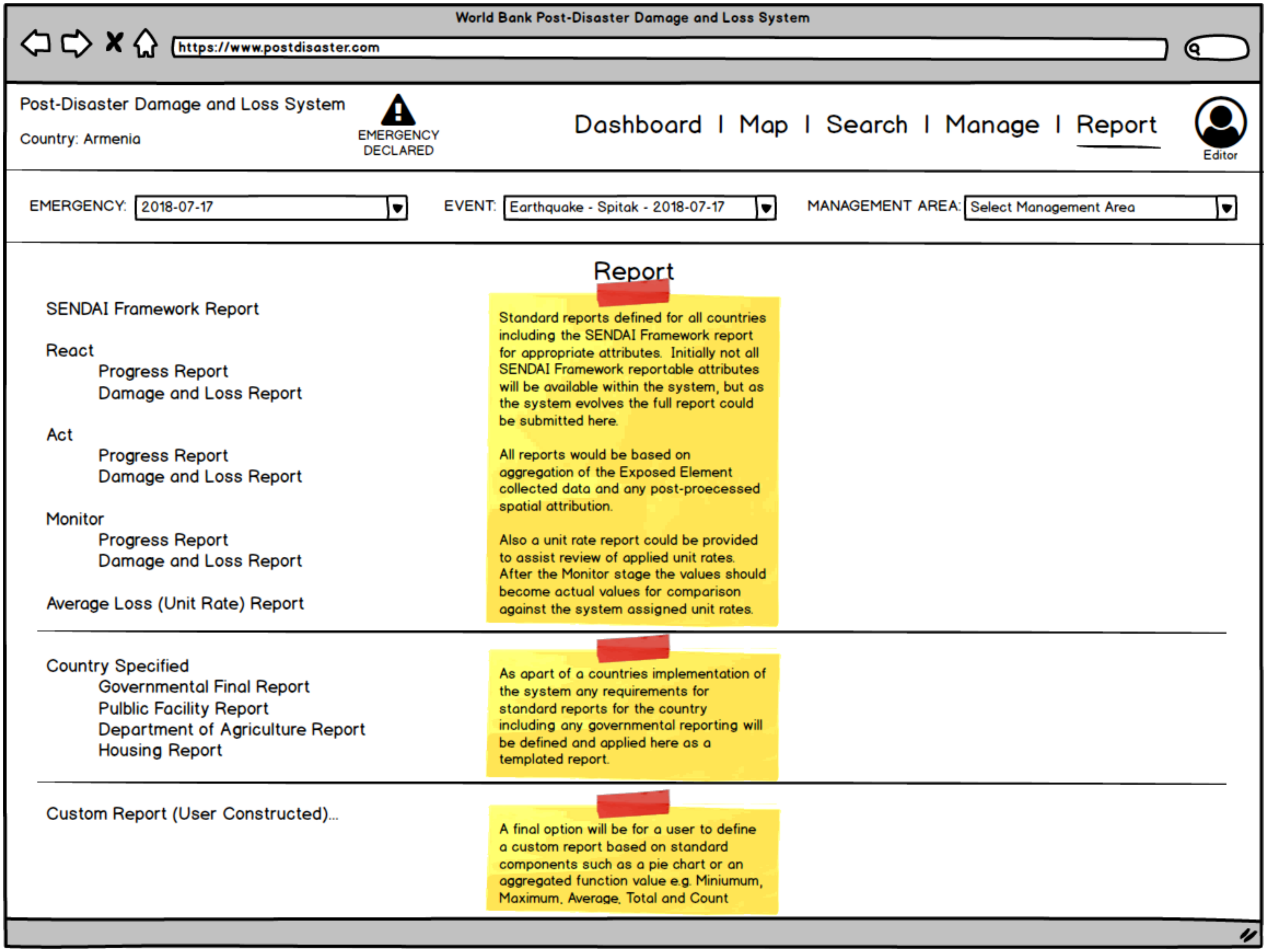

Figure 21 - Report wireframe

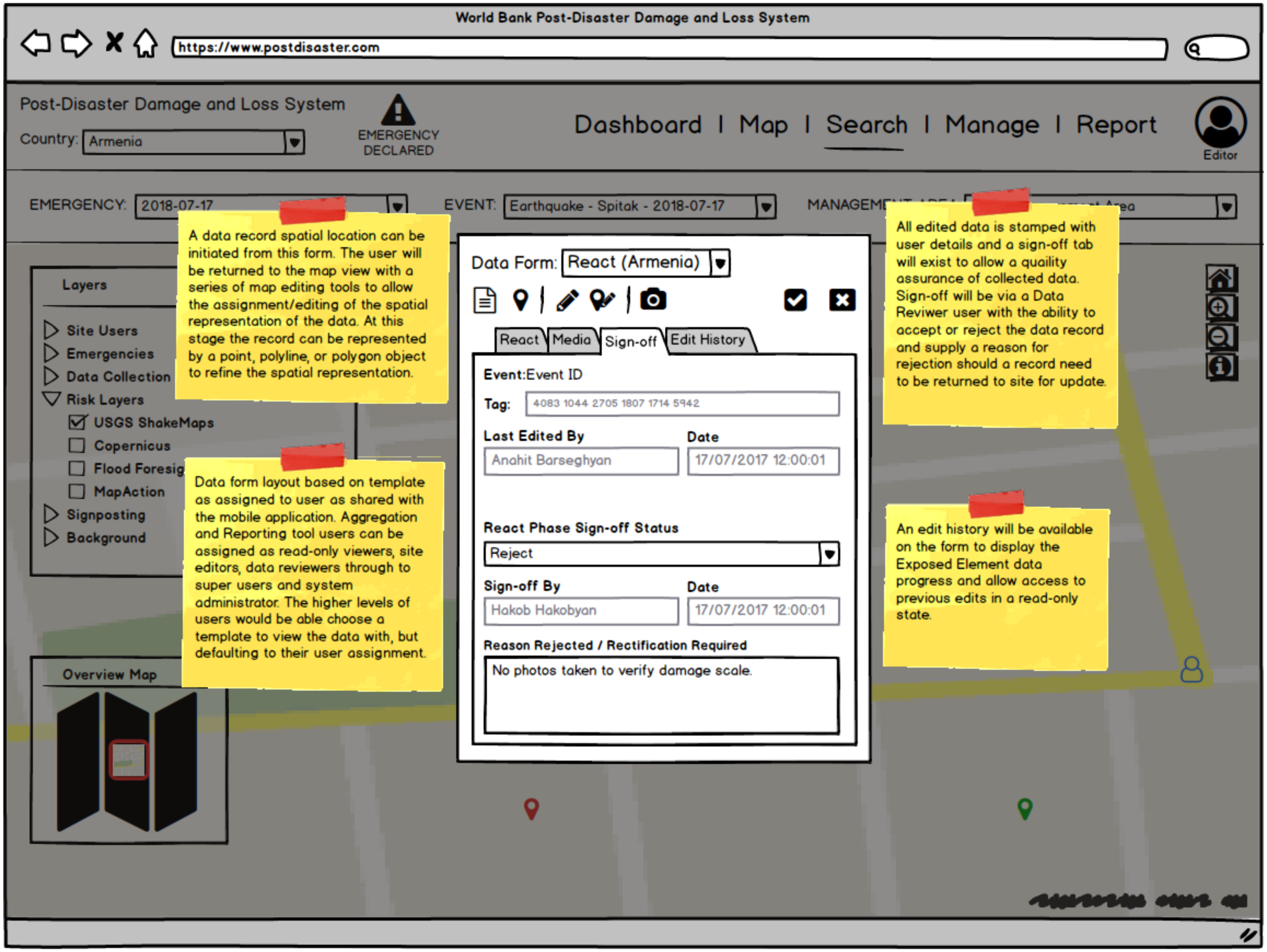

Figure 22 - Data Form wireframe

7.4. **Final remarks**

A conceptual design for a data aggregation and reporting system for use across the phases of the conceptual framework, including damage, loss and recovery assessment has been presented.

The major functions of the data aggregation and reporting system are:

- Clear easy to use and customizable/expansible data collection forms.
- Provide visual support to relevant pick lists generated from pre-defined taxonomies.
- Geo-reference all collected data and media.
- Map interface to display collected data and user location against street level background mapping or user-input imagery.
- Allow for user loading of simple spatial datasets to be overlaid on the map interface
- User and template management.
- PDF reports for individual exposed element records.
- Export of data to Microsoft Excel and spatial formats such as Esri Shapefiles and Keyhole Markup Language (KML).
- Evidence based damage and loss estimation.
- Aggregation of data to inform decision-makers.
- Flexible aggregation reporting to meet legislative and administrative requirements.

A detailed documentation of the functional features and requirements is presented in Section 6 of Appendix I. A supplementary prioritization of the key features is also provided in section 9 using the Must have, Should have, Could have, Won't have (MoSCoW) nomenclature. An estimate of effort using a High Medium, Low scale is also provided based on a new code development.

8. Recommendations for future development

8.1. Prototyping a linked data collection and aggregation system

From the review of tools and system laid out in this report and the subsequent design of a new data collection tool, it is clear there is an opportunity to develop an expansible, open-source data capture tool that is able to capture data in numerous phases of the disaster cycle. We propose initiating a follow-on project to develop an initial baseline prototype of both the data capture tool and data aggregation and reporting system. These prototypes could be developed to fit the requirements of Armenia or a number of countries interested in trialling the system and tailoring the protocols to their specific needs and context.

In undertaking a new development project, additional review of the potential to repurpose existing systems should be carried out. In particular, the MAGE system should be investigated further as there are several components that could be used in the new system – reducing the overall effort required for developing the tool (see section 8.4).

8.2. Implementation strategies

Consideration has been given to the location of the repository for the data collection tool and central aggregation and reporting server. The levels of desired autonomy of individual countries were also considered. The implementation strategy would become a part of an individual requirements for a country. There will be a trade-off between the efficiency and cost of implementation against the autonomy and perceived security of a country data as illustrated in Figure 23.

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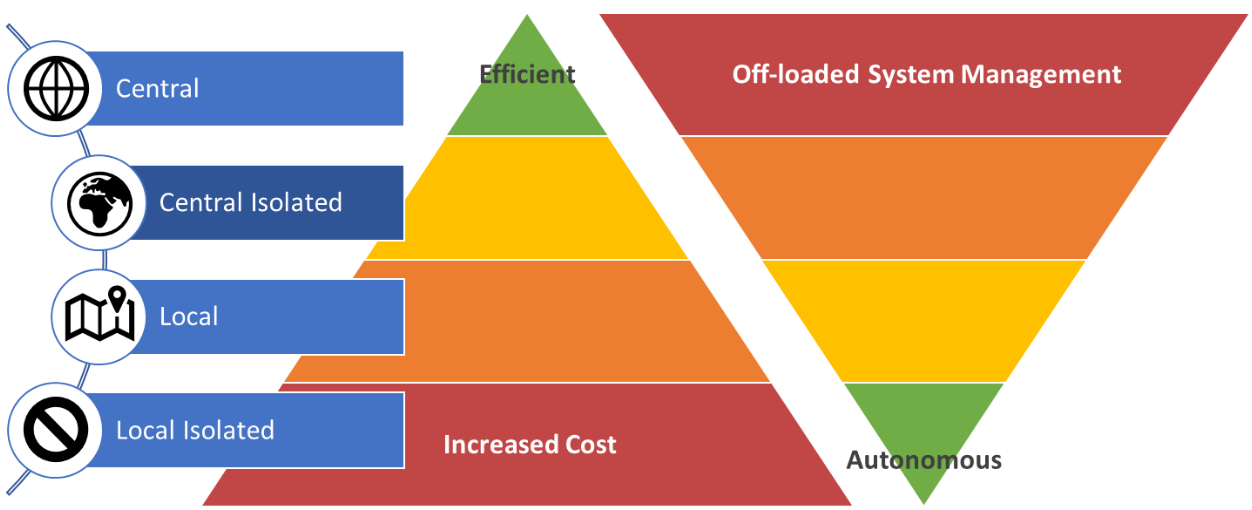


Figure 23 - Implementation Strategy Balance.

A central server for global use will be the most efficient way of deploying a common set of tools that can be adopted by a national or regional agency. However, there is a trade-off here in the management and control of a central system. This would be the responsibility and in the jurisdiction of the central hosting organization, and local users would have little control over the setup, maintenance or security of the server. At the other end of the scale, a locally-deployed solution would be costlier, but the user organization would have full control of the server and hosted data. A matrix of options is therefore described in Figure 24 which could be used in the implementation strategy decision making but with a clear separation of options for the location of the application and database server.

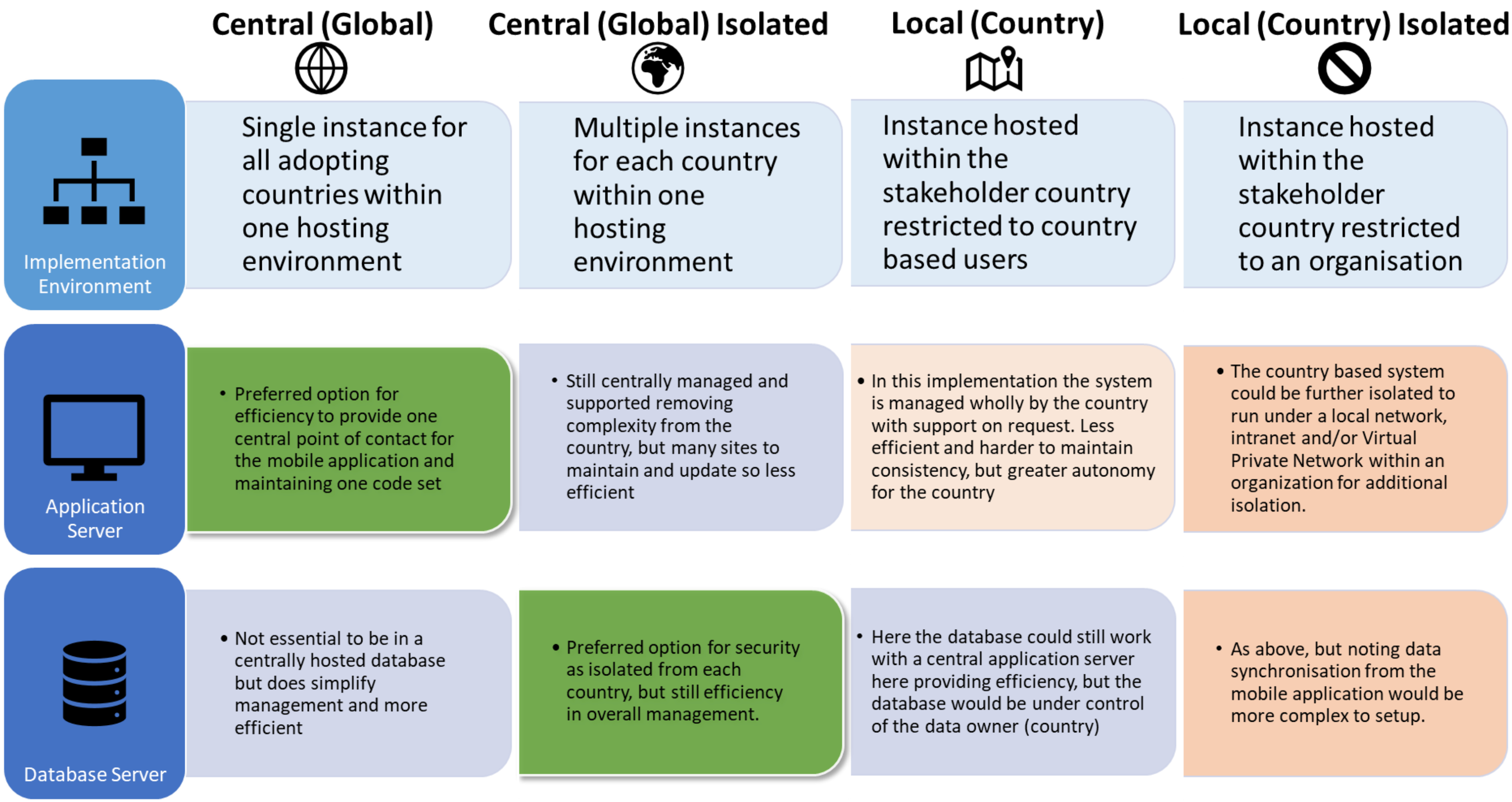


Figure 24 - Implementation Strategy Options Matrix. A single global instance would be the most efficient way for maintaining a single codebase for the toolset. However, more local instances are the most likely option, given the control over security of the locally-collected data.

A central server would be considered to be a hosted server providing a single point of connection globally. The hosted servers might take the form of a scalable hosting solution such as Amazon Web Services (AWS) or Microsoft Azure, but could be fixed server hosted within a partner organization such at the World Bank or the Global Earthquake Model Foundation. In either scenario, the central hosted server could be connected to from anywhere in the world provided user and device restrictions are met.

A local server would be considered to be a server restricted to a single country with the intention the server would provide a single point of connection for the stakeholder country only. It should be noted the country-based server could still be shared with a centralized and approved support team to provide a more efficient support service pending the degree of autonomy desired.

The options matrix highlights the web server hardware could be implemented in a number of ways with differing configurations. Primarily though the following options can be used:

- Central (Global)
  - Cloud Hosting i.e. AWS, Azure
    - Providing scalable servers
    - Instant upscaling in high demand or with increased stakeholders
    - Can be hosted in different continents or ‘regions’ i.e. US, Europe, Asia etc.
  - Partner hosting
    - On-premises servers
    - Fixed server
    - Harder to scale
- Local (Country)
  - Country hosting
    - As per country requirements and available resources
    - Assumed to be on-premises server(s)
  - Local hosting
    - Within a country-based organization
    - Assumed to be on-premises server(s)
  - Laptop
    - Providing a mobile server for backup and transfer of data within a site team

The recommended hardware for efficiency of usage, support and maintenance would be to use multiple instances of cloud hosted servers but is dependent on individual countries requirements.

With each of the implementation options suggested above the data ownership and responsibility would remain with the individual stakeholder countries. It is the connection, physical location, implementation, maintenance, and support responsibility that would vary.

8.3. Alternative data collection methods

The focus of this report has been to conceptualize a method of evidence-based data collection, restricting data collection to trained and expert users seeking a high reliability and consistency in data. However, some limitations could exist in the system outlined for:

- Site conditions, such as severe damage to power grids
- Availability of trained resources at short notice to react in sufficient time.

Alternative data collection methods have therefore been considered to potentially expand the system and meet the limitations listed above. These include:

- Paper-based pro-forma for scanning and automatic data extraction
- Public data capture and crowdsourcing following Text alert
    - Confined public web data entry
    - Confined public version of the site data collection application.
- Deriving data from remotely-sensed imagery

In all the above scenarios the usage of a QR code/barcode and unique scan tag referencing to uniquely identify exposed elements will greatly improve the reliability of the alternative methods and be implemented as an option within any of the suggested alternatives.

8.3.1. Paper forms

A paper-based version of the data collection form could be generated. This would be provided as downloadable PDF from the aggregation and reporting system web-application and should be distributed to the survey team members when responding to a defined Emergency and Event. The current taxonomies noted in make use of alpha-numeric codes as a short descriptor of a classification. These and any additionally required short descriptor codes should be employed on the paper-based form to ease form filling and provide consistency. It is envisaged the paper-based forms can be returned and scanned to aid data entry back into the main system and potentially imported to a database. However, scanned data may need to be reviewed before applying to the main system. Due to these limitations, any **paper-based survey should be a back-up only** and usage discouraged under normal circumstances.

8.3.2. Crowdsourcing

In disaster events, citizens are often the first responders for rescue and emergency relief. In terms of post-disaster damage data collection, especially in the emergency response phase (the first days), some key information can be provided by citizens that can help triage areas of major damage/loss ahead of more structured, planned survey deployments in the Detailed Damage Assessment (Act) phase of the conceptual framework, using the site data collection tools.

A potential option for crowdsourcing is based on centralized text alerts pushed to recipients with a number of basic prompts for data:

1. In the first days of the emergency, the national or local authority sends out a text message to the local population containing a URL directing them to a website. In a more sophisticated version a mobile number used for texting could be assigned to an exposed element and the URL direct a user to linked record.
2. When clicked, a simple web-page will request permission from the user to share their current location (assuming a smart phone with GPS is being used).
3. Users will see a map on a web-page centered on their current GPS location and be prompted to provide an alternative location – i.e. the location of their house.
4. Users will be prompted to input their construction type – and prompted by a series of graphics (e.g. from the World Housing Encyclopedia (WHE)[12] or the Glossary for GEM Building Taxonomy[13]).
5. Users will be prompted to input the damage level of the event – prompted by a series of graphics (e.g. from EMS-98 or IMS-14 – see Appendix A of the site data collection tool FRD).
6. The central system will then generate an estimation of loss by using assumptions of replacement costs by structure and modifying the proportion of loss according to the damage category.
7. As the emergency response phase progresses and moves into the detailed damage assessment (ACT) phase, further prompts to respondents can be made to provide more information, such as photographs. Photographs would not immediately be requested to preserve bandwidth.

The public web page could be extended to a public version of the site data collection application. This would allow a single data entry per device.

This approach would provide a high-level overview of damage from which a rapid, but rudimentary estimation of loss can be generated. The resulting dataset should be separated from those data collected by the site data collection tool. The use of each dataset is likely going to be time-dependent, with crowdsourced data being most valuable in the hours and days after a loss event occurring. The data captured from a subsequent structured field survey in the detailed damage assessment (Act) phase (using the site data collection tool) is likely to be more detailed and more reliable than unsupervised citizen-derived data. However, there is potential value of citizen-contributed data in the emergency response phase to aid prioritization and targeting of more structured surveys.

This approach relies on several assumptions:

- Requires that cellular data availability is available post-event and users have access to smart phones to view image prompts;
- Requires that local data protection regulations are adhered to;
- Relies on users being receptive to passing information directly to the local or national authority. We should acknowledge that this may come with an implicit assumption of the contributing

[12] http://www.world-housing.net/

[13] https://taxonomy.openquake.org/

citizen that they will directly benefit (either through emergency assistance or compensation) from providing data, or that relief and detailed damage

- assistance will be made available more rapidly as a result of their contribution.
- The system may be open to potential misuse or misreporting of information. There is no quality assurance of these data.
- Loss estimates will have large uncertainties due to the lack of quality assurance, use of assumptions on local construction categories and associated replacement costs;

Although, data could be connected using the scan tag reference, publicly sourced data would still be stored separately due to accuracy and security but could be viewed as a data overlay within the system. Any merging of public data into the aggregation and reporting system would need to go through a data validation stage gate, effectively managed by export and import across the systems, but could form a part of data development in the Prepare phase of the conceptual framework.

8.3.3. Remotely-sensed imagery

There continue to be major advancements in provision of satellite, aerial and UAV imagery. Coupled with increases in computing power and development of data processing algorithms for automated feature extraction and image classification, it can be assumed that prevalence of remote sensing-derived information will increase in the coming years. Although the toolset conceptualised in this project does not explicitly cover the procedures required for collecting data from remote sensing, the tools have been devised to allow for integration of data derived from remote sensing – both in the field data collection tools (loading imagery or derived data to contextualise in-field data collection) and the data aggregation and reporting system. Integrating derived vector and raster datasets will enable users of the toolset to get an up-to-date, objective view of disasters as they unfold, as well as provide a transparent, replicable and independent method of tracking physical recovery from disaster events.

8.4. Core development work

This report provides a conceptual design for a consolidated and consistent evidence-based post-disaster data collection, aggregation and reporting system. Following a sense check of the proposed concept, the next step will be to develop the concept into an implementable system. This should be done in a phased manner and would develop the following items in parallel:

- System development.
- Glossary development to extend the GED4ALL taxonomy for provision of contextual help in the tools.
- Standardize language/taxonomy used in describing damage, extending EMS98, IMS14 for flood, landslide, tropical cyclone and the remainder defined events in the Disaster Loss Data (DATA) event classification.
- Suitability of the implementation strategy and conceptual design to the country stakeholders (clients).

8.4.1. System development

With respect to system development and initial feasibility phase should be considered to further investigate the usage of MAGE as a base system to the conceptual design for both the data collection tool and aggregation and reporting system. The feasibility would seek to:

- Install the MAGE system for review
- Further contact should be established with the MAGE development team
- Assess the technology used for data collection and data reporting
- Review the templating available within the system and implied expansibility
- Compare the conceptual system features against the identified features of MAGE
- Assess a closer alignment of the backend iOS and Android application code base to reduce development costs
- Assess any gaps in designs
- Asses user interface adaptation
- Attempt to set up a prototype of the React data template as a trial of the system and capabilities
- Report on suitability, and work required to meet the conceptual design

The MAGE system uses compatible technology for the conceptual design and therefore has a high likelihood of supplying a suitable base system, but it is almost certain adaptation will be needed to achieve the goals of the conceptual design. To an extent this is an intended function of MAGE which clearly invites the open-source codebase to be 'forked'. The term to 'fork' code refers to the copying of an open source code base as a basis for an adaptation of the original code, whilst keeping linkage to the original code for provision of code updates.

Consideration will be needed as to whether any open source code is developed as a private or public community. The usage of a private community, to include all stakeholders for transparency, may be advisable for security, whilst maintaining the code under an open source (free) licence and contributing back to the original public community source code represented by MAGE.

Following the feasibility study, a decision should be made as to forward development based on the findings of the study. The decisions would be:

- Use MAGE as a base system and develop concept into an implementable system
- Develop a new application to the requirements laid out in the conceptual design
- No development

Further development should be managed in an Agile manner seeking to prototype and user review/test functionality based on a prioritization laid out in the MoSCoW analysis, Section 9 of Appendix G and I. Any user review/testing should include on-site usage to assess the practicalities of the design.

8.4.2. Glossary, taxonomy and contextual help menus

The conceptual design incorporates the contextual help features from the GEM-IDCT Android App. These are based on a descriptive glossary[14] developed alongside the GEM Building Taxonomy, including visual examples from several countries. This glossary is available to field teams through a help feature in the application and aids user interpretation of structural information.

The glossary is only currently available for the GEM Building Taxonomy parameters which have subsequently been expanded in the GED4ALL project. It would be helpful for the glossary to be expanded, allowing use within the site data collection tools.

In addition to structural attributes, users should also be able to have visual guides/prompts to aid with their classification of damage. There are suitable damage scales and visual clues available for earthquake (EMS-98, IMS-14 – see Appendix A. Further work is required to source libraries of images that could be used to populate contextual help menus for non-earthquake perils – flood, landslide, windstorm. Associated damage taxonomies and gradings would also greatly improve standardization of damage classification by large survey teams.

[14] https://taxonomy.openquake.org/

Section II

Revision of the current situation in Armenia regarding disaster data collection and reporting and customization of the solution to the context of Armenia

9. Summary of the disaster data collection in Armenia

The post-disaster data management (collection, assessment, aggregation and reporting) in Armenia is implemented through a 3-level system (communicates, regional and national), which is regulated by corresponding legislation and executive institutions. The system was developed through long-term cooperation with international organizations, the United States, the European Commission, Japan and Commonwealth of Independent States during a period of 30 years. The system as a whole covers a wide spectrum of DRM activities, part of which is the Post-Disaster Data Management for efficient allocation of resources to mitigate the consequences of natural disasters.

Armenia has experience in the application of the system to mitigate the consequences of large landslides (e.g. Ayrum, Toumanyan) and flash floods (e.g. floods in Ararat valley). Nonetheless, the practical disaster damage data collection methodology and associated tools still need to be improved for an efficient resource allocation.

Within this project, the following activities have been implemented to evaluate the existing situation in terms of legislation, methodologies, protocols and tools in Armenia:

- **Interviews and group meetings**: Several key players who have participated in disaster data collection, aggregation, assessment and reporting in a multitude of natural disasters in Armenia were interviewed. The interviews were conducted using the questionnaire developed by this project consortium, with recommendations from GFDRR. Additional information was also collected that was not originally covered in the questionnaire. The team visited marzpetarans in Ararat, Lori and Shirak marzes, communities of Getapnya, Ranchpar and Sipanik (Ararat marz), Lanjik (Shirak marz), Arevashogh and Spitak (Lori marz), Rescue Service Departments in Lori and Shirak marzes, the central office of the Ministry of Emergency Situations, Ministry of Territorial Administration, Ministry of Agriculture and Ministry of Transportation.

- **Review of legislation related to disaster damage data collection**: The following governmental decrees have been reviewed: Governmental Decree No 753, dated August 14, 2001, which regulates the assessment of damages to state-owned property and 1582-N of 2011, which defines the workflow for damage and economic loss estimation caused by natural and man-made disasters to legal and physical entities.

- **Review of disaster damage data collection protocols in Armenia**: ARS Departments in the regions currently use specific protocols (Forms No 65 and 35) for reporting damage data to the (MES). At present, MES has developed a new form, based on decree 1582-N, that local communities may use for reporting disaster damage data. At the same time, regional authorities have developed special data reporting forms for village mayors for reporting damages caused by natural disasters.

- **Identification of toolkits for data collection and reporting:** At this stage, MES has adopted the MIRA Toolkit by decree No 888 of Minister of Emergency Situations dated May 4, 2017. The decree was adopted within the framework of the "National Strategy Programme on Disaster Risk Management" adopted on April 4, 2016 by Decree of Government of Armenia. The MIRA toolkit guideline was translated and adapted to Armenia according to paragraph 4.1 of the aforementioned governmental decree. The Ministry of Agriculture of Armenia with support from the European Union and the Food and Agriculture Organization has developed a methodology and guideline for post-disaster data collection, assessment and reporting of damages and losses in the agricultural sector. This guideline is an upgrade and modification of the existing post-disaster needs assessment (PDNA) methodology developed by the United Nations, World Bank and European Union in 2014. The Methodology was adopted by decree of Minister of Agriculture No 275-A, dated December 29, 2015.

- **Identification of gaps in the disaster damage data collection process:** The analysis of information received through interviews and available documents shows that the existing post-disaster data management system in Armenia has a strong organized legal and institutional base. At the same time, it has serious gaps in terms of its methodological components and implementation tools, as listed below:
    - **There is no single methodology for carrying out the damage data collection** at the lower (community) levels, since they have difficulty in aggregating and presenting the collected data to the government in one format.
    - **There is no single methodology for damage and loss assessment**, (especially for quantifying the damages and losses in monetary terms). Hence, the development of such methodology would increase the efficiency of such a system.
    - **Current damage data collection and aggregation workflow is based on paper format**. Introduction of automated damage data collection and aggregation system would allow all key players to use a single system for damage data collection and aggregation in a uniform way.
    - **There is no comprehensive database on disaster occurrence, damages and losses**. MES has stressed the importance of having a single web-based platform for registration and sharing of damage and loss data collected by communities, verified by regional authorities, regional ARS departments and MES.
    - **There are organizational gaps**, which are stipulated by the flaws in current protocols and methodologies for damage data collection. For example, communities preparing the LAAs mentioned that there is no time frame specified for collecting and submitting the LAAs to

marzpetarans. This is specifically important for those settlements that are included in communities having more than one village.

- **Drafting of recommendations**: Taking into consideration the collected information, feedback from the interviews, and revision of the legislation and tools, the following recommendations have been suggested:

  - Improvement of existing protocols and IT methodologies for disaster damage collection, aggregation and reporting.
  - Development of IT tools for disaster damage data collection in the field.
  - Development of IT systems for disaster damage data aggregation and reporting.
  - The proposed software system should be easy to install and maintain and preferably be pre-installed on the server before it is taken to MES
  - Provision of organizational measures for a successful implementation of these recommendations.

Detailed analysis of gaps and steps for improvement of Post-Disaster Data Collection and Management System in Armenia is outlined in Chapter 9 and 10.

10. Customization of the conceptual design to the context of Armenia

The main approach for the customization of the conceptual design is in defining the usability of the product and description of the additional modifications for its application for improving post-disaster data management System (PDMS) in Armenia. The need for customization is stipulated by the fact that PDMS was operating in Armenia for a long time and has well-developed legislative, institutional and organizational structure.

The proposed conceptual design provides comprehensive and well organized solutions for post disaster data collection and management process. At the same time, this system has taken into account the best practices from many countries and allows applying expandable data content and functionality, which would make it easier to integrate the existing system of Armenia into an up-to-date system.

As it will be outlined below, the methodology and general concept for data collection, aggregation and reporting developed and presented in this report will essentially improve the current system in Armenia, particularly for standardization and unification of data collection and centralization of all information. At the same time, the conceptual design will be more efficiently applied to Armenia, if changes and additions corresponding to the current institutional and functional structure and workflow in the country are integrated as described further in this chapter. We also present the necessary steps for adaptation of the developed conceptual design to the specific needs of Armenia regarding the perils, damage data collection tool, aggregation and reporting.

10.1 Description of Customization Tasks

The Post-Disaster data management system in Armenia has been used for a long time but it has no unified and standardized IT system for damage data collection, aggregation and reporting. This gap decreases the system efficiency, transparency of resource allocation and emergency management, and damage recovery activity.

A large number of methodologies for post-disaster data collection were discussed within the project Phase 1 and none of them can be used without the implementation of some modifications to context of Armenia. The proposed application should provide a practical, easy to use, low-cost application for data aggregation and reporting including accurate and efficient damage data collection on site (mobile app) within a challenging working environment.

The customization task must cover the integration of the MIRA and PDNA methodologies with the proposed data collection tool and aggregation and reporting system. The tools should be interoperable with existing data collection protocols (paper-based) already existing in the country.

10.2 Intended users of the proposed conceptual design in Armenia

As previously described, the Conceptual Design will be used for post-disaster data management in Armenia which includes participants with different roles and expertise. Four type of users have been identified: damage data collectors, sectoral experts, ARS departments in marzes, and MES personnel. The access to the platform is regulated through the login interface. *The following groups of persons and specialized experts should be trained:*

- Damage data collectors at local level (municipality personnel) – should be trained how to collect data in the field and implement the data transfer.
- Sectoral experts at regional level – should be trained on data collection in the field and data validation.
- Personnel at ARS Departments in marzes – should be trained on data collection in the field and data aggregation to be sent to the MES of Armenia.
- MES personnel – part of the personnel should be trained on data collection in the field, data aggregation, and preparation of reports to the Republican commission and statistical service. This group should also export data in the formats compatible with the Sendai framework for disaster risk reduction.

The existence of trained staff in MES is of vital importance, because they will be the main point of contact in case local government heads or officials at regional authorities change.

10.3 Customization of Scope of Events

The Conceptual Design should be able to capture data regarding damages caused by earthquakes, floods and landslides. The *Conceptual* Design should be flexible to add other perils in the future specific to Armenia, such as windstorms, hailstorms, droughts, extreme temperature and rock falls.

10.4 Customization of attributes

In the Functional Requirements Document for the Damage Data Collection Tool (see Appendix H), several tables describing the logical attributes of the system are presented. In this section we provide a modified version of these tables following the requirements for Armenia.

Table 3 - Logical Attributes for the Emergency entity

Attribute	Description	Type	Mandatory	Capture
Scale	Emergency is of Local, Regional or Country scale	Text	Yes	Lookup List
Locality 1	Marz (es) that emergency was declared, Should be able to select multiple marzes	Text	Yes	Lookup List
Locality 2	Community (ies) that emergency was declared. Should be able to select multiple communities	Text	Yes	Lookup List
Locality 3	City/village (s) where emergency was declared.	Text	Yes	Lookup List

	Should be able to select multiple settlements			

Table 4 - Event Entity Attributes

Field/Attribute	Description	Type	Mandatory	Capture
Locality 1	Marz (es) that emergency was declared, Should be able to select multiple marzes	Text	Yes	Lookup List
Locality 2	Community (ies) that emergency was declared. Should be able to select multiple communities	Text	Yes	Lookup List
Locality 3	City/village (s) where emergency was declared. Should be able to select multiple settlements	Text	Yes	Lookup List

Table 5 - Exposed Element Entity Attributes

Field	Description	Type	Mandatory	Capture
Surveyor Name	Name of Person implementing survey	Text	Yes	Assigned by Administrator
Centroid Latitude	Latitude location of exposed element	Float	Yes	Auto
Centroid Longitude	Longitude location of exposed element	Float	Yes	Auto
Area Damaged	Approximate area damaged in ha or sqm	Float	Yes	Manual
Damages incurred	Depending on element sub-category, damages to crops, livestock should be registered in tons	Float	Yes	Manual
Validated	Checkbox showing if the record was validated by marz (regional administration)	Boolean	Yes	Checkbox
Name of land/building owner	Shows the name of person who owns land parcel/building/structure for further compensation	Text	No	Manual

10.5 Customization of assumptions and dependencies

The following general assumptions are required for the customization of Conceptual Design:

- *Operating and code description language will be in English.*
- *Operating language (interface, help, manuals) should be in Armenian and English.*
- *Damage categories (classification) caused by flooding, landslide and windstorm should be compiled for use in contextual help.*

10.6 Customization of external interface

The “data collection screen” proposed in Chapter 6 must be customized to the context of Armenia. The figures below show customized mockups for data collection, aggregation, and reporting for Armenia.

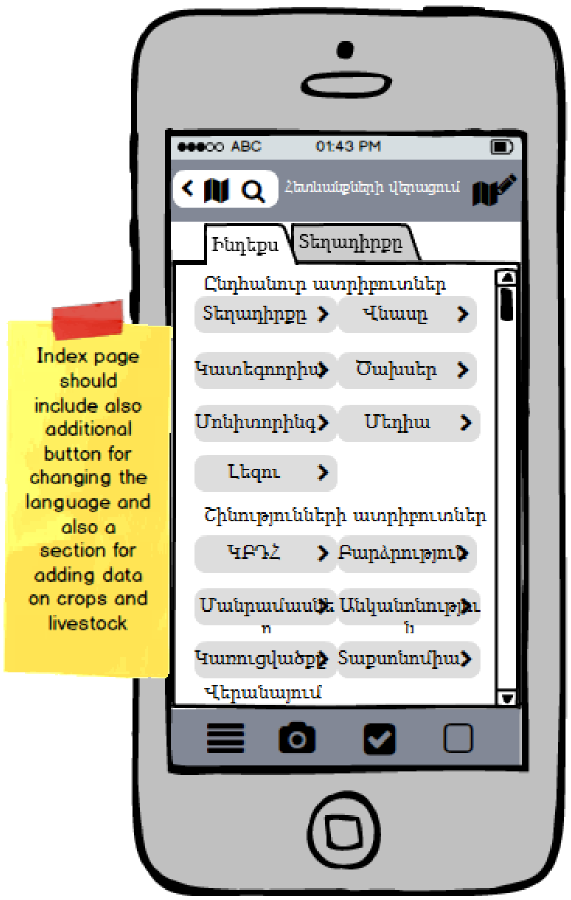


Figure 25 Customized mockup for index page

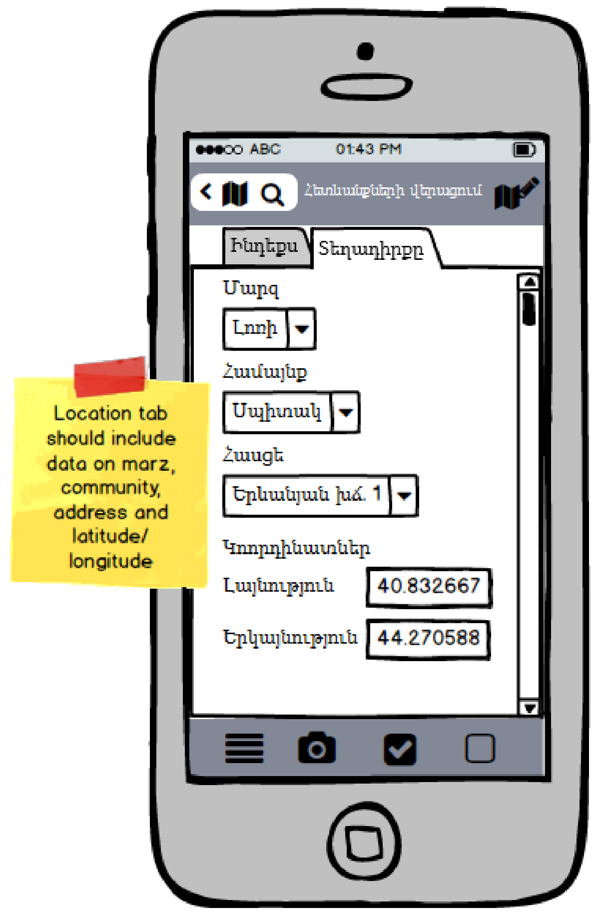


Figure 26 Customized mockup for location page

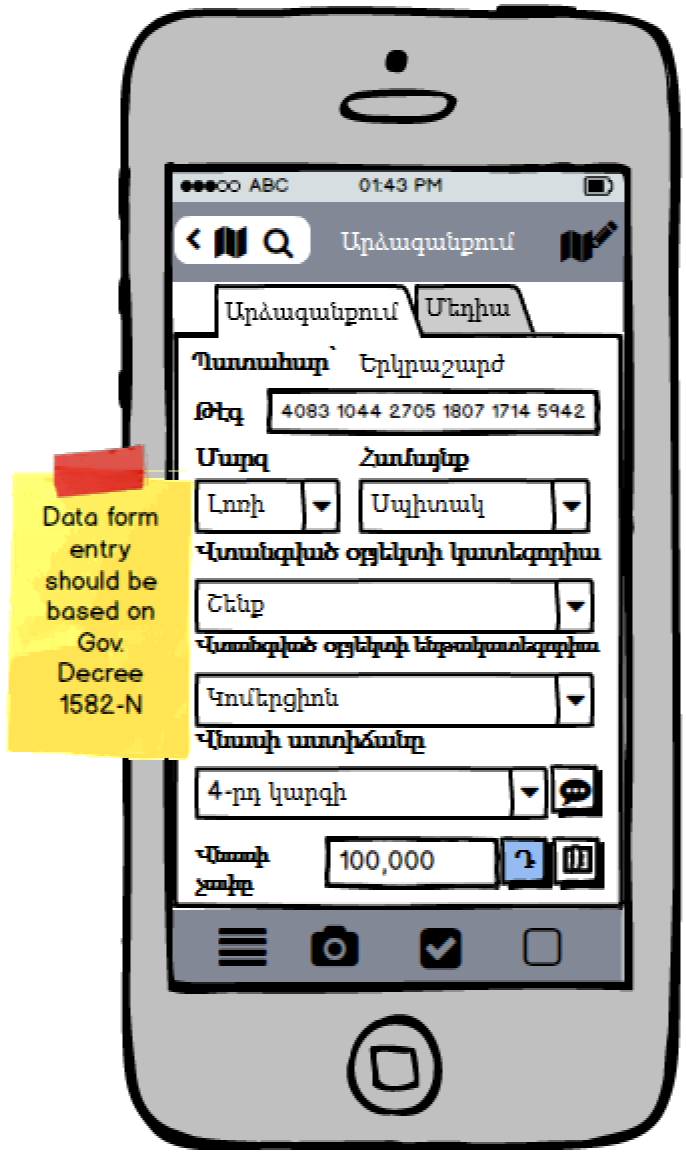


Figure 27 Customized mockup for data entry form

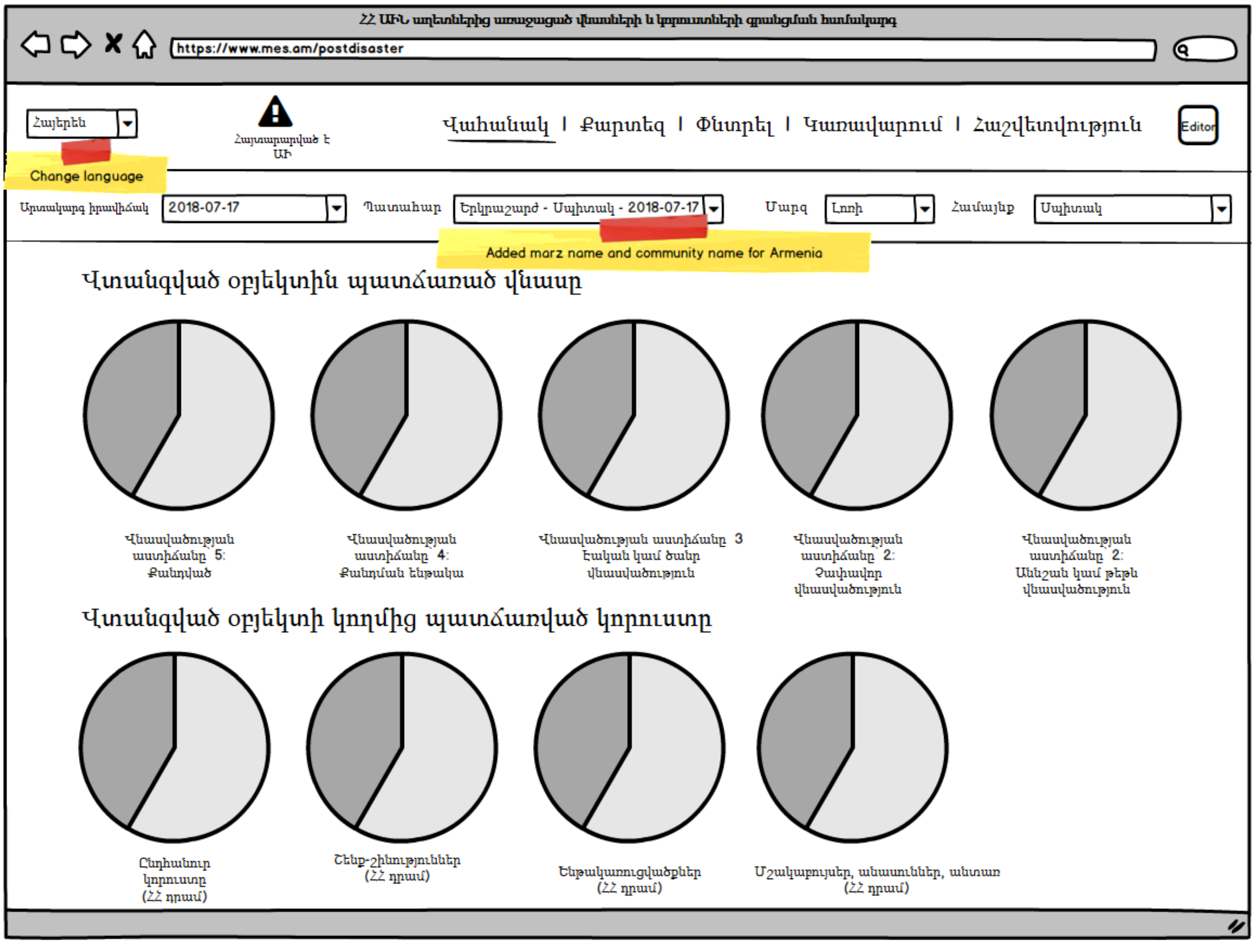


Figure 28 Customized dashboard web interface tool

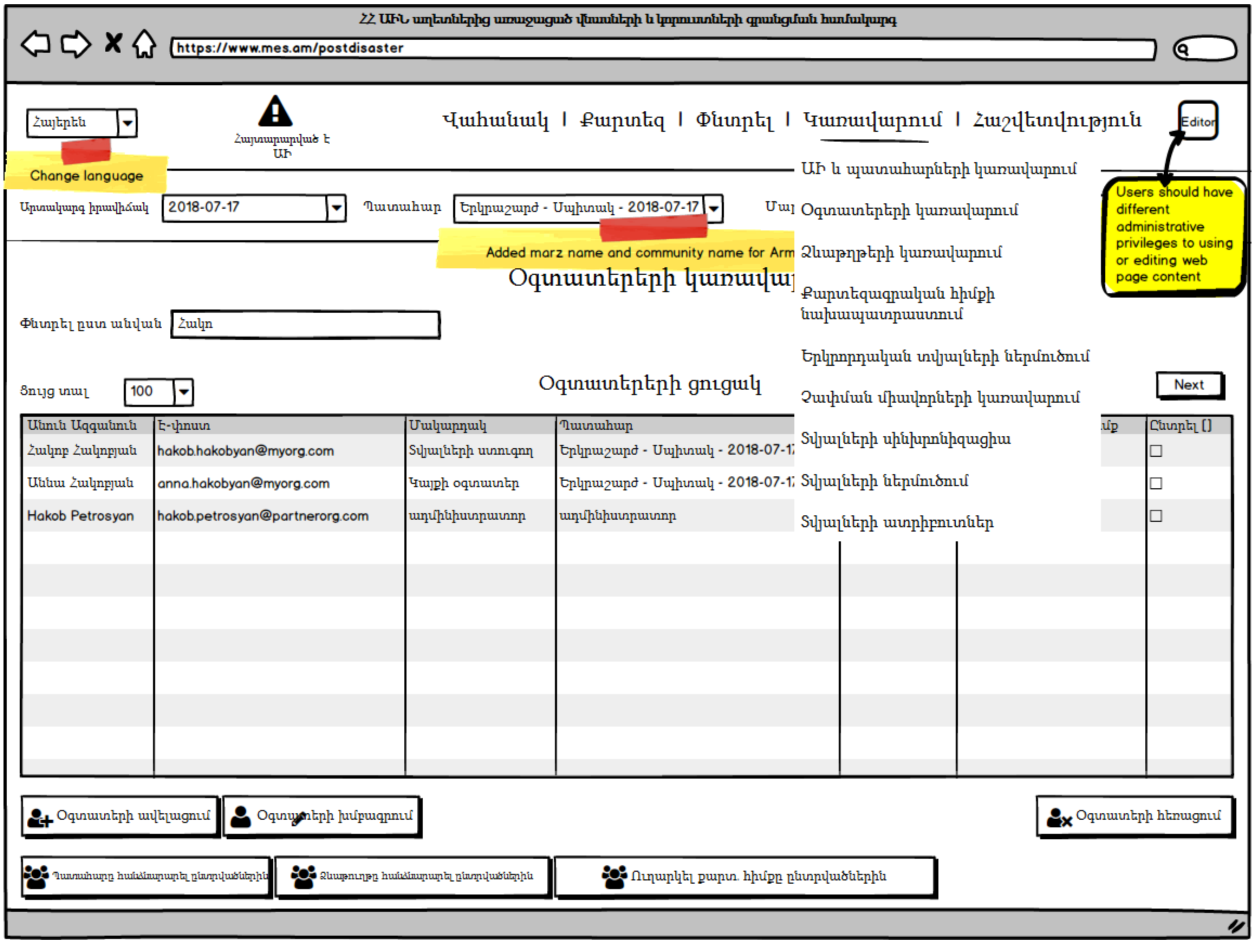


Figure 29 Customized user management web interface tool

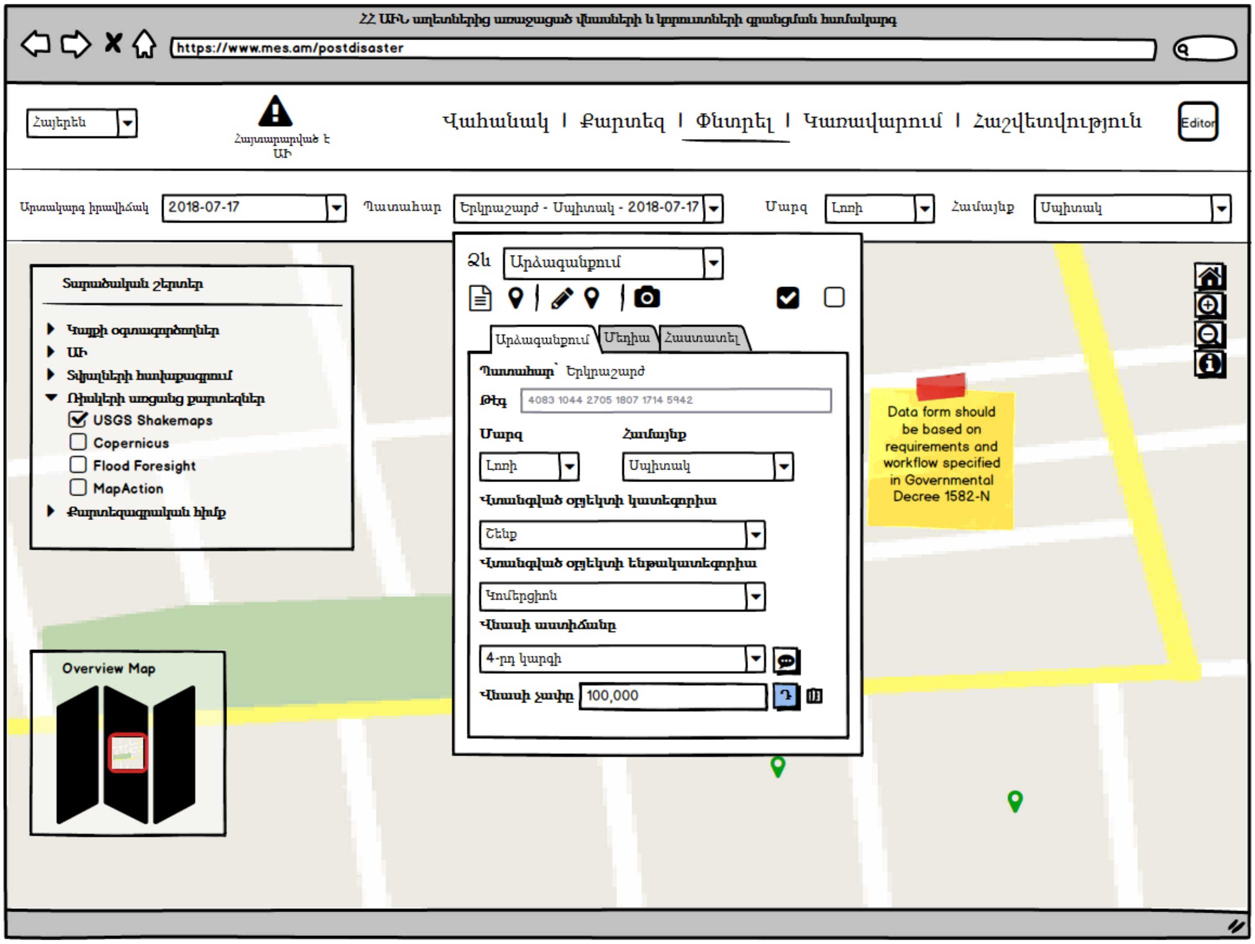


Figure 30 Customized data search and navigation screen: react tab

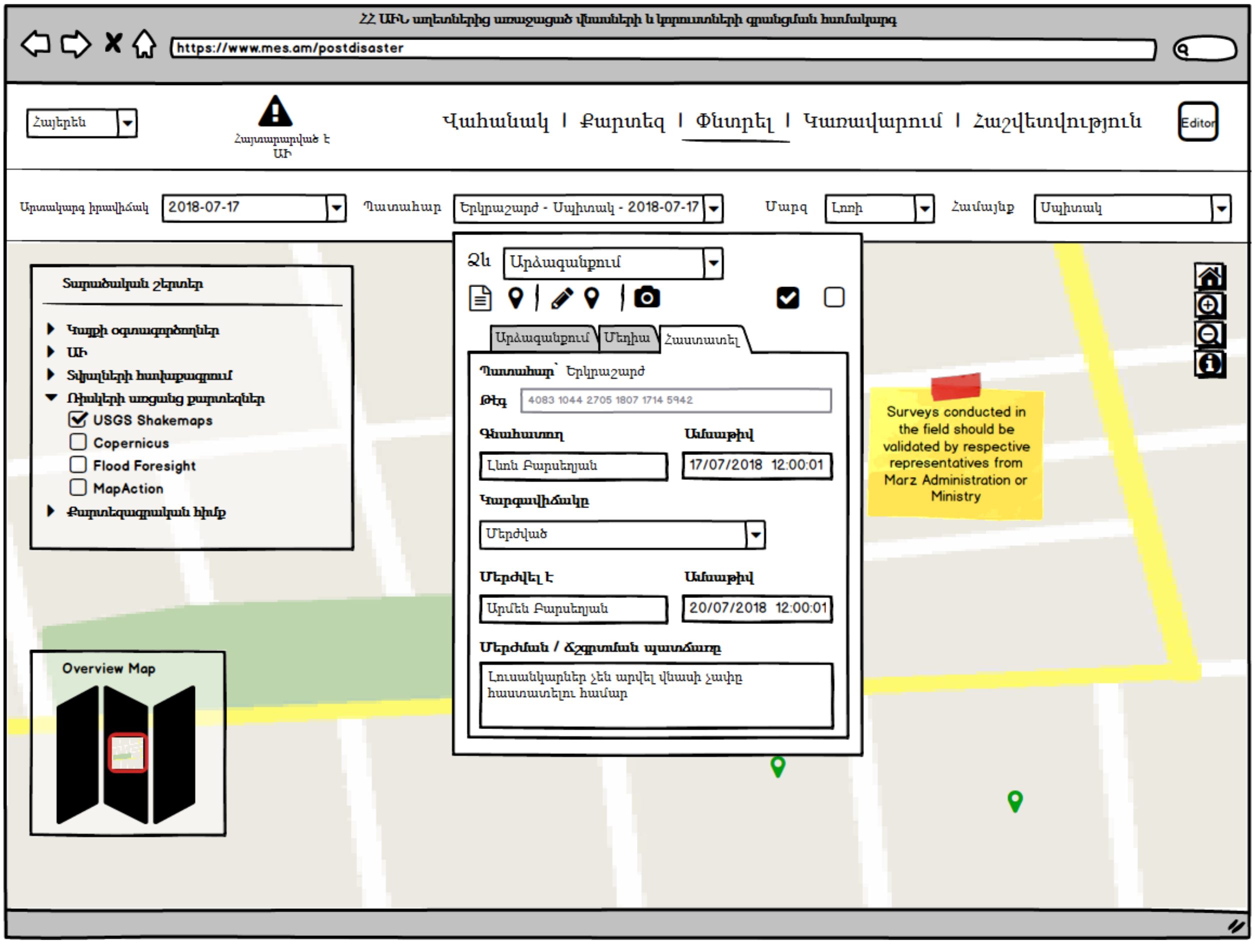


Figure 31 Customized data search and navigation screen: validation tab

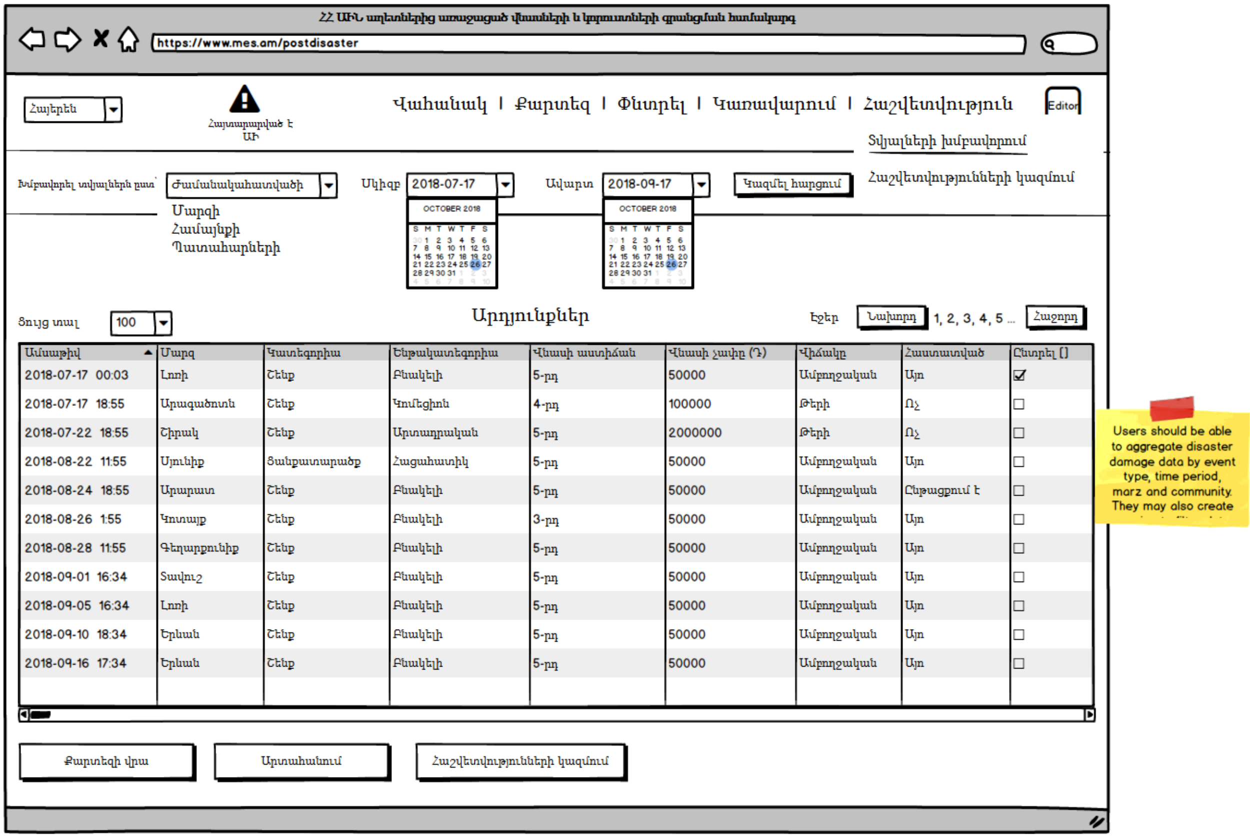


Figure 32 Customized data aggregation interface

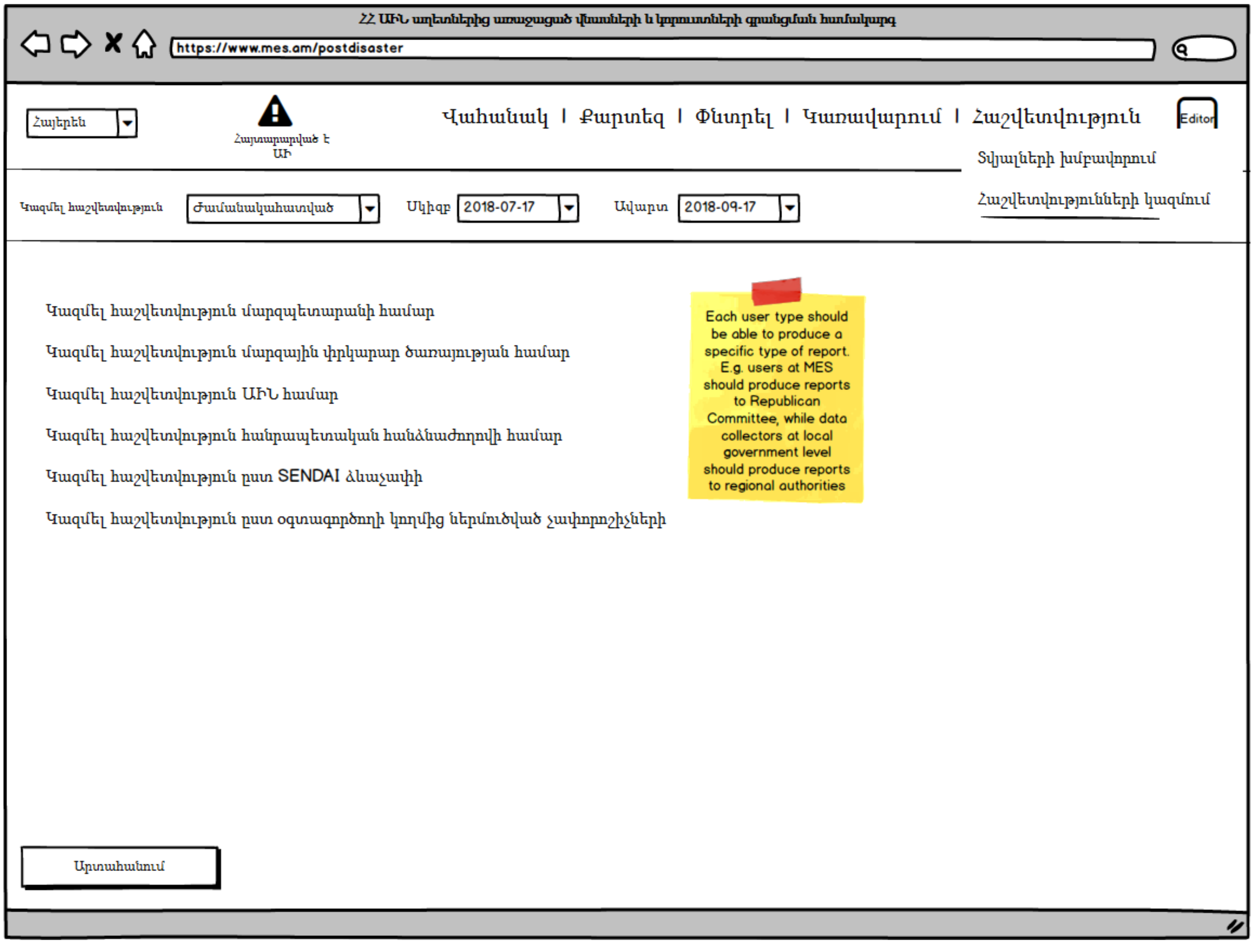


Figure 33 Customized data reporting interface

10.7 Customization of Hardware and Software Architecture

10.7.1 Stimulus for Customization of Hardware and Software Architecture

The Conceptual Design should be customized to comply with the features presented in the workflow of disaster data management system in Armenia, described in Table 6, and further illustrated in Figure 34. The suggested workflow would allow eliminating the existing gaps in the system, i.e. standardize the assessment of damage and loss, centralization of post-disaster damage data in a central repository for ease of data access, aggregation and reporting of the damage and loss estimates. The central repository should be located on local server. The proposed information workflow is further explained below:

1. Post-disaster damage collection is implemented at Level 1 by the Loss Assessment Commission and presented to the Regional Commission (Level 2). In several cases (depending on the scale of the disaster) these data may be collected by Sectorial Ministries, by ARS and other state bodies. ARS participates in disaster damage collection as a coordinating body. The collected data is registered in a "raw database".

2. The Regional Commission should have access to the raw database to validate the initial data collected by the communities. The regional commission validates the data in a new “validated” database, which is sent to ARS and then to the MES for preparation of the Report to the Republican Commission.
3. MES aggregates and prepares a report for the Republican Commission.
4. The Republican Commission discusses the report submitted by MES and sends it to the Government of Armenia for compensation of losses.

The data flow presented below allows for storing the collected data in a central server and minimizes data loss and data duplication at all levels.

Table 6 – Description of the Information flow according to new proposed disaster management system

	Data flow / Institutions	Setup	Data Collection	Data transfer	Post-Processing	Aggregation	Reporting to Republican Commission
LEVEL 3	MES	Statement of Emergency Situation	Yes, if disaster is at National level			Full or Partial Data Aggregation	Yes
	MoTC				Preparation of Design Docs and Submitting to Government for Funding		Partial
	Other Ministries and Government Adjunct Bodies						Partial
LEVEL 2	Marzpetaran Loss Assessment Commission		Yes, if disaster is at regional scale or state property is involved		Loss assessment (Editing and validation)		
	ARS regional Department of MES					Data aggregation	
LEVEL 1	Disaster Loss Assessment Commission of Communities	Define event and send message to Crisis Management Centre	Yes (mandatory)				
	Road maintenance companies	Define event and send message to MoTC	Yes, with road design companies				
	Utility companies (Water supply, Electricity supply, Gas supply)	Define event and send assessment of damages to MES	Yes				

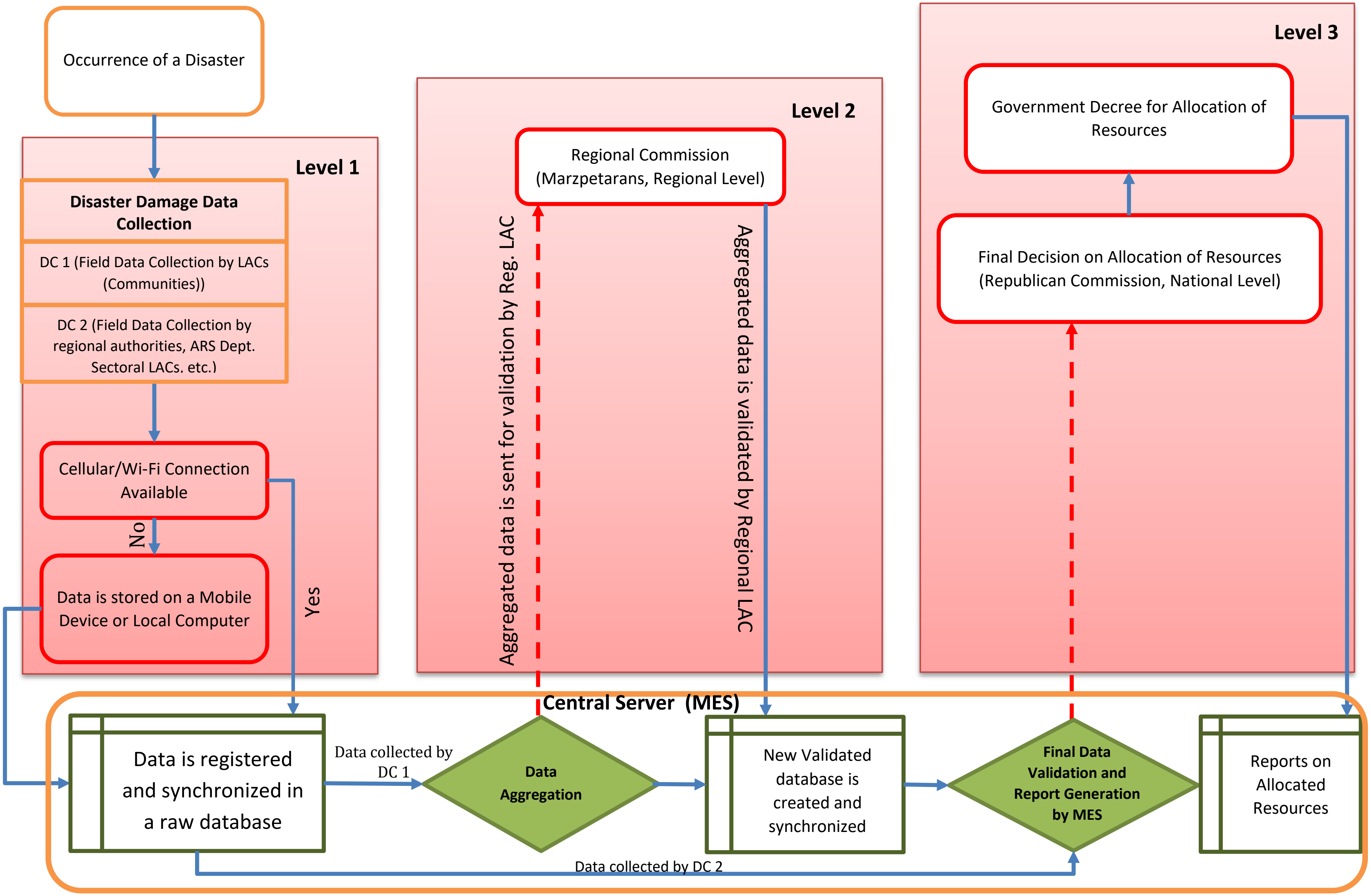


Figure 34 - Representation of the Information flow according to new customized disaster management system.

10.7.2 Customization of Hardware Architecture

Disaster-related data in Armenia is considered sensitive and hence post-disaster damage data should be collected in a secured server located in the MES. It is recommended to include on a cloud-based server only data aggregated at a certain level (based on the Sendai framework, for example). Cloud-based data might be also used to inform the population about the current status of damages caused by natural disasters. It is also useful to implement local backup of data on disaster site location only for collected data in a certain format and then upload it to central server when mobile or wi-fi connection is available. The architecture of this proposed system is depicted in Figure 35.

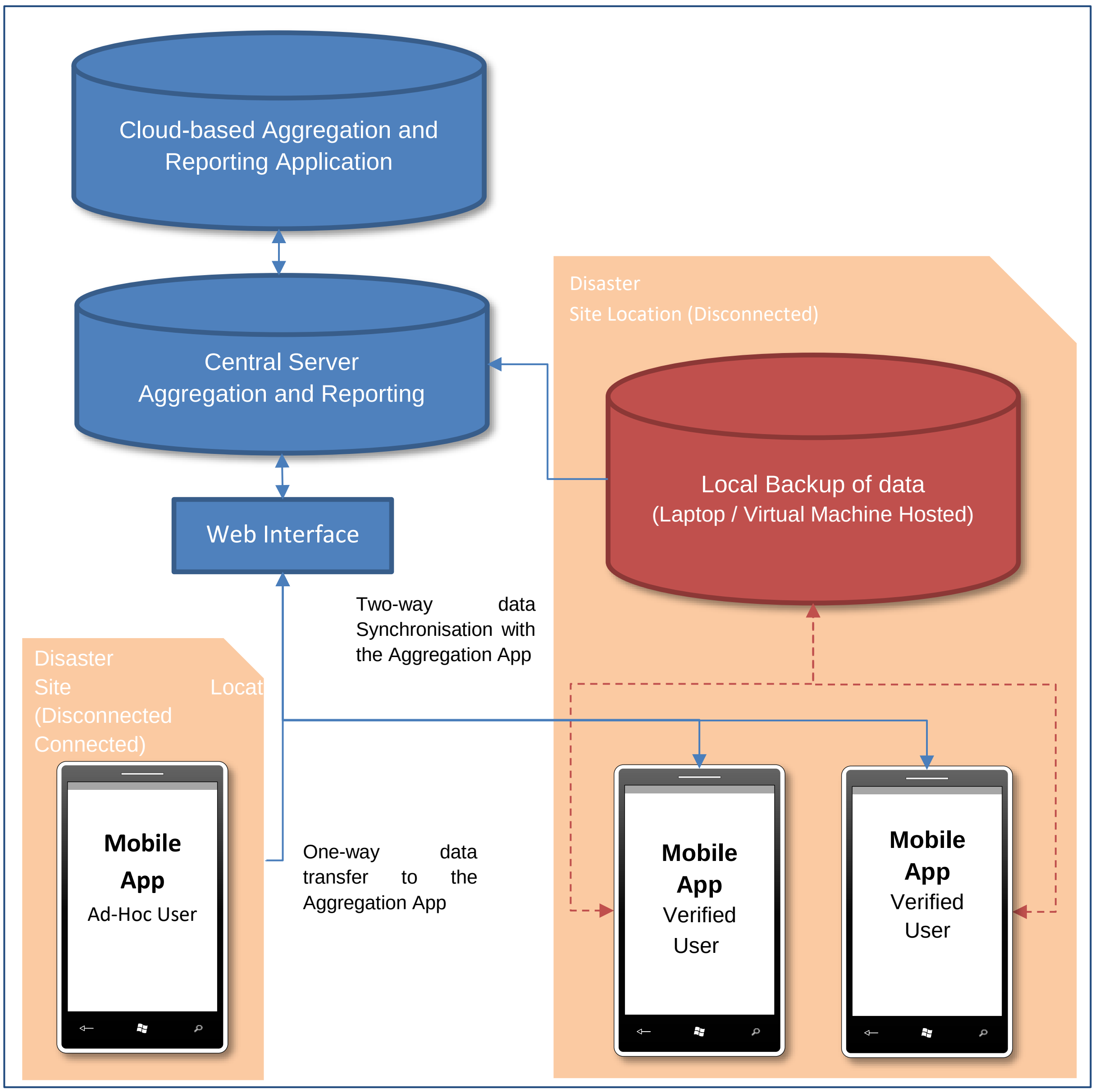


Figure 35 The customized conceptual view of the hardware architecture.

10.7.3 Customization of Software Architecture

The proposed software architecture is based on the conceptual framework (Prepare – React – Act – Monitor) presented in Chapter 3, and illustrated in Figure 2. At this stage, damage data collection and utilization in Armenia is limited to the Prepare, React and Act phases. Introduction of the new system would allow integrating all phases of the conceptual framework protocol into the damage data collection, aggregation and reporting system. Since Armenia is using a three-level damage data collection and reporting system, as described in Chapter 9, the software interface was modified to reflect the protocols and workflow for Armenia.

Table 7 – Proposed interaction between the methodology, tools and external resources.

Phase	Aggregation and Reporting Tool	Site Data Collection Tool	External Software/Tools
Prepare	• Implement instance on hosted server • Setup any local backup instances • Create data from templates • Assess/Reassess damage unit rates	• Setup mobile devices • Download background maps and default templates • Develop exposed element data and QR scan tags • Site-based emergency exercise and training	• **Prepare any external tools** • **Pre-prepare OSM background mapping for area** • Identify third-party sources of secondary data
React	• Define Emergency • Define Event and assign any existing exposed elements to event, resetting damage attributes • Assign/create users to event and data template • See data collection workflow	• Inform site users to sync data • Use ad-hoc user and default templates if communication issues exist • Create written scan tagging if no QR tags exist • See data collection workflow	• *Apply data sampling (e.g. GEM-IDCT protocol)* • *Process secondary map layers e.g. remote sensing* • Apply additional data attributes by spatial query
Act	• Data viewing/review/validation • Reassign/create users to event and data template • See data collection workflow • Data aggregation for Regional LAC • Reports for Republican LAC	• Use scan tags to identify and edit React records • Verified users only for detailed data collection • See data collection workflow	• Apply additional data attributes by spatial query
Monitor	• Data aggregation (using pre-loaded admin, data) • Work progress • Dashboard for event • Export report, maps	• Use scan tags to identify and edit Act records Verified users only for recovery review data collection • See data collection workflow	• **Sendai Framework-DesInventar import** • **Export to other systems and analytics** • **GIS Disaster Catalogue** • GEM Consequences Database etc

10.8 The Approaches and Steps for Improvement of Post-Disaster Data Collection and Management System in Armenia

This chapter outlines consecutive steps aimed at improving the PDM System in Armenia and presents approximate costs required for the development and introduction of disaster damage data collection, aggregation and reporting in Armenia.

The steps are based on the conceptual design described in Chapters 6 and 7. The customized interface mockups in the context of the PDM System are in Section 10.6. The improvement of the PDM System in this chapter covers the implementation of comprehensive measures aimed at filling the gaps described and analyzed in Chapter 9. All of the proposed measures are interrelated, but in the same time one of the gaps can be filled only by specific groups of measures. Based on this consideration the proposed measures for PDM System improvement are grouped and described in connection with a gap which should be filled. The gaps and related groups of measures are described in successive steps according to a chain of post-disaster data collection, aggregation and reporting activities (see Table 7). For each of gap, "Proposed Solutions", "Required Activities" and "Required Resources" are described in Table 8.

Step 1

The objective of Step 1 is to fill the following gap: ***"Absence of single methodology and tool for damage data collection"***. This gap limits the ability of PDMS to register and present the disaster damage and loss data in a unified manner. The following measures should be implemented to fill this gap:

- **Development of protocols and templates for registration of damage and loss data in a unified manner:** This measure will ensure that data collection is implemented by use of newly compiled protocols, guidelines, templates and data forms (as described in Chapter 6). The principal content and structure of the rules, documents and input forms should be based on the Conceptual Design and take into consideration the practice of the PDM System in Armenia. Developed materials should be discussed and agreed with key-players of the PDM system and presented to stakeholders.
- **Customization and adaptation of the Conceptual Design of the site collection tools (described in Chapter 6) to the context of Armenia:** The main aim of this activity is the adaptation of the design of the existing data collection tools used within the PDM System in Armenia. Particularly, the disaster damage data collection templates created within this Project will be adapted to the existing three-level system in Armenia for damage data collection and reporting. In addition, administrative local attributes specific for Armenia will be added to the system, as well as types of disasters that are specific to Armenia.
- **Development of site data collection tool and its integration into PDM System in Armenia:** This activity considers the integration of the site collection tools with the PDM system

through the development of the corresponding program environment: UI/UX for mobile devices (section 6.3.4). Previous attempts in Armenia to develop a methodology, guidelines, or a web-based program to assist communities and marzes for providing disaster damage data at the asset-level failed.

- Training of trainers (from MES staff) will be conducted for advanced users of PDMS, who will then train Data Collectors from communities, regional administrations and regional Rescue Service Departments.

Step 2

The objective of Step 2 is to fill the following gap: ***"There is no single methodology used by stakeholders for damage and loss assessment, (especially for quantifying the damages and losses in monetary terms)".*** The lack of such methodology usually leads to exaggerated estimates of damage at first and second levels of PDM System. The following measures should be implemented to fill this gap:

- Comparative analysis of damage and loss assessment methodologies used by the case studies reviewed within this Project and used by the MES (MIRA Toolkit), as well as documents developed by MES and other relevant ministries. The final methodology will be selected through consultations with MES specialists and key players of the PDM System.
- Integration of the selected methodology into PDMS is the second activity for damage and loss assessment improvement on the regional (Marz) and republican (ministry) levels. This activity will be implemented through the development of UI/UX and forms for web-based software. An example of such requested interface is *"Form N 65; Information Note: On Loss Assessment Acts compiled by Loss Assessment Commissions based on Government Decree No 1582-N dated November 10, 2011 "On Establishment of the Procedure for Assessing the Damage Caused to Physical and Legal Entities as a Result of Emergency Situations"* (see Table 17) and "*Form N 35; On hazardous natural phenomena and natural disasters in the marz (Yerevan) and the work done to eliminate their consequences and others".*
- Training of trainers (from MES staff) will be conducted for advanced users of the PDM System, who will then train Data Collectors from communities, regional administrations and regional Rescue Service Departments.

Step 3

The objective of Step 3 is to fill the following gap: ***"No automated damage data collection, aggregation and reporting system"*** in Armenia. Filling this gap is crucial for Armenia, because at present only paper-based damage data collection, aggregation and reporting system operates in Armenia. The automated system should be developed as a web-based platform and protocols for data transfer, storage and processing of the collected data, its aggregation and reporting. To implement this step the following activity should be performed:

- **Development of a web-based platform (server side) and development of platform for downloading/uploading data from mobile devices (in case internet is unavailable):** In general, the developed web-based software will follow the logic of the Conceptual Design proposed by this Project. At the same time, it should also be integrated into the existing system in Armenia, which has been in use for a long time. For this purpose, the developed tools should be interoperable with existing data collection protocols (paper-based) already existing in the country. To achieve these objectives the Conceptual Design should at least customize the following features: scope of events, intended users, database structure and attributes, assumptions and dependencies, external interface, hardware and software architecture. Described solution will essentially improve the current system in Armenia, particularly for standardization and unification of data collection and centralization of all information. At the same time, the conceptual design will be more efficiently applied for Armenia and correspond to the current institutional and functional structure and workflow in the country.

Step 4

The objective of step 4 is to fill the following gap: ***"No comprehensive database on disaster occurrence and damages and losses".*** To fill this gap, a local (country) hosting server and a database for post-disaster data management system should be developed. In terms of the development strategy of the Conceptual Design (see Chapter 7), such database is characterized as follows:

- Implementation environment – hosted within the country, restricted to country based users.
- Application server – the system is managed wholly by the country with support on request.
- Database server - the database could work with Central application server, but would be under control of the country.
- Aggregated data may be submitted and served from a cloud database.
- A separate server may be needed for storing and serving geospatial data.

STEP 5

The objective of Step 5 is to fill the following gaps: ***"There is no clear definition on how different stakeholders interact and disseminate information on damage and loss data collection and assessment"*** and ***"There is no timeframe specified for damage data collection and submission".***

To fill the first gap - clear protocols for ministries, regional administrations, local governments and adjunct bodies should be developed, explaining the order of interaction for post–disaster data collection and damage and loss assessment. Implementation of this measure will improve interaction between MES and MoTCIT, for example, who are monitoring and eliminating the consequences of such natural hazards along the road infrastructure such as landslides and rockfalls. It should be noted that the MoTCIT and other companies involved in infrastructure assets (water supply, gas supply, electricity supply) do not submit any reports to the MES on the damage costs incurred from natural hazards. MoTCIT reports these costs directly to the Government.

For dissemination of the Conceptual Design and proposed measures for improvement of the PDM System in Armenia, meetings and discussions will be organized among key stakeholders.

Table 8 – Gaps, Solution Steps, Required Activities and Required Resources for Development and Introduction of Disaster Damage Data Collection, Aggregation and Reporting Tools in Armenia

Gaps	Solution Steps	Required Activities	Required Resources
1.No single methodology and tool for damage data collection	Development of protocols and templates for registration of damages and losses in a unified way	Discussion and agreement of protocols and templates with stakeholders	One disaster management expert
	Customization and adaptation of this Project's site collection tools' design (described in Chapter 6) to context of Armenia (Chapter 10)	Integration of Site collection tools' concept developed within this project into Armenian Post-Disaster Management System (PDMS)	One disaster management expert
	Development of site data collection tool	Development of UI, UX and forms for mobile devices (described in Chapter 6 and Chapter 10)	One mobile (android) programmer
		Training of Trainers (Data Collectors)	One trainer
2.There is no single methodology used by stakeholders for damage and loss assessment, (especially for quantifying the damages and losses in monetary terms)	Selection and adaptation of damage and loss assessment methodology from reviewed case studies within this Project (described in Chapter 11 and 12) to context of Armenia	Consultations and meetings with MES specialists and key players of the PDM System for discussion and agreement on required methodology	One disaster management expert
	Integration of the selected methodology into PDMS for damage and loss assessment on the regional (Marz) and republican (ministerial) levels	Development of UI, UX and forms for web-based software	One web developer
		Training of Trainers	One disaster management expert
3.No automated damage data collection,	Development of Web-based software and protocols for data transfer,	Development of Web-based software (server side).	• One android developer,

aggregation and reporting system	storage and processing of collected data, its aggregation and reporting	Development of software for downloading/ uploading data from mobile devices (in case no internet is available).	• Four web developers • One GIS Specialist • System Administrator • Mobile data connection expert • One disaster management expert • Server • Mobile devices • Mobile internet connection
4.No comprehensive database on disaster occurrence and damages and losses	Development of Local (country) hosting server and database for post-disaster data management system	• Development of Entity – Relationship Diagrams • Database Development • Development spatial data layers	• One database programmer • One GIS Specialist • One web programmer • Database Management System • Spatial Database Management System • Data Security System
	Importing of disaster occurrence data from other sources into existing database	Data input	
5.Organizational gaps: 5.1. There is no clear definition on how different stakeholders interact and disseminate information on damage and loss data collection and assessment. 5.2.There is no timeframe specified for damage data collection and submission	Development of clear protocols for ministries, regional administrations, local governments and adjunct bodies on order and execution timeframe for collection, aggregation and reporting of damage and loss data	Dissemination of developed conceptual design and proposed measures among stakeholders for definition and agreement of improved PDMS	One disaster management expert

Table 9 –Outputs and Related Costs for Development of Disaster Damage Data Collection, Aggregation and Reporting Tools for Armenia

Outputs of Implemented Solutions	Benefits of Implemented Steps	Required Resources	Months	Approx. Cost (USD)
Step 1. Developed field data collection tool based on customized Conceptual design including new protocols and templates.	Operating, unified and formalized description of damage and loss	One disaster management expert One disaster management expert One mobile (android) programmer One trainer	4 2 2 0.5	17600
Step 2. Selected and integrated into PDM System of Armenia efficient methodology for damage and loss assessment.	Accurate and objective assessment of damage and loss	One disaster management expert One web developer One disaster management expert	1.5 2 0.5	9000
Step 3. Developed automated damage data collection, aggregation and reporting system.	Efficient and timely management of post disaster information, that supports disaster mitigation activity.	One android developer, Four web developers One GIS Specialist System Administrator Mobile data connection expert One disaster management expert Server Mobile devices Mobile internet connection	1 6 8 4 4 2	95000
Step 4. Developed Local (Country) hosting server and database for PDM System	Secure server, that will store all disaster damage and loss data	One database programmer One GIS Specialist One web programmer Database Management System Spatial DBMS Data Security System	8 6 4	40000
Step 5. Developed and agreed with PDM System's stakeholders clear definition on order and execution timeframe for collection, aggregation and reporting of damage and loss data	Improvement of interaction among PDMS stakeholders	One disaster management expert	2	3000

The implemented steps mentioned-above would eventually improve the PDMS activities in the following way:

- Increase the data flow speed from data collection to final decision on resource allocation.
- Increase the accuracy and objectivity of the collected data.
- Increase speed of data aggregation and reporting.
- Increasing speed for submitting critical information to international organizations for support in case of natural disasters.

All of these factors eventually will result in saved lives and efficient allocation of resources in the React, Act and Monitor stages.

11. Appendix A: Review of protocols for Disaster Data Collection

Protocols or guidelines for damage and loss data collection aim at establishing a uniform and reliable procedure to evaluate the impact of disasters. During the inception report four existing protocols were selected for an in-depth review based on the availability of detailed documentation, the ability of consider exposure data at a fine resolution, the possibility to incorporate past hazard and/or risk studies, the link with technological tools for data capture and the existence of uniform procedures for the estimation of damage and loss. This section provides a detailed description of these four protocols, with a particular focus in identifying the strengths, limitation and gaps.

11.1. Damage, Loss and Needs Assessment (DaLA)

11.1.1. Description

The Damage, Loss and Needs Assessment (DaLA) methodology aims at estimating the damage and losses in the aftermath of a natural disasters based on sectorial assessments of the overall economy in the affected region. The quantified damage, in monetary values, is further used for estimating the reconstruction needs, while the amount and type of losses allow estimating the overall socio-economic impact of the disaster and the needs for economic recovery. On the other hand, the Post-Disaster Needs Assessments (PDNA) methodology, aside from the purely economic aspects of the DALA, also aims at assessing the effects of a disaster on the population livelihoods, taking into consideration the human, socio-cultural, economic and environmental perspective. Therefore, the steps of the PDNA is to conduct a DaLA estimating the physical damages and economic losses of the disaster and based on these to identify the recovery needs of the society using a Human Recovery Needs Assessment (HRNA) approach. The current in-depth review is focused on the data collection, and damage and loss assessment according to the DaLA guidelines.

The DaLA initially estimates the short-term governmental activities required to initiate relief operations, and then the financial requirements to achieve overall post-disaster recovery and reconstruction, towards disaster risk reduction. It is worth mentioning that the end product is a recovery and reconstruction program tailored to guide all the post-disaster activities. This program is based on the existing domestic sectoral capacities and guided by the Build Back Better concept to increase the disaster resilience, potentially for other perils as well. For this reason, the financial mechanism to support the program is assumed to be formed by a combination of governmental funding, World Bank's financial assistance (if available), private sector contributions, insurance policies, and additional funding from other international organizations.

The DaLA's methodology framework is based on a sector-by-sector bottom up approach to estimate the overall effects of the disaster and the impact on society and economy. The overall activities included in its application are summarized below:

1. Definition of pre-disaster baseline data for each sector, including the physical assets, the provision of basic services, and the performance of the productions.
2. Development of a post-disaster situation based on the sectoral data collection.
3. Estimation of damages and losses on a sector-by-sector basis and subsequent aggregation.
4. Estimation of the overall impact of the disaster at a national level.
5. Assessment of the macro-economic impact.
6. Estimation of the impact on the personal/household employment and income.

The methodology has established clear definitions about damage and losses, as listed below (Jovel et al. 2010):

- **Damage**: represents the total or partial destruction of physical assets existing in the affected area, including buildings, infrastructure, equipment, machinery, furniture and household goods, means of transportation and storage, irrigation works, etc. Damage occurs during and immediately after the disaster and is measured in physical units (e.g. square meters of housing, kilometers of roads). Its monetary value is expressed in terms of replacement costs according to prices prevailing just before the event.
- **Losses**: Are the changes in the economic flows arising from the disaster, including decline in production and sales, increased operational costs and lower revenues from the provision of services, and unexpected expenditures to meet emergency needs. They occur until full economic recovery and reconstruction is achieved, in some cases lasting for several years. Typical losses include the decline in output in productive sectors (agriculture, livestock, fisheries, industry and commerce) and the lower revenues and higher operational costs in the provision of services (education, health, water and sanitation, electricity, transport and communications). The estimated losses are expressed in current values.

Considering the above definitions, the baseline data of physical assets includes the number and type of buildings and infrastructure in the affected areas before the disaster for all sectors (e.g. housing, education, health, electricity and power, transportation and communications, agriculture, industry, commerce). Moreover, the baseline information includes the performance of all economic activities in the affected area as projected prior to the disaster for the current and subsequent two years. This is measured as the volume and value of production and sales of goods and services.

The development of the post-disaster situation is based both on the findings of the field surveys where the assessment teams collect data from each impacted sector, and on interaction with local sectoral specialists (public and private sectors). Apart from the collected data about the damaged and destroyed physical assets, the following information is also collected in consultation with the local specialists:

- The typology of physical assets, compiled by attributes such as the size, capacity, construction materials, occupancy, and age.

- The unit repair and reconstruction prices for each typology.
- A preliminary calendar of repair and replacement of physical assets, taking into account the existing construction sector capacity and the expected availability of resources (financial and materials).

By comparing the pre-disaster baseline information to the post-disaster situation, the methodology estimates the damages and losses as a result of the disaster, at the level of each sector of the economy as defined in the country's national system. Subsequently, the aggregation of such damages and losses provides an estimation of the overall effects of the disaster on the affected society and economy. In order, to determine the overall disaster effects, the damages and losses for all affected sectors must be included, considering all interdependencies between the various sectors in the estimation of losses.

The application of the protocol starts with a formal request from the respective governmental authorities to the country or regional representative from the World Bank. Afterwards, meetings are held between GFDRR representatives, local experts, and responsible governmental agencies for disaster management. During the initial interactions, the primary objectives of the assessment are defined, the Task Team Leaders (TTL) responsible for the application of the methodology are established, and other NGOs (e.g. UN) which will participate in the assessment and/or in the humanitarian relief activities are identified. The Terms of Reference (ToR) for the execution of the DaLA are set by the officials of GFDRR, and depending on the severity of the disaster, a team of trained staff and consultants that will participate in the activities is formed, including experienced advisors for the training and support of the assessment teams.

The DaLA initiates two to three weeks after the occurrence of a disaster and after the completion of the emergency response and rescue operations. This initial time is usually exploited to gather the sectoral baseline information, carry out training sessions, and plan further activities. The general timeframe of the DaLA methodology is presented in Figure 36.

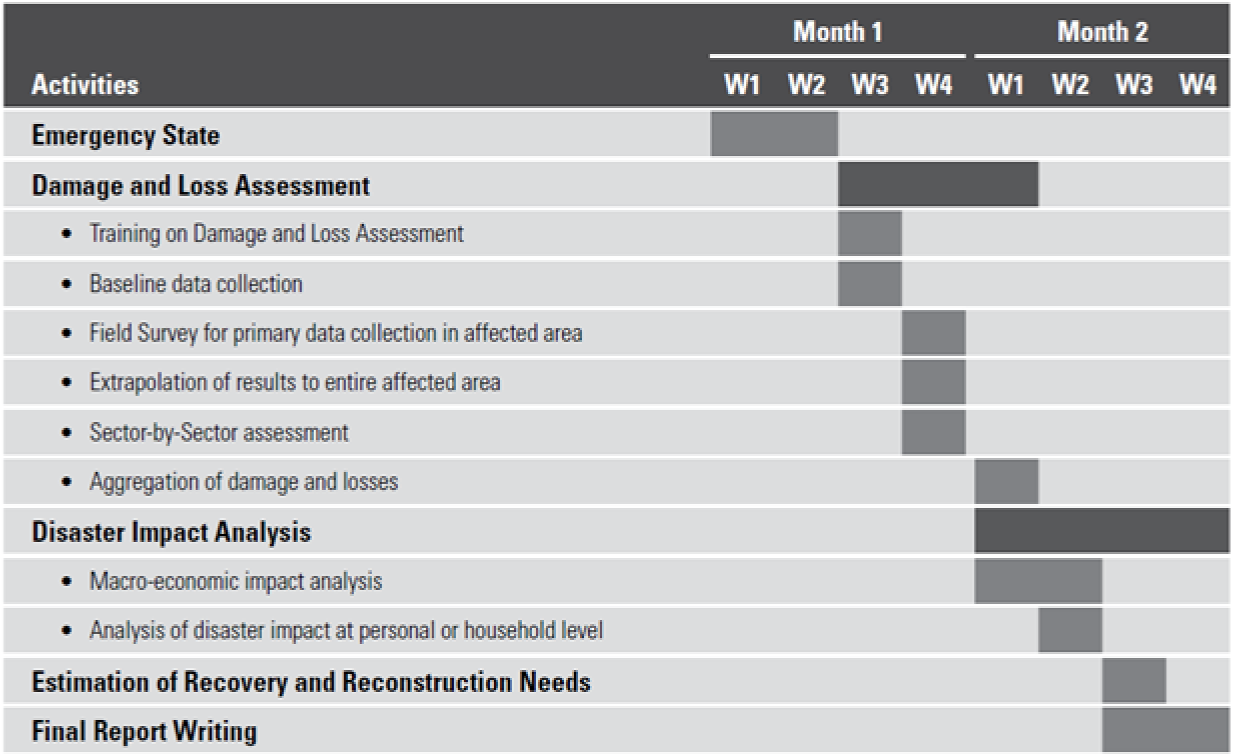


Figure 36 - Timeframe of DaLA activities (Jovel et al. 2010).

The time of execution of certain tasks may need to be adjusted depending on the severity of the disaster, and the complexity and structure of the affected area and economic activities. However, the sequence of activities should not be altered, and the sectoral field assessments must be fully completed. Due to the importance of the comprehensive sectoral assessment, a target date is defined after which no changes in the estimated sectoral damage and losses estimations can be made, since it may have a negative impact on the subsequent phases of the assessment. Nonetheless, this restriction allows refinements of the initial estimates whenever additional verified damage and loss data become available.

The sectors to be included in the assessment depend on the extent and characteristics of the natural disaster, the national context, and on the human and economic activities of the affected areas. The TLL along with the respective governmental organization decide which sectors to include in the assessment before the initiation of the field missions. In principle, no sector or activity of importance is left out even if some sectors do not seem directly affected, as the interdependence between the different sectors could lead to indirect losses. Pre-disaster baseline information is distributed to the assessment team members before the field visits. This includes general information on the population, cartography, social and economic characteristics of the affected country, and information on the functioning of each sector of economic.

The first activity comprised by the DaLA consists in the training on the assessment methodology and sectorial baseline data collection. Frequently GFDRR specialists are appointed to conduct a two-day workshop in order to train all assessment team members and involved personnel on the theory and practice of the DaLA methodology. The training is tailored to the respective natural disaster, national context and affected sectors, while it provides the guidelines for the particular sectorial assessments. All the governmental officials, and representatives from other international and national organizations and stakeholders participate.

The composition of the assessment team depends on the sectors included in the assessment, although each team includes engineers, architects, sociologists, and economists as their expertise is required for the assessment of every sector. Depending on the sector, different disciplines are included in each sectorial assessment team, while a typical list of specialists required for the assessment of each sector is provided in the DaLA guidelines. From the government side, officials belonging to the ministries or departments of the affected sectors participate in the assessment teams, including representatives from the statistical agency, economic and social planning. GFDRR assigns experienced advisors who can participate in the assessment and train the sectorial assessment team members. The TTL, in conjunction with the responsible governmental organizations, plan how the field assessment will be carried out, by which leadership, and define the participation and support from the government.

The field visits to the affected areas are planned in detail in order to cover the most important areas and sectorial assets within the defined timeframe and avoid as much as possible unvisited areas. Under this scope, field visits are planned to representative locations, where each assessment team can interact with the local managers and operators of affected sectors. Each sectorial assessment team may decide to visit different areas, depending on their relative importance. Policies by the local authorities concerning the sharing of information from the private sector should be established before the visits. Overall, the entire baseline information is gathered prior to the field assessments in the affected areas.

The field visits are carried out considering all the preliminary information collected by the local authorities and other organizations during the emergency response. The damage data collection usually takes place using standard paper-based forms (output tables) for the damage and loss assessment of each sector, within each geographical area. In addition, guidance is provided during the training workshop on how to conduct the assessment and compile the forms. An example of the form used for the housing sector is shown in Figure 37. The GFDRR specialist monitors the field visits, advices the assessment teams, and assists in the estimation of monetary damages and losses.

		Type of housing unit[1]					Disaster effects		
		A	B	C	D	E	Damage	Losses	Total
Estimation of damage									
a) Houses Fully Destroyed									
	Number of houses								
	Average replacement cost								
	Estimated value of damage								
b) Houses Partially Destroyed									
	Number of houses								
	Average replacement cost								
	Estimated value of damage								
c) Household Goods									
Estimation of losses									
Duration of reconstruction period, months									
Cost of demolition and rubble removal									
Cost of temporary housing scheme									

Figure 37 - Table for the damage and losses assessment of the housing sector (Jovel et al. 2010).

Specific guidelines are provided for the estimation of damage and losses of each sector based on the collected data and unit replacement costs. Once the damage and loss assessments have been completed, another session takes place to train the assessment teams for the quantitative estimation of post-disaster recovery and reconstruction needs. The estimated damage and losses are aggregated per sector and per administration unit (e.g. municipality, district) of the affected areas in order to clearly define the performance of each sector after the disaster, and more importantly, the timeframe and cost for recovery and reconstruction. As an example, the estimated sectorial damage and loss from the 2015 Gorkha earthquake in Nepal are illustrated in Figure 38. This event will be further analyzed in Section 14.3.

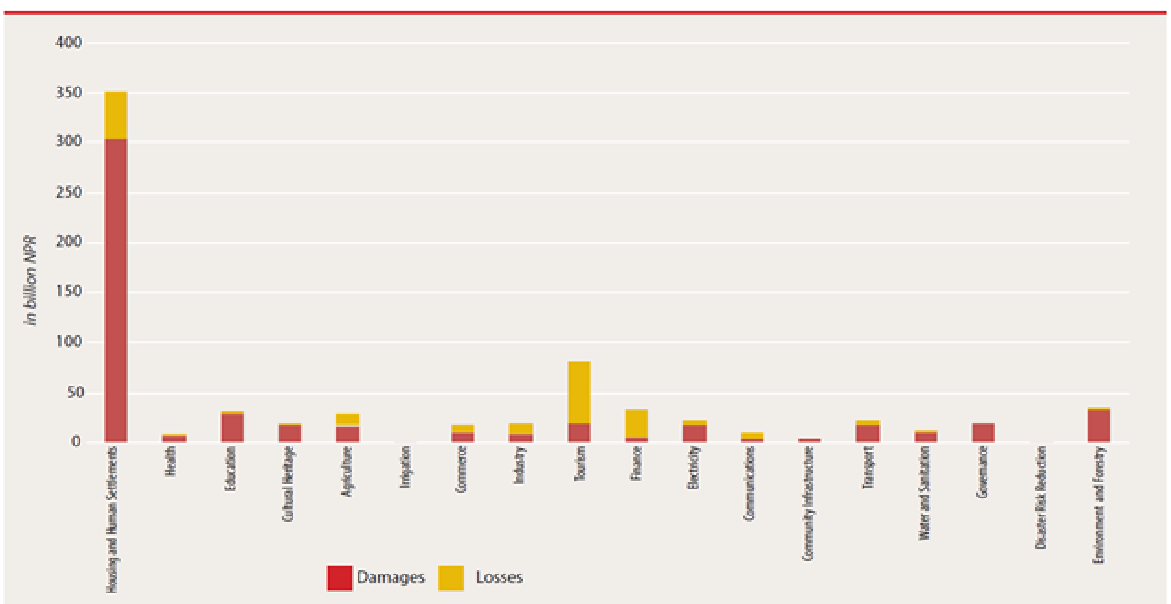


Figure 38 - Disaster effects across all sectors after the 2015 Gorkha earthquake in Nepal (PDNA Volume A).

11.1.2. Strengths and limitations

The DaLA methodology has evolved into a globally recognized methodology to quantify the impacts of a disaster, and to estimate the necessary financial resources for recovery and reconstruction. In the past decades it has been widely applied in various disastrous events all over the world, especially in developing countries. For these reasons it was selected for in-depth review, as it represents a considerable amount of the past and present post-disaster data collection applications. The main strengths and limitations that should be considered for the conceptual framework of this project are listed below:

- It is a multi-hazard methodology, which can be applied in any country regardless of its domestic protocols and level of socioeconomic development. Other collection protocols can be performed in parallel and interact with the DaLA, by supplementing additional results from more detailed assessments.
- All the activities include and require strong cooperation among various stakeholders, organizations, and governmental agencies. In addition, these activities are under a high-level management team which oversees the process and provides strategic guidance, working under the government leadership in a daily planning and execution of the guidelines. The lessons learnt from past applications of the methodology regarding these features can serve as valuable input to the project.
- The multidisciplinary assessment team composition with the inclusion of various sector specialists both from the country and GFDRR is very important for a comprehensive damage assessment. The sectorial damage and loss estimation considering the interdependency of the affected sectors is an essential tool for decision making and resource allocation, since it provides a comprehensive image of the disaster effects and allows prioritizing of the recovery activities.
- There is a lack of scientific or engineering background in the damage data collection, since it is one-sided, towards a post disaster needs assessment. In addition, hazard related features and local intensity measures are not captured.
- The granularity of the data collection is not at the asset level, the information is not georeferenced and linked to the peril's spatial characteristics. The spatial resolution of the end product is the geographical area of the affected country or a smaller administrative unit, such as district or municipality level.
- The availability of baseline data is a key element of this methodology. Insufficient or bias in the baseline information or inefficiencies in sharing it across the respective agencies and ministries could result in a major problem for the damage and loss assessment. Furthermore, the lack of official protocols and policies in sharing the baseline information might delay the processes, particularly from the private sector due to lack of trust regarding how the information might be used.
- When it is not feasible to visit all affected areas, the methodology enables the extrapolation of current results to cover the entire geographical area, based on sufficient baseline data. This introduces uncertainty and potentially bias in the damage and loss estimation.

- Each assessment specialist should be able to devote sufficient time to participate fully during all stages of the assessment and field visits, otherwise the quality and reliability of the assessment could suffer substantially.
- The success and accuracy of the methodology is strongly dependent on the local and domestic capacity of the affected country, while some countries do not have a well-defined regulatory framework and institutional arrangements to support its implementation.
- The absence of data collection tools and IT systems for reporting and aggregating the information constitutes a major gap.
- Satellite data is not considered in the estimation of the impact in large areas, nor cross-referenced with field observations. This is especially important in the initial damage assessment where the use of space technology can support the rapid estimation of damages by comparing the images before and after the occurrence of the disaster. Under the same concept, the methodology could adopt the use of risk or vulnerability assessments conducted for the affected regions in order to get a deeper knowledge of the areas likely to be impacted.

11.2. Reliable Instruments for Post-Event Damage Assessment (RISPOSTA)

11.2.1. Description

The RISPOSTA system was developed by Ballio et al.[15] in collaboration with the Italian Civil Protection Authority of the Umbria Region in Italy and Politecnico di Milano, to facilitate the disaster data collection during the Umbria floods in 2012-2014. The main goal of this methodology is to develop a "complete event scenario". This implies collecting different types of data from a variety of stakeholders (e.g. local authorities, utilities companies, governmental agencies, private sector, citizens) at different moments in the aftermath of the event. In this perspective, having a comprehensive and complete picture of the event, including a characterization of the damaged elements and their main causes, is fundamental to inform the recovery and reconstruction process in the affected region. Nevertheless, information must be available, during the various phases of the procedure, to be used for multiple purposes (e.g. emergency management, recovery planning, disaster forensic, risk modeling). The framework and the associated timeframe consist of three main phases:

- **The emergency and post-emergency phase:** between 1-20 days after the event, where the fundamental information to guide the necessary actions is collected. This includes the main features of the physical event (e.g. spatial and temporal evolution), information about the affected areas and the state of essential services and required assistance to affected people.

[15] Ballio F., Molinari D., Minucci G., Mazuran M., Arias Munoz C., Menoni S., Atun F., Ardagna D., Berni N. and Pandolfo C. (2015) "The RISPOSTA procedure for the collection, storage and analyses of high quality, consistent and reliable damage data in the aftermath of floods," *Journal of Flood Risk Management*,11 (2018), S604-S615.

- **The recovery phase**: between 1-6 months after the event, data are collected about the direct damage in order to obtain a comprehensive event scenario. A loss estimation is conducted by taking into account damage claims and already allocated resources, while assisting decision makers in the definition of the best recovery strategy.
- **The complete event scenario phase**: between 6-12 months after the event, the scenario of the previous phase is completed, including the description of potential indirect losses. These can be identified several months after the occurrence of the disaster due to industrial and commercial business interruption, and environmental damage.

The activities within each phase are organized based on four main logical axes: *time*, the *actors*, the required *actions*, and the *exposed sectors*. In order to coordinate the activities comprised within this protocol, a "data coordinator" is identified. This expert oversees collecting and organizing data obtained from the various involved stakeholders at different times in the aftermath of the event, and for regulating the application of the protocol. In the Italian context, this role is assigned to the Regional Civil Protection Authority (RCPA). The fundamental difference between the data coordinator and other stakeholders is that the coordinator aims at collecting all the information related to the impact of the event (towards a complete event scenario), while the other stakeholders are interested only in the damage to their sector or jurisdiction (e.g. residential, commercial and industrial buildings, roads, infrastructure, public buildings). In addition, another important role within this protocol is represented by the Expertise Centre, which remotely supports the data coordinator in all the activities that are executed, such as validation, processing, analyses and sharing of the collected data.

The framework of the methodology currently considers the data coordinator (RCPA) as the only actor. Although other stakeholders are involved, no mandatory data collection activities are required by this protocol. Nevertheless, public actors are legally forced to share their data with the coordinator, in order to plan and assist the emergency and recovery phases. On the other hand, private stakeholders are neither obliged to collect data nor to disseminate them apart from key information for emergency management.

The required actions are categorized into three groups: field survey, data gathering, and data coordination. Field surveys are carried out to ensure the availability and consistency, when the collected data from independent stakeholders are not sufficient or incomplete. The data gathering refers to communicating and sharing the data collected by centralized actors (i.e. local authorities, utility companies, private stakeholders). The data coordinator negotiates with the data owners, avoids data duplication, minimizes the data collection efforts, and ensures data integration and dissemination. To enable efficient data gathering, protocols define the type and format of data to be shared, and at which time during the application of the procedure. As for the data coordination, it involves all the tasks towards the derivation of a complete event scenario, such as data processing, analysis, aggregation, and integration.

The data collection and management follow a sector-based approach, adopted by pre-existing methodologies such as DaLA. This protocol covers the following sectors: a) residential buildings, b) industrial and commercial buildings, c) agriculture, d) infrastructure, e) public items, f) emergency costs, g) people, h) environmental and cultural heritage, and i) the physical scenario (i.e. event footprint, flood characteristics). The procedure foresees complementary field surveys, carried out by the data coordinator with the support of trained staff for the sectors a), b) and i), while for sectors c) to h) a centralized data collection process is carried out and data from the associated stakeholders are gathered. The procedure provides guidelines for carrying out field survey and collecting data from the flooded areas (sector i), residential buildings (sector a), and commercial and industrial buildings (sector b). The activity framework and the associated timeframe of the RISPOSTA procedure are illustrated in Table 10.

<u>Data acquisition on the physical event and investigation of the flooded areas:</u>

- Initially, pre-existing knowledge about the hazard in the affected areas is obtained from existing studies and information on past events. This step provides useful information about the flood-prone areas and assists the planning of the field surveys.
- Remote sensing techniques and monitoring data are utilized, such as satellite and aerial images, along with recommendations from experts in the field. These activities are completed 2-3 days after the event and provide enough information about the spatial and temporal evolution of the flood.
- Based on the information collected in the previous steps, the Expertise Centre indicates the regions to be surveyed. These regions are divided in sub-regions and assigned to investigation teams composed by trained staff. Field surveys are carried out in order to record the water elevation (from watermarks) and water depths, analyze the topography of the region and identify the perimeter of the flooded area. During this process guidance is provided by the Expertise Centre to identify key locations for measurements. Subsequently, the data are analyzed and validated, and the information is shared among all the stakeholders (public and private) and actors. This phase should be completed around 20 days after the event.

<u>Damage data collection on the residential, industrial and commercial buildings:</u>

- Pre-existing information on the exposure and vulnerability characteristics of the buildings is extracted from cadastral datasets, housing census databases, and risk maps. The desired data, such as construction material, number of floors, surface area, type of activity, and level of maintenance provide essential information for the field surveys.
- The Expertise Centre identifies the assets and premises to be surveyed on a map and subdivides them among teams of trained surveyors. The surveys are carried out using ad-hoc forms, according to the timeframe of the recovery phase (1-6 months after the event) of Table 10. Additional field surveys are conducted a few months later mainly for the commercial and industrial facilities in order to capture the indirect damage caused by business interruption, loss of orders, and long-term damage to the contents. In case the data collected from the first investigation of the residential buildings are not satisfactory, a

second survey is carried out using pre-compiled forms based on the existing information from the first survey.

- The monetary damage values are obtained based on the compensation requests submitted by the owners, according to regional and/or national funding after the event. During the field surveys the damage to structural and non-structural components is assessed in physical units, for example, numbers of damaged doors and square meters of damaged floor.

Table 10 - Activity framework and associated time-frame of RISPOSTA procedure. Reproduced from Flood Damage Survey and Assessment (2017): "*New Insights from Research and Practice*".

	ACTOR		ACTION		SECTOR								
ACTIVITIES	RCPA	Expert. Centre	Survey	Gathering	Coordination	Residences	Businesses	Farms	Infrastructures	Public items	Emergency	People	Environ./cultural	Physic. scenario
Acquisition of pre-existing knowledge on the hazard	X			X										X
Acquisition of pre-existing knowledge on exposure and vulnerability	X			X		X	X	X	X	X	X	X	X	
Set-up and management of the IS		X			X									
Data sharing		X			X									
Event														
Acquisition of data on the physical event	X			X										X
Data sharing		X			X									
2–3 days														
Survey of the flooded area/water elevation	X		X											X
Organization and coordination of the survey (flooded areas)		X	X											X
Data analysis (field survey)		X			X									
Data validation (physical event)		X			X									
Inputting data (physical event)		X			X									
Data sharing		X			X									
20 days														
Survey of damage to residences and businesses	X		X			X	X							
Organization and coordination of the survey (residences and businesses)		X	X			X	X							
Acquisition of damage data from the Regional Emergency Room (SOUR)		X		X				X	X	X	X	X	X	
Data analysis (field survey)		X			X									
Data validation (residences/businesses/SOUR)		X			X									
Inputting data (residences/businesses/SOUR)		X			X									
Data sharing		X			X									
90 days														
Survey of damage to residences (optional)	X		X			X								
Organization and coordination of the survey (residences)		X	X			X								
Acquisition of damage data from the responsible stakeholders (optional)		X		X				X	X	X	X	X	X	
Acquisition of monetary damage data		X		X		X		X	X	X	X	X	X	
Data validation (all sectors except businesses/monetary damage data)		X			X									
Inputting data (all sectors except businesses/monetary damage data)		X			X									
Data analysis (field survey, complete event scenario)		X			X									
Data sharing		X			X									
6 months														
Survey of damage to businesses	X		X				X							
Organization and coordination of the survey (businesses)		X	X				X							
Acquisition of damage data from the responsible stakeholders		X		X				X	X	X	X	X	X	
Acquisition of monetary damage data		X		X			X	X	X	X	X	X	X	
Data validation (all sectors except residences/monetary damage data)		X			X									
Inputting data (all sectors except residences/monetary damage data)		X			X									
Data analysis (field survey, complete event scenario)		X			X									
Data sharing		X			X									
12 months														

The field investigation forms are designed in order to meet the information needs for all end users and involved stakeholders. The collected damage data covers damage compensation, hazard, exposure, vulnerability, and direct physical damage. Detailed information for each damaged residential and commercial/industrial buildings is collected using different forms for each sector. The form for commercial/industrial buildings covers specific information regarding damage to machinery, equipment, products, and raw materials. The first version of the ad-hoc forms was tested in the flood that hit the Umbria region in 2012, and as a result the forms were updated and validated. After the flood event in 2013 in the same region, pre-compiled forms were used, including aerial images, damaged building locations and essential information to accelerate the field surveys.

The experience in the field indicated the need to move from a paper-based form to a tool for a mobile device. A prototype mobile application for the Android platform was developed for this purpose and used by trained surveyors during the floods in 2014 in the Umbria region. Apart from the mobile application tool for data collection and gathering, all RISPOSTA activities are supported by a Geographical Information System. The core component of the system is a PostGIS database for data storing and processing, along with an integrated web portal for data visualization and management. All the data associated to the activities of the procedure are stored in the database, such as the exact locations of the surveyed buildings, the flood characteristics that affected the buildings, and the damage of each investigated unit. The mobile application incorporates pre-compiled field investigation forms, and assists the data collection surveys in multiple ways:

- It provides supplementary information about the context of each section to be filled with illustrative examples, and expandable/collapsible lists.
- The application is structured by multiple sections according to the structure of the forms.
- The completed surveys are stored on the portable devices, and they can be browsed, modified and uploaded into the database. Incomplete forms can also be uploaded at any time and finalized afterwards.
- The set of buildings under investigation by each survey team is identified within the application.
- The location of each building can be identified and stored by utilizing the GPS system of the mobile device.

The data coordination is facilitated by the Geographical Information System, where data acquisition, storage, analysis, and sharing take place. The collected data for the residential, commercial and industrial sectors, along with the acquired data for the other exposed sectors are analyzed. The data analysis is carried out at different times during the application of the procedure, and the processed information is shared with the corresponding actors according to the data and format of interest. Nevertheless, security restrictions are applied, and consequently data availability differs according to the stakeholder.

11.2.2. Strengths and Limitations

The strengths and limitations of this procedure can be summarized in the following:

- The data collection is carried out at the asset level in a sector-by-sector basis, which allows for further data analysis and disaggregation. This process allows meeting the requirements of different end users. In addition, the data collection and gathering are performed in different times after the event, thus capturing the effects of the disaster including indirect losses.
- The integration of various types of data towards a complete event scenario is a fundamental step for efficient disaster management and recovery, risk mitigation strategies, and provides essential information for risk modeling.
- All the relevant actors and stakeholders are involved in the procedure, and coordinated by the "data coordinator", who is supported by an Expertise Centre for all the tasks that can be performed remotely. This regulatory structure enhances the successful application of the protocol, ensures the flow of the information among the actors, and provides consistent and validated data to decision makers.
- The mobile application for data collection, the designed PostGIS database for data storing, and the integrated web portal for data management and visualization, constitute an innovative IT system capable of facilitating the effective application of any protocol.
- The procedure was designed to be applied in the Italian context, which is characterized by small-scale or scattered events, with a limited number of affected assets in every flooded area. The only applications of the procedure took place in the Umbria region in the floods of 2012-2014.
- The methodology is developed explicitly for floods, and therefore adjustments are required for its applicability to other natural hazards, especially in the investigation forms implemented in the mobile application.
- The procedure foresees data collection for the residential, commercial and industrial sector, and on the physical event. For the remaining sectors the data are gathered from the respective actors and stakeholders who carried out the data collection. Even though the data coordinator supervises and coordinates the data collection, it is not clear how these data is collected not which guidelines are employed.
- The procedure considers only one primary actor, the data coordinator, who is supported by the Expertise Centre (represented by the Politecnico di Milano in the Italian context). However, in the data collection various local authorities and public stakeholders are involved, which are not identified as official actors, at least for the sector of their jurisdiction.
- Despite the fact that a wide spectrum of detailed information is collected, gathered and analyzed, apart from the derivation of a complete event scenario, their end use is not clear.
- The assessment of monetary losses is performed on the basis of the compensation requests submitted by the public and private owners. A loss estimation methodology does not seem to exist. Since the damage of the affected elements is captured in high detail, the estimated losses could be compared to the compensation requests, followed by a calibration process.

- It is evident that the human impact (e.g. fatalities, injuries, and homeless) is not evaluated by the data coordinator during the field surveys. The acquisition of this information relies on other actors.
- During the application of the procedure in the Umbria floods, the survey teams experienced difficulties in filling the forms and interpreting the measurements, which considerably increase the required amount of time to complete the surveys. This issue highlighted the need to endorse specific training for the surveyors, and the need to include the possibility to draw the flooded area perimeter on a geo-referenced map and store the measurements and photographs.
- After the data collection in the 2013 floods in Umbria, a test was conducted to verify the validity of the collected data by the ad-hoc forms. The results showed that even if a high validity of the acquired information was achieved, around 23% of the submitted forms were unusable due to the lack of fundamental information. However, this issue was improved by the introduction of the application for mobile devices.
- The experience in the Umbria region highlighted the importance of defining protocols for data sharing amongst the data owners, in order to avoid negotiations every time that a disaster occurs. There were difficulties in reaching a formal agreement on data sharing, even though most of the data were shared during the meetings. More specifically, these difficulties were related to bureaucratic reasons, and the lack of willingness of private owners to share their data due to the existence of sensitive information.
- The lack of resources for the data collection field missions was a mutual concern for both public and private actors, which clearly indicates the importance of a common protocol to reduce the duplication of efforts.
- The application in the Umbria region suggests that a better integration with the data owners should be achieved, by including them as key actors in the procedure. For example, involving private owners in the data collection procedure will boost the damage declaration process for accessing compensation funds.

11.3. Damage and loss assessment methodology from Mexico's Natural Disaster Fund (FONDEN)

11.3.1. Description

Mexico’s Fund for Natural Disasters (FONDEN) is a funding mechanism for supporting the rapid rehabilitation of federal and state damaged infrastructure by natural disasters, which started in 1996 as a budget line in the Federal Expenditure Budget. In 1999, the first guidelines on damage assessments and access to FONDEN resources were established, including regulations, requirements and procedures to be followed by the federal and state agencies. Subsequently, in 2000, FONDEN’s guidelines were adjusted to include emergency operations and the establishment of sector committees to support damage assessment. These committees are formed by representatives from both federal and state governments, which manage the damage assessment jointly. Finally, within the following decade, further additions took place regarding the procedures for reconstruction activities, including the Immediate Partial Support Mechanism (APIN) to fund urgent post-disaster activities before the completion of the damage assessment.

The funds from FONDEN are used for the reconstruction and recovery of:

- Public infrastructure at federal, state and municipal level; including schools, hospitals, critical assets, and transportation infrastructure.
- Low-income residences. FONDEN can verify the income of the affected household through the information provided by the Ministry of Social Development from the census database.
- Certain components of the natural environment.

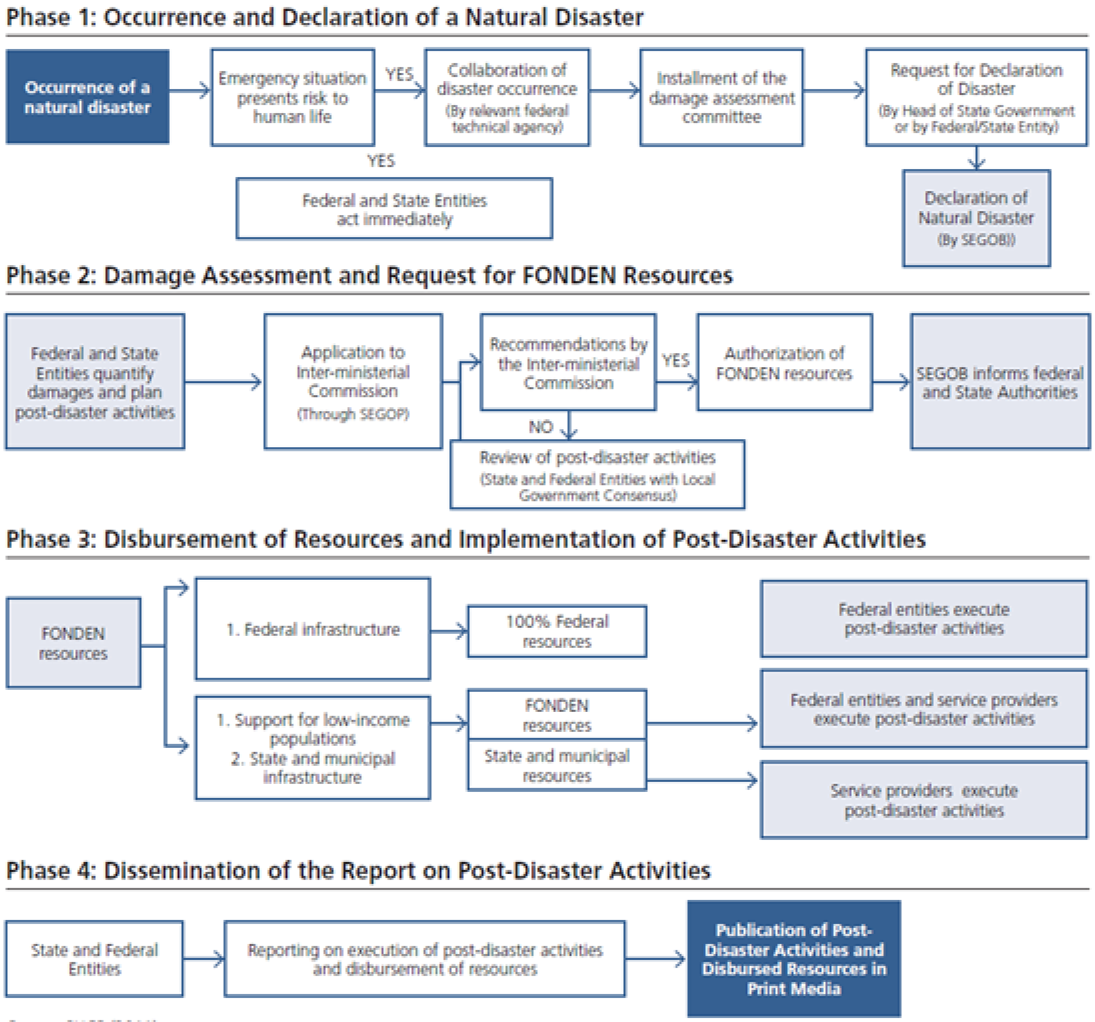
FONDEN consists of two complementary budget accounts, the FONDEN Program for Reconstruction and FOPREDEN Program for Prevention. The former is the primary account, while the latter was introduced later in the development process. Both financial accounts are administrated by BANOBRAS, Mexico's state-owned development bank. In the aftermath of a disaster, the financial account for reconstruction allocates funds from the Federal Expenditure Budget to specific reconstruction programs, through a dedicated sub-account in the FONDEN Trust for execution. The FONDEN Trust holds these resources until reconstruction programs are implemented and makes payments for reconstruction services to implementing entities. On the other hand, the FOPREDEN program funds disaster prevention activities related to risk assessment and risk reduction, through the FIPREDEN preventative trust. Furthermore, certain sub-accounts for emergency relief and recovery activities have been established, such as APIN, in order to deal with funding requirements during the early post-disaster phases. Finally, the reconstruction of public buildings and infrastructure is guided towards the Build Back Better concept, introducing better reconstruction practices.

It is worth mentioning that after the 1985 earthquake in Mexico, the Mexican National Civil Protection System (SINAPROC) was established, under the Ministry of Interior (SEGOB). SINAPROC was established as a multi-level organization, integrating stakeholders from the three levels of government (federal, state, and municipal), the private sector and academia. Its initial purpose was to provide a framework for coordinated emergency response operations, but nowadays manages the mechanisms and policies for reconstruction activities as well. FONDEN operates within SINAPROC, and is administered by SEGOB along with the planning and monitoring of the reconstruction process, in order to ensure the proper use of FONDEN resources.

The affected federal and state agencies are obliged to demonstrate that the reconstruction needs exceed their financial capacity and file a specific request detailing the extent of the damage and estimated cost of reconstruction. A detailed framework exists and defines the process to access FONDEN resources (see Figure 39), which consists of four main phases:

- Declaration of a natural disaster.
- Damage assessment and official request for FONDEN resources.
- Disbursement of resources and implementation of reconstruction activities.

- Public reporting on post-disaster activities.



Source: SHCP (2011).

Figure 39 – Illustration of the different phases of FONDEN.

After the occurrence of an event, the governors of the affected states or relevant ministers must request the technical federal agency to confirm within 3 days of an event the occurrence of a disaster in at least one municipality. For this purpose, there are technical federal agencies pre-assigned to each type of natural hazard (e.g. earthquake, flood, hurricane) and to a specific area of responsibility. The technical agency analyzes the severity of the natural disaster according to the criteria defined by FONDEN rules, but it does not conduct damage assessment or data collection. If the technical agency confirms the occurrence of a natural disaster, the SEGOB has 12 days to publish the declaration of natural disaster in the Official Journal of the Mexican Federation. After the publication of the declaration, the affected state governments and federal entities have 30 days to submit a documented request for FONDEN's financial support, including the damage assessment evidence.

A FONDEN Damage Assessment Committee is established within 24 hours following the confirmation by the technical agency, and is composed by both federal and state representatives from the affected agencies. Additionally, subcommittees are formed for each affected sector, such as housing, education, healthcare, roads and bridges, hydraulic infrastructure, and urban infrastructure. Many actors at the local, state and federal level in conjunction with the committee develop a plan to access the field to collect damage data. Field work and site visits are then expeditiously conducted to assess the damage. The Damage Assessment Committee identifies affected public infrastructure at the federal, state, and municipal levels and determine the extent of the losses.

For the damage assessment of each sector, a team is formed by a group of specialists and experienced surveyors in the FONDEN damage criteria, as different damage and loss indicators are used for each sector. The damage assessment is carried out asset-by-asset under specific guidelines and schedule. The assessment teams are equipped with handheld devices and a camera with incorporated GPS. The data collection includes information about the structural and non-structural damage, and is accompanied by georeferenced photographs of the observed damage. According to FONDEN's regulations, minimum 4 photographs are required for each damaged asset. Additionally, detailed reconstruction needs and related costs should be proposed within the damage assessment in comparison to the replacement cost of each public asset. Subsequently, all the collected information including the georeferenced photographs are uploaded directly to a central web-system called FONDEN LINEA (online), for consideration by the Damage Assessment Committee. Automatic validation of the information takes place in the database, such as the location of the assets, the unit costs and size of the components.

Each sector team has ten working days from the date of the Committee's establishment to assess the damage and confirm the resources needed for reconstruction. This period can be extended by an additional ten working days in exceptional circumstances. After this period the information can only be modified by the Federal government or the Damage Assessment Committee. The data can be exported from the system in an excel format, and with a formal request to the FONDEN committee from any governmental department certain information can be disseminated. The data are stored in a database for further analysis and future use, such as calibration of probabilistic risk models under the R-FONDEN[16] program, insurance policies, and CAT bonds.

Subsequently, each subcommittee presents its findings to the Damage Assessment Committee, regarding the identification and quantification of damage and related reconstructed needs at a Results Meeting chaired by the Governor of the affected state. Within seven days of the Results Meeting, each federal agency must deliver its final diagnosis to the Directorate General of FONDEN. Within two additional days, the Directorate General of FONDEN must verify that:

- There is no duplication of requests amongst the federal and state agencies.

[16]https://www.oecd.org/governance/toolkit-on-risk-governance/goodpractices/page/probabilisticriskmodellinginmexicor-fonden.htm

- The requested funds are only intended to cover damage caused by the disaster and not pre-existing damage.
- Each reported asset has not previously received any reconstruction funding from FONDEN. If any have, and catastrophe insurance was not secured for the asset following the disaster, then lower levels of support will be made available for those assets.

Technical validation of the damage assessment information is fundamental within FONDEN's framework, and therefore technical institutions review the information before the committee authorizes the funding. For example, for the education sector, the Institution of Educational Infrastructure which is responsible for establishing the guidelines for schools and educational institutes, validates the information. The FONDEN rules do not establish the criteria or damage grades for the damage in public infrastructure, although for low-income residences three levels of damage are defined (minor, moderate and major), each one with a level of monetary compensation. Federal agencies are responsible for the planning and supervision of all FONDEN-supported reconstruction activities, and they are required to submit regular progress reports to FONDEN using a standardized template. Finally, FONDEN finances 100% of the reconstruction of federal assets and 50 % of the reconstruction of local assets.

11.3.2. Strengths and limitations

The strengths and weakness of FONDEN's framework are summarized in the following:

- FONDEN's operation relies on a clear and comprehensive framework for damage assessment, resource allocation, within a predefined timeframe and cooperation at federal, state and municipal level.
- The FONDEN's framework is applicable for all natural hazards, and is based on a sectoral damage assessment approach, which is quite important for informing decision making for reconstruction and risk awareness.
- The structure of the IT system, including the data collection tool and central database with automatic validation, ensures the high quality and quick flow of information. Hence, it increases the transparency and level of control of resource allocation for reconstruction.
- There is considerable gap in the data collection of building damage. The damage assessment is limited to low-income residences and public buildings, and no data collection takes place for the private sector (commercial and industrial buildings). This exclusion is related with the fact that no financial compensation is issued, but damage in these assets will also affect the recovery process.
- One important challenge in FONDEN is the employment of existing data about the current building inventory, and other baseline information to could prepare for future events.
- Even though the main purpose of the data collection is to trigger the funding mechanism and reconstruction process, the damage data are utilized for developing and calibrating risk assessment models and insurance policies.

- Remote sensing data and satellite imagery are not used currently, neither in the emergency response operations nor in the planning of damage assessments, although the use of drones and similar advanced technologies are under development.
- Since 2010, when the FONDEN LINEA system was established, there have been attempts to improve the FONDEN's guidelines, by incorporating the lessons from past applications and similar systems all over the world. However, only minor improvements have been introduced so far.

11.4. Damage Assessment and Reconstruction Monitoring System (DARMsys™)

11.4.1. Description

The Queensland Reconstruction Authority (QRA) was established after the flooding and cyclones in 2010 - 2011, and it manages the Natural Disaster Relief and Recovery Arrangements (NDRRA) program of the state, cooperating with the local authorities, state departments and other agencies. QRA acknowledged the limitations in the previous methodology, which consisted in small teams of trained operators performing rapid damage assessment using paper-based form. Such procedures proved to be impractical for large scale disasters. QRA collaborated with other key agencies such as the Department of Housing and Public Works and the Queensland Building Services Authority (QBSA) to establish the data collection requirements, and to set the foundations for the new procedure.

The DARMSys™ system was designed to enable quick and reliable damage assessments of buildings and infrastructure, in order to facilitate the applications for NDRRA funding, and monitor efficiently the reconstruction process. Even though it was developed to facilitate the damage assessment and reconstruction phase in the aftermath of the 2010-2011 floods, it is essential a multi-hazard procedure. Apart from a few activities related with disaster preparedness (e.g. risk assessment and identification of potential life-threatening situations), the DARMSys™ methodology consists of three main phases:

<u>Initial response phase</u>:
The first phase is initiated after the main spatial and temporal evolution of the event, where the affected areas are safe to access. Similar to an emergency response, the primary objective of the activities is to ensure the safety of residents, and that no further life-threatening situations exist within the first 72 hours of the event. The responding state emergency agencies, coordinated by the Department of Community Safety (DCS) and the Queensland Fire and Emergency Services (QFES), carry out preliminary assessments to provide an overview of the direct damages to essential infrastructure, services, residences and businesses. This information is used to assist in the planning of the next phase by defining specific areas where damage assessments at the asset level are required. The data collection in this phase is limited to the estimation of the number of fatalities, injuries, and missing people. Depending on the nature and severity of the event, various means are

utilized to access and assess the affected areas, such as vehicle-based (or windshield) assessments, to estimate the initial impact of the event.

The damage assessment phase:
The goal of this phase is to capture and quantify damage to residences, businesses, public infrastructure, services, and private property. The data collection requires a high level of detail in order to support relief and recovery decision making, and more importantly, to provide the necessary information for funding under the NDRRA provisions. The rapid damage assessment is led by the field staff of QFES in conjunction with QRA, the State Emergency Services (SES) and the local authorities, and it is conducted on an asset-by-asset basis, covering all the damaged buildings and infrastructure. However, depending on the extent of the disaster and level of damage, the tasks are divided amongst the responsive agencies. For example, SES may lead activities related with the public safety on buildings with minor to moderate damage, while QFES leads the rapid damage assessment for higher emergency cases. The damage assessment teams are composed by a small number of full-time staff of the responding agencies, but mainly from volunteers who are gathered by SES in the regional emergency operations centers (7 in Queensland). Also, there are numerous stations within Queensland to plan the damage assessment surveys and coordinate the volunteers. Nonetheless, there is a set of guidelines to inform and support volunteers to carry out the damage assessments, as they may not have a technical background, but still sufficient knowledge to categorize the observed damage.

Originally in 2010-2011, the damage estimation was conducted using GPS-enabled Trimble[17] handheld devices based on ArcPad, provided by QFES and QRA. The collected data were accompanied by geotagged photos of each affected asset indicating the observed damage along with other information, such as the status of reconstruction and occupancy details. An example of questions implemented in the Trimble devices for the damage assessment is shown in Figure 40. The collected damage data were uploaded into two GIS databases (dashboards), one managed by the QRA and QFES for further analysis, while the other is managed by the SES. Additionally, the collected information is shared with the Disaster Coordination Center based in Brisbane. Nowadays, the Trimble devices have been replaced by the Survey123[18] ArcGIS application, developed by QFES and the Public Safety Business Agency (PSBA), which can be installed in any mobile device or tablet. QFES switched to this data collection tool due to the involvement of numerous volunteers in the rapid damage assessment, which required a vast number of devices to be provided. The Survey123 application allows many surveyors to be involved in the damage assessment phase. Another very important improvement is that the new application allows uploading the collected data in real time using a mobile communication or wireless network, in comparison with the previous devices which required the surveyors to return to a docking station and upload the data manually. Finally, since the SES operates under QFES, the protocol will soon use a unique database, integrated with the new Survey123 IT system.

[17] https://geospatial.trimble.com/products-and-solutions/data-collectors
[18] https://survey123.arcgis.com/

Throughout the field surveys and damage assessments, the field information is shared amongst decision makers and authorities responsible for the recovery process in order to initiate the reconstruction phase. In addition, technical staff utilizes these data in the preparation of the submission forms to enable access to NDRRA funding. The activities of this phase continue until all the damaged buildings (public and private) and infrastructure of the affected areas are mapped, the damage is quantified and stored in the QRA's web-portal database, and the relevant information has been communicated to the relevant decision makers.

Figure 40 - Example of questions implemented in Trimble devices for the DARMSys™ damage assessment.

<u>The reconstruction monitoring phase:</u>

The objective of this phase is to provide systematic feedback on the recovery and reconstruction progress, approximately every 3 months, based on the collected information from the previous phase. However, the reconstruction monitoring initiates once the restoration of essential services and infrastructure, such as transportation, electricity and communications have been accomplished. All the disaster management arrangements cover the activities from the initial response phase to the data collection and recovery phases through a formal transition period. The activities are managed and coordinated by QRA, in cooperation with other agencies, and they involve systematic field surveys and data collection on the mapped damaged assets during the damage assessment phase. The collected information is analyzed and compared to the damaged data collected in the previous phase, in order to benchmark the progress and level of completeness of the reconstruction process. At this stage, QRA takes ownership of the collected data, while insurance companies can use and verify the information. Similar to the previous phase, the information is disseminated to recovery and reconstruction organizations to assist in the remaining actions. The monitoring and evaluation of the reconstruction efforts is an ongoing process during the recovery stage, and the inspection of the affected areas is carried out until the reconstruction is sufficiently completed.

The collected damage data on the damaged public assets and infrastructure throughout the second and third phase of the procedure are uploaded directly on QRA's platform, under the Infrastructure Damage Assessment and Reconstruction Monitoring (IDARM) system (see Figure 41). The IDARM system supports local government authorities to identify the damaged public buildings and infrastructure, quantify the extent of damages, and enable the funding application and approval process immediately after the rapid damage assessments. Assessment officers from QRA assist the local government personnel to prioritize the disaster recover activities. The platform and web portal enable the direct use of field data in the funding applications and supply them with additional evidence, such as geotagged photographs and engineering reports. This enhances dramatically the councils' revision procedure, reduces the time-consuming paperwork, and assists the NDRRA submission acquittal process. As a consequence, the recovery of the essential public services and infrastructure can emerge as soon as possible, and the monitoring of the reconstruction efforts through IDARM ensures the successful and consistent progress.

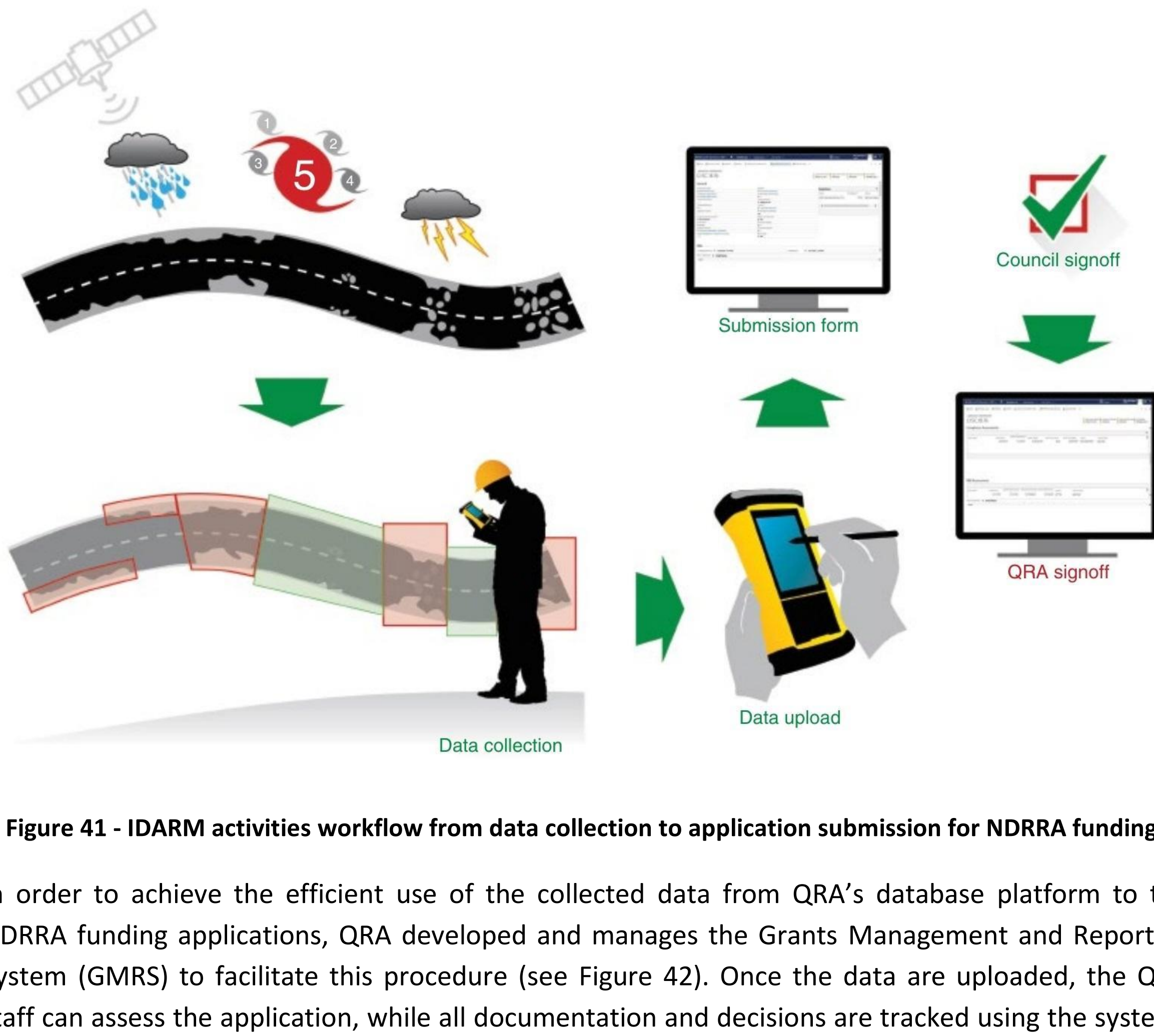


Figure 41 - IDARM activities workflow from data collection to application submission for NDRRA funding.

In order to achieve the efficient use of the collected data from QRA's database platform to the NDRRA funding applications, QRA developed and manages the Grants Management and Reporting System (GMRS) to facilitate this procedure (see Figure 42). Once the data are uploaded, the QRA staff can assess the application, while all documentation and decisions are tracked using the systems web portal. Public and private stakeholders are also able to submit documents and evidence directly to the system using the online web portal. During the reconstruction monitoring phase, QRA's web portal allows the update of damage assessment locations, and benchmarked rates to inform the assessment of submissions. The success of GMRS has encouraged other Queensland governmental agencies to either replace their current information and communications technology systems or to replace laborious paper-based processes with the GMRS system.

Furthermore, the QRA developed and applies a value-for-money (VfM) strategy during the coordination and monitoring of the reconstruction phase, in order to deliver the best outcome from the NDRRA funding. The VfM strategy is based on rigorous and flexible applications to restore essential economic and community infrastructure with the objective of delivering outcomes that offered value for public expenditure. The QRA identified five key phases within the lifespan of a reconstruction program that resulted in optimal cost-benefit outcomes: 1) Establishment and mobilization, 2) NDRRA application submission, 3) Application approval, 4) Project delivery, and 5) Compliance and Acquittal. The QRA's early establishment of the VfM strategy has provided immediate and significant cost and time savings and set the conditions that enable reconstruction works to be completed within specified timeframes and often below forecast cost estimates. Additionally, the knowledge and expertise developed through the VfM process has provided the Queensland government with enduring benefits that will support the successful planning and delivery of future natural disaster funding programs.

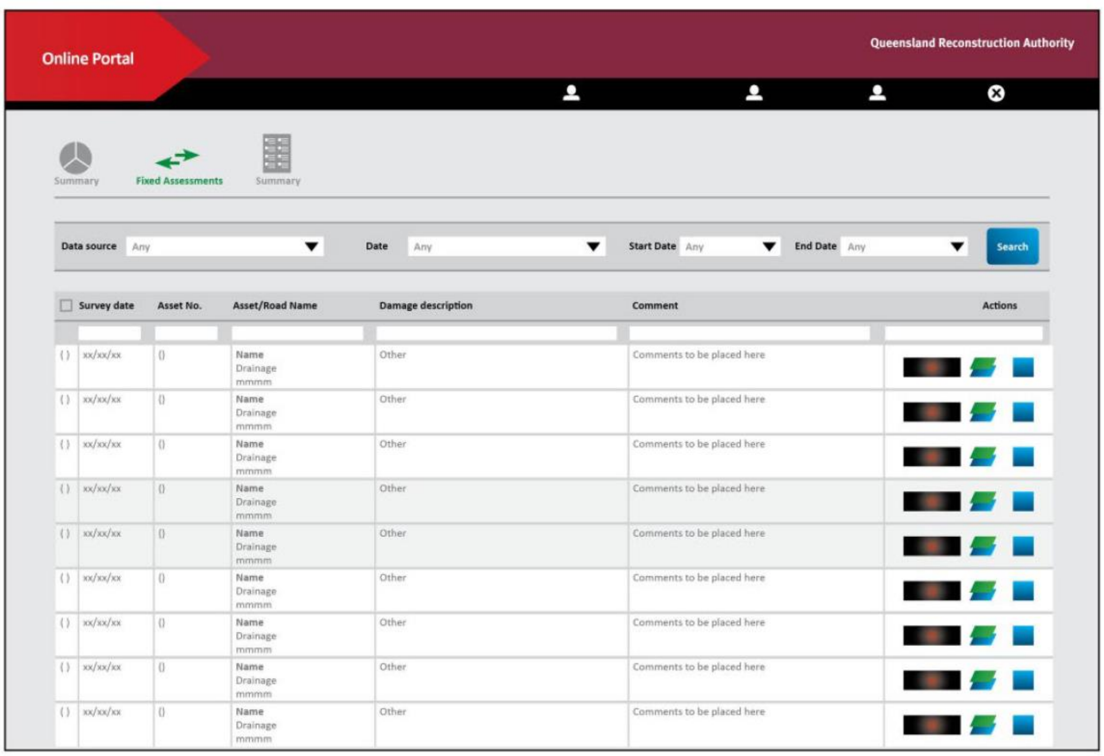


Figure 42 - Grants Management and Reporting System (GMRS) web-portal.

11.4.2. Strengths and limitations

The Queensland Government, through the establishment of QRA, developed comprehensive disaster management arrangements, including a legislative framework, governance mechanisms, planning processes and financial instruments. The DARMSys™ consists of a state-of-the-art end-to-end post-disaster data collection, reporting and aggregation system. This protocol covers the real-time damage assessment, reconstruction monitoring considering a VfM strategy, and following a Build Back Better concept and disaster resilience. The development of IDARM and GMRS systems have ensured a smooth transition from the initial response and damage assessment methodology to the recovery and reconstruction under NDRRA arrangements. These systems in conjunction with the State's flood mapping tools enables local governments to be prepared for potential natural disasters and to make considered and informed decisions regarding the implementation of mitigation and resilience works into recovery programs.

Since its establishment in 2011, the DARMSys™ guidelines, tools, and IT systems have been constantly improved, especially due to the contribution of QFES and QRA. However, there are a few limitations in the current practice of the methodology, which can be summarized by the following:

- QFES administrates the data collection and the application of the protocol, while QRA is the owner of the data and utilizes the information for the NDRRA applications and reconstruction. More information is required about how the information is disseminated among the relevant stakeholders. The application of the methodology requires inter-agency and interdepartmental cooperation under a strong coordination, thus requiring a complex regulatory framework tailored for Queensland's reality and capacity. Consequently, considerable adjustments are required for its application in other regions.
- The damage assessment is not linked to the physical event and local intensities, meaning that there are gaps in the scientific or engineering information towards natural hazards risk modelling. In particular, the data collection is one-sided and guided towards reconstruction.
- The system has been very successful in its past applications from 2011 until present, although these events were mostly floods, with the inclusion of damage due to cyclones. Even though the methodology, tools and IT systems can be easily extended to any peril, there is a lack of experience about their overall performance.
- Many volunteers are involved in the damage assessment phase in conjunction with some full-time staff from QFES and SES. There is clearly an absence of technical knowledge in the damage assessment and data collection. Nevertheless, QRA has deployed post-disaster officers since 2013 to assist volunteers and local authorities with infrastructure damage assessments, conducting more than 16,000 assessments and capturing more than 130,000 damage photos.
- Aerial imagery and remote sensing techniques are limited in the current practice, as the planning of the initial response and damage assessment phases rely on satellite images. However, QFES and SES are planning to introduce the use of UAVs (drones) for this purpose, which can significantly boost the accessibility to remote areas or regions that cannot be

safely accessed by the DARMSys™ teams. Moreover, the goal is that information will be reported into one system, integrated with the damage data collected by people on the ground.

- The introduction of the Surver123 application improved significantly the damage assessment surveys in comparison with initial Trimble ArcPad devices. Apart from the major advantages of real-time data acquisition, the new application allows more accurate post-processing and data verification, but it requires connection to the server. In the absence of a mobile network the application can function in an offline mode using offline map services, which allows the surveyor to place the location of the asset accurately. However, this map needs to be stored locally, and considering that Queensland covers a large area, a large amount of data may exceed the current capacity of the local system.

12. Appendix B: Tools for field disaster data collection

This section provides an in-depth review of existing tools for disaster damage and loss data collection, including the main strengths and limitations.

12.1. DARMsys™ Damage Assessment and Reconstruction Monitoring system (also IT system for disaster data aggregation and reporting)

12.1.1. Description

As described in the section 11.4, the Queensland Reconstruction Authority (QRA) has developed a Damage Assessment and Reconstruction Monitoring system (DARMsys™) for fast and accurate identification of the extent of damage following disaster events. This system is also used to monitor the status of recovery and reconstruction.

For the in-field damage assessment of the 2010-2011 floods, Trimble[19] portable devices integrated with Global Navigation Satellite System (GNSS) were used. In 2012 Queensland Fire and Emergency Services (QFES) switched from Trimble devices to a more advanced ESRI ArcGIS "Survey123" mobile application for field mapping and data collection. QFES, in collaboration with the Public Safety Business Agency[20] (PSBA), developed the data form for "Survey123" mobile application, which has been used since October 2017. The collected from a field data is stored within QRA's Microsoft SQL Server instance (available only for internal use). It is also published as an ESRI service available on ArcGIS Online.

QRA publishes the records in CSV format, and all services are shared amongst authorized stakeholders. The geo-referenced information on surveys is shared in real-time amongst decision makers and organizations responsible for the recovery process. On the basis of survey data, the technical staff and assessing engineers prepare the Submission Forms for responsible councils in order to begin the application process for the NDRRA funding.

There are twelve official Submission Forms[21] for applicants[22] for assessment and NDRRA funding:

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[19] http://www.trimble.com/embeddedsystems/portable_devices.aspx

[20] http://www.psba.qld.gov.au/

[21] Submission Guide for NDRRA Restoration of Essential Public Assets (REPA) and Counter Disaster Operations (CDO) Funding, 2016

[22] An Applicant must be an eligible undertaking and be a body that:
- a department or other agency of a state government; or
- established by or under a law of a state for public purposes (for example, a local government body); and provides community, social or economic services free of charge or at a nominal charge well below the costs of production.

- Form 1: Submission checklist – contains necessary documents required for submission.
- Form 2: Single assets (superseded) – contains details for single asset submissions. Superseded by Form 4.
- Form 3: Unit rates (superseded) – where councils have used unit rates as part of their submission, details of assumptions, evidence used and calculations must be provided. Superseded by Form 4.
- Form 4: Multiple assets – key submission document containing details for multiple asset submissions including calculations, assumptions and supporting documentation,
- Form 5: Summary sheet – Summary of claim submission.
- Form 6: Value for money (VfM) statement – contains details as to how councils intend to complete work and completion expenditure estimates. Used by QRA VfM team.
- Form 7: Variation application – contains details from agencies/councils who wish to make variation on original claim.
- Form 8: Progress reporting checklist – contains necessary documents and information regarding work progress.
- Form 9: Progress report – contains details of restoration progress including work photographs.
- Form 10: Final reporting checklist – contains necessary documents required for final close out.
- Form 11: Signed VfM Outcome report – contains final VfM teams' assessment.
- Form 12: Counter disaster operations – contains details as to why activities were undertaken, evidence of actual expenditure (invoices), G/L report, media reports.

The Forms 4, 6, 10, 11, 12 are sent by e-mail (submissions@qldra.org.au) or Mail – Post USB with documents to PO Box 15428, City East, 4002.

For evidence of damage and/or expenditure, applicants must provide:

- Evidence of all damage and/or activities which are intended for grant assistance.
- For restoration submissions, photographs (JPEGs with EXIF metadata, including GPS coordinates and time/date taken) must accurately reflect the damage and scope of claim.
- Photos that sufficiently demonstrate the event impact should be provided for each asset.

During the Second and Third phase of data collection process, the collected data on the damaged public assets and infrastructure are uploaded directly on QRA's web-portal. The QRA web-portal enables the direct use of field data in the funding applications and supply them with additional evidence, such as geo-located photographs and engineering reports. The QRA portal can be accessed via https://portal.qldra.org.au by authorized users (login is required by the system). Applicants should contact their Regional Liaison Officer for access details and guidance on how to use the QRA portal[23].

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[23] Submission Guide for NDRRA REPA and CDO Funding, 2016: http://www.qldreconstruction.org.au/u/lib/cms2/Submission-Guide-Version5-November-2016.pdf

QRA designed and managed the Grants Management and Reporting System (GMRS) to facilitate the procedure of efficient use of the collected data from QRA's database platform to the NDRRA funding applications. The QRA staff can assess the application when data are uploaded, and all documentation and decisions are controlled using the systems web-portal. The online web-portal is also open for public and private stakeholders to submit documents and evidence directly to the system. During the Third phase of reconstruction monitoring, QRA's web-portal permits the updating of the damage assessment locations, and benchmarked rates to inform the assessment of submissions.

Figure 43 - DARMSys Trimble GPS-enabled handheld device for field data collection (2010-2011 floods).

Survey123

Survey123 for ArcGIS is a form-based data collection solution that makes it possible to create, share and analyze detections. The Survey123 data collection solution consists of three components, each of which performs different functions:

1. Survey123 for ArcGIS field app - Enable field workers with the Survey123 for ArcGIS mobile app to get answers in the field.
2. Survey123 Connect - Quickly design advanced surveys and publish them to ArcGIS (surveys, forms, polls, and questionnaires).
3. Survey123 website - Analyze responses from the field in real time to support decision-making processes, which provides functionalities to visualize the results of a survey and share it with other users.

The different options are indicated by multicolor circles:

- Collect — Opens a new, blank survey page for inputting data.
- Drafts — Opens to a form currently left uncompleted by closing the survey before sending it.
- Outbox — Opens to a listing of all forms finished but unsent, either by choice or due to the device being offline when submitting.

- Sent — Contains the records of all forms submitted to the survey's creator.
- Inbox — Opens to an inbox of responses within the feature service (after enabling).

Survey123 for ArcGIS supports XLSForm[24] specifications. XLSForm provides a practical standard for sharing and collaborating on authoring forms. The output formats are Excel spreadsheet, a KML file, a shapefile, or a file geo-database. The Survey123 application runs on smart phones, laptops or desktops as a native app and also in the browser on OS: Windows phone, Windows, Mac OS X, Ubuntu, Android, iOS or Linux.

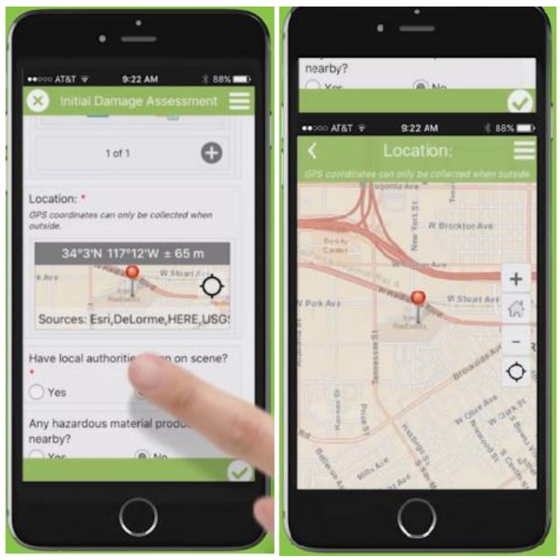

Figure 44 - The "Survey123"[25] ArcGIS mobile application.

The following operating systems (with minimum versions) are supported for Survey123 Connect: Windows, Mac OS X, Ubuntu.

Hardware requirements to be considered are:

- CPU—2.2 GHz minimum or higher; Hyper-Threading Technology (HTT) or multicore recommended.
- Processor—Intel Pentium 4, Intel Core Duo, or Xeon processors; SSE2 minimum.
- Graphics card—An independent graphics card with a hardware acceleration driver.
- OpenGL—Version 2.1 or later is required.

The main functionalities[3] of the QRA portal include:

- Direct upload of information from DARMsys™ or local government devices.
- Direct lodgment of NDRRA submissions to QRA.
- Presentation of data in a format consistent with NDRRA submission forms.

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[24] https://doc.arcgis.com/en/survey123/desktop/create-surveys/xlsformessentials.htm

[25] https://survey123.arcgis.com/

- Monitoring of submission progress and approval by applicants.

Technology[26] used:

- Survey123 for ArcGIS software.
- GPS tracking of affected assets.
- MS SQL-based database.

Disasters covered:

- Used for floods but can be adapted for other disasters.

12.1.2. Overall evaluation

Strengths

- The “Survey123” tool provides the ability to run the software on a wide range of devices and offers multiple languages.
- The filed-application accepts audio records and images. Captured information can be automatically georeferenced.
- The “Survey123” allows to use tracking and collect data in online or offline mode. By default, the Survey123 field app requires an Internet connection to display a map, but it is possible to configure a survey to work offline[27].
- The data are stored under ArcGIS map server, that makes them available according to OGC standards.

Limitations

- Storage of a very large amount of geospatial data on a local server after a field data capture is needed.
- Internet connection is necessary to access to ArcGIS API, ArcGIS Online or ArcGIS Enterprise. The field app also requires internet connection to download and submit surveys.
- Survey123 is not open source solution but is only available as web service under subscription.

[26] https://doc.arcgis.com/en/survey123/reference/systemrequirements.htm

[27] https://doc.arcgis.com/en/survey123/desktop/create-surveys/preparebasemaps.htm

12.2. Damage and loss assessment methodology from Mexico's Natural Disaster Fund (FONDEN) (also IT system for disaster data aggregation and reporting)

12.2.1. Description

FONDEN (Natural Disasters Fund)[28] is an instrument for the coordination of intergovernmental and inter-institutional entities to control allocation of funds in response to natural disasters. FONDEN procedures are clearly defined under Mexican government law. Within the framework of the FONDEN an information technology system has been implemented for Disaster Risk Management applications. Geocoding and digital image capture is used to provide evidence of damage in affected sectors. The three key steps of the FONDEN procedure are:

Step 1: Collecting information on damaged infrastructure by using georeferenced photos.
At the initial stage of data collection, an affected entity requesting post-disaster FONDEN support must provide georeferenced photographs for each damaged object. The damage to public infrastructure is categorized by sector: schools, hospitals, hydraulic infrastructure etc. Photographs as evidence of a disaster impact are uploaded to FONDEN's automated system for submission to the Damage Assessment Committee, which is expected to be established within ten days after a disaster. The georeferenced photographs are accompanied by polygons of an affected area, and by information quantifying the damage in each sector.

The Damage Assessment Committee (subcommittee expert team) collects information on the field using a GIS application and takes pictures of damaged infrastructure (including the location and the date). The mandatory information and evidence that must be provided for each sector includes:

1. Geolocated photographs documenting the type of damage to each affected asset in all the municipalities covered by the disaster declaration.
2. Detailed reconstruction needs and related costs - proposed improvements as part of the reconstruction work to mitigate and prevent possible disaster damage, related costs, and a comparison of these costs with the replacement cost of each public asset.

Step 2: Submission of the collected information online.
The subcommittee expert team presents its findings on the identification and quantification of damage and related reconstructed needs. The Directorate General of FONDEN uploads the collected information into the FONDEN system of requests and creates an inventory of post-disaster activities. The geo-referenced photographs allow the Damage Assessment Committee to efficiently record and manage resources for the reconstruction of damaged infrastructure.

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[28] Mexico's Natural Disaster Fund – A Review, World Bank, 2012.

Step 3: Storing the information in FONDEN's database-central system.

The uploaded photographs are stored in a central database for further analysis. The compiled data is used by officials for preparation of graphics and statistics, calibration of damage and loss models, validation of past FONDEN financial support for the reconstruction of public infrastructure, and identification of insured infrastructure assets. The database for improved DRM and disaster risk financing strategies was a fundamental input for the exposure and risk profile analysis necessary to place this insurance scheme.

Requirement of Equipment, Software and Services[29]:

- Operating System Windows XP or higher.
- Silverlight Plugin.
- Internet service.
- Compatible Browsers: Internet Explorer, Chrome, Firefox Mozilla.
- GPS device with integrated camera and Windows Mobile Operating System 6 or higher (Technical Specifications of GPS Devices).
- If GPS device not equipped with a camera, separately digital camera is necessary to take digital pictures.

Disasters covered:

- Geological (Avalanche, Volcanic eruption, Tsunami, Slope movement, Extreme wave, Earthquake, Subsidence).
- Hydrometeorological (Severe hail, Hurricane, River flooding, Rain flooding, Severe rain, Severe snow, Severe drought, Tropical storm, Tornado).
- Forest fire and other natural phenomenon with similar characteristics.

12.2.2. Overall evaluation

Strengths

- The use of IT tools improves the quality and timeliness of information, which flows throughout a DRM system. The transparency and control of resources for prevention and post-disaster reconstruction are increased. In the case of Mexico's FONDEN, the requirement for geo-referenced photographic images to be provided to the Damage Assessment Committee has helped FONDEN to efficiently record and manage its resources for the reconstruction.
- The information collected on the field is sent to the central database and used to feed into the risk model.

Limitations

- The detailed information on IT field tool for data collection and local database is not provided by the official documentation.

[29] http://www.proteccioncivil.gob.mx/en/ProteccionCivil/SistemaFondenenLinea

- The FONDEN IT field tool for data collection is not available for public and for familiarization on functional possibilities.

3.1 FiDAT Field Data Analysis Tool

Geoscience Australia has developed a set of tools and processes for an effective and consistent capture and processing of post-disaster information. These tools cover field capture, desktop data processing and value addition from other data sources[30].

The tools are the following:

- The Rapid Inventory Capture System (RICS)[31,32] is a transportable system, which captures high resolution building and street view images after a disaster. The system consists of Ethernet cameras attached to a tripod mounted on a motor vehicle, a GPS receiver, and accompanying software. The RICS system is mounted on the vehicle and can operate up to four cameras concurrently. The supporting software system is available under a Creative Commons license.
- Handheld computers with GPS functionalities, high-resolution camera and durable case have been used for consistent data capture (2010). The computers were equipped with hazard-specific survey templates capturing building types and damage severity in a consistent digital form.
- The Field Data Analysis Tool (FiDAT) is a desktop information-processing platform. The FiDAT tool incorporates an Open Source geospatial information system software for development other information, (e.g. building footprints).
- Other survey instruments have been developed for postal and on-line survey of households and businesses.
- The RICS survey is conducted for a specific area. Then RICS imagery is incorporated into FiDAT tool. The first task for an assessment expert is to determine whether the attached image is a good representation of the property. This can usually be determined by identifying the street number of the house, looking at the aerial imagery and the Google Street View image of the property. Images can always be deleted, and better ones can be dragged and dropped.

The system consists of Ethernet cameras attached to a tripod mounted on a motor vehicle, a GPS receiver, handheld computers with GPS and a desktop computer (Figure 45).

[30] http://www.ga.gov.au/scientific-topics/hazards/risk-and-impact
[31] RICS Risk and Impact Analysis Group Geoscience Australia, N.Corby et al., Sydney, Australia, 11-16 April 2010 http://fig.net/resources/proceedings/fig_proceedings/fig2010/ppt/fs03b/fs03b_corby_ppt_3899.pdf
[32] Copyright © 2011-2012 Commonwealth of Australia (Geoscience Australia).

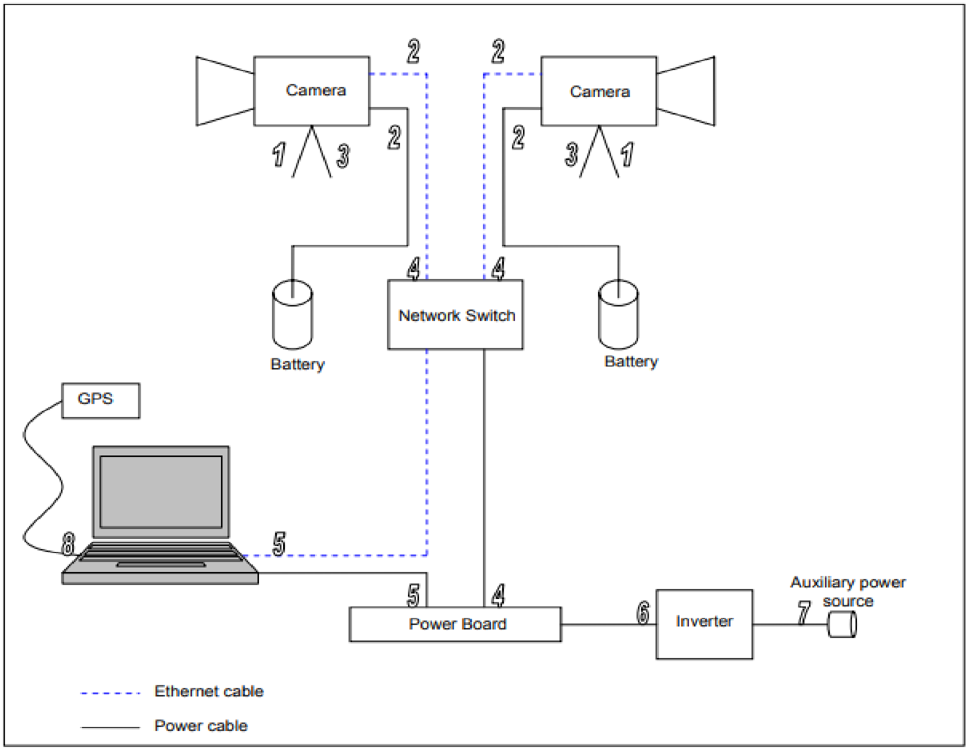


Figure 45 -Diagram of rapid inventory collection system, N.Habili, Geoscience Australia, 2012.

RICS Graphical User Interface consists of three sections (see Figure 46):

- Streamed images are displayed in the top section.
- The middle section displays the collected GPS data
- The bottom section is a notepad, where users can type notes during a field session.

Figure 46 - RICS Graphical User Interface.

FiDAT[33] geospatial is a tool for building analysis for pre- or post-disaster surveys. FiDAT is used to extract data on the nature and damage to a building structure. The data can be updated, modified and/or corrected to accurately reflect the severity of damage to a building.

FiDAT reflects the information from the NEXIS (National Exposure Information System) database which provides exposure information aggregated at the smallest statistical unit in Australia[34]. Exposure information is produced by sourcing the best publicly available census information, statistics, spatial and survey data about buildings, demographics, community infrastructure and agricultural commodities[35]. Buildings and structures are classified into the following major occupancy classes: Residential, Commercial, Industrial, Public Institutions, Infrastructure, and Agriculture to ease data collection and synthesis from a range of sources. NEXIS information is not intended for operational purposes (at building or individual feature level). FiDAT incorporates information from both databases to provide the user with a single platform to view an area of interest with all the corresponding building footprints, centroids and NEXIS points, along with elevation data (if DEM exist) and fundamental spatial datasets such as cadastre.

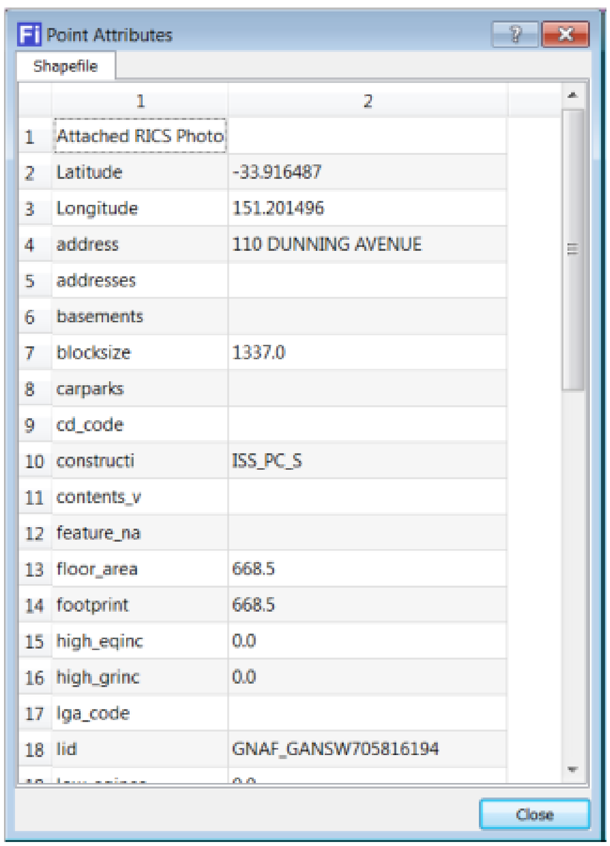
Figure 47 - RICS vehicular data collection system (image and GPS).

[33] FiDAT User Manual, (Version 1.0.3), N.Habilli, N.Corby, Geoscience Australia, 2013

[34] https://data.gov.au/dataset/national-exposure-information-system-nexis-building-exposure-statistical-area-level-1-sa1

[35] http://www.ga.gov.au/scientific-topics/hazards/risk-and-impact/nexis

Figure 48 -Tools for Street Survey, N.Corby et al., Sydney, Australia, 2010[36].



Point Attributes

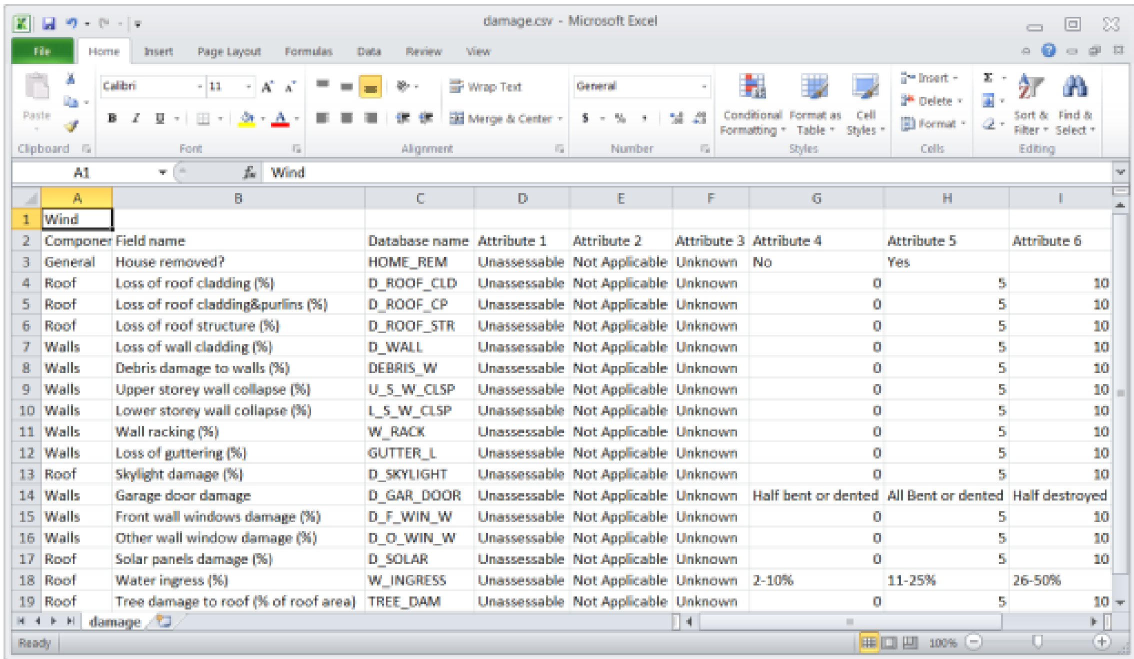
Shapefile

	1	2
1	Attached RICS Photo	
2	Latitude	-33.916487
3	Longitude	151.201496
4	address	110 DUNNING AVENUE
5	addresses	
6	basements	
7	blocksize	1337.0
8	carparks	
9	cd_code	
10	constructi	ISS_PC_S
11	contents_v	
12	feature_na	
13	floor_area	668.5
14	footprint	668.5
15	high_eqinc	0.0
16	high_grinc	0.0
17	lga_code	
18	lid	GNAF_GANSW705816194

Close

Figure 49 - NEXIS shapefile data of a building.

[36] Source: http://fig.net/resources/proceedings/fig_proceedings/fig2010/ppt/fs03b/fs03b_corby_ppt_3899.pdf



	A	B	C	D	E	F	G	H	I
1	Wind								
2	Componer	Field name	Database name	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Attribute 6
3	General	House removed?	HOME_REM	Unassessable	Not Applicable	Unknown	No	Yes	
4	Roof	Loss of roof cladding (%)	D_ROOF_CLD	Unassessable	Not Applicable	Unknown	0	5	10
5	Roof	Loss of roof cladding&purlins (%)	D_ROOF_CP	Unassessable	Not Applicable	Unknown	0	5	10
6	Roof	Loss of roof structure (%)	D_ROOF_STR	Unassessable	Not Applicable	Unknown	0	5	10
7	Walls	Loss of wall cladding (%)	D_WALL	Unassessable	Not Applicable	Unknown	0	5	10
8	Walls	Debris damage to walls (%)	DEBRIS_W	Unassessable	Not Applicable	Unknown	0	5	10
9	Walls	Upper storey wall collapse (%)	U_S_W_CLSP	Unassessable	Not Applicable	Unknown	0	5	10
10	Walls	Lower storey wall collapse (%)	L_S_W_CLSP	Unassessable	Not Applicable	Unknown	0	5	10
11	Walls	Wall racking (%)	W_RACK	Unassessable	Not Applicable	Unknown	0	5	10
12	Walls	Loss of guttering (%)	GUTTER_L	Unassessable	Not Applicable	Unknown	0	5	10
13	Roof	Skylight damage (%)	D_SKYLIGHT	Unassessable	Not Applicable	Unknown	0	5	10
14	Walls	Garage door damage	D_GAR_DOOR	Unassessable	Not Applicable	Unknown	Half bent or dented	All Bent or dented	Half destroyed
15	Walls	Front wall windows damage (%)	D_F_WIN_W	Unassessable	Not Applicable	Unknown	0	5	10
16	Walls	Other wall window damage (%)	D_O_WIN_W	Unassessable	Not Applicable	Unknown	0	5	10
17	Roof	Solar panels damage (%)	D_SOLAR	Unassessable	Not Applicable	Unknown	0	5	10
18	Roof	Water ingress (%)	W_INGRESS	Unassessable	Not Applicable	Unknown	2-10%	11-25%	26-50%
19	Roof	Tree damage to roof (% of roof area)	TREE_DAM	Unassessable	Not Applicable	Unknown	0	5	10

Figure 50 - **FiDAT database screenshot.**

Figure 51 - RICS Rapid Inventory Collections System images (Source FiDAT User Manual, (Version 1.0.3), N.Habilli, N.Corby, Geoscience Australia, 2013).

FiDAT Software:

- FiDAT is developed in Python using the following libraries: PyQT; GDAL; PROJ4; PySHP[37]. For the purpose of building assessment, a dual screen monitor setup is recommended.
- Template files are used to populate the drop-down menus in the taxonomy pane. The template files are in CSV (comma separated value) format and can be modified outside of FiDAT using Excel or any text editor.
- FiDAT data can be exported in to a shapefile (dbf, shp, shx and prj).

RICS Software components:

- Written in C++ using Microsoft Visual C++ Express 2008.
- Widgets, a GUI library, is used to implement the user interface.

[37] FiDAT User Manual, (Version 1.0.3), N.Habilli, N.Corby, Geoscience Australia, 2013

- Image streaming (via the Ethernet network) and compression in the JPEG format are performed on a separate thread for each camera.
- The GPS data fetch and NMEA 0183 parsing is also performed on a separate thread. SQLite is used to store image filenames and the corresponding GPS data, enabling images to be geo-referenced.

RICS Hardware components:

- High-resolution video cameras operating at approximately 4 frames per second.
- Cameras attached to an aluminium structure mounted either on the tray of a 4WD with three magnets or on a vehicle roof via suction cups.
- Streaming data is captured via an in-car laptop running RICS.
- 300W Inverter used to power the laptop, network switch and cameras.

Disasters covered:

- Earthquake.
- Bushfire.
- Severe wind.
- Storm surge.
- Riverine flooding.

12.2.3. Overall evaluation

Strengths

<u>RICS system</u>

- RICS is written in C++, uses a SQLITE database and supports georeferenced images. RICS implements an easy and smart user interface.
- Enabling key engineering staff to focus on damaged structures and rapid prioritization of worst-hit regions.
- Maximum coverage of building damage in a disaster-affected area.

<u>FiDAT system</u>

- FiDAT is a software developed in Python with integration of open source Geospatial Information System (GIS). The most important FiDAT point of strength is related to the possibility of using data from several sources including RICS imagery, Google street view imagery, aerial imagery, information captured in the field using handheld computers and NEXIS.
- The analysis results can be exported in an ESRI[38] shapefile that is a de facto standard for geographic data exchange.

[38] http://www.floodplainconference.com/papers2013/Tariq%20Maqsood%20Full%20Paper.pdf

- The FiDAT tool can use data from several sources including RICS imagery, Google Street View imagery, aerial imagery, information captured in the field using computers and NEXIS.

Limitations

- RICS is not an Open Source software.
- Streamlining the database upload into the GIS environment is not supported.
- JPEG compression is slow.
- The automatic registration of comments of the operator during data capturing is not supported.
- RICS technology uses a complex hardware implementation. If on the one hand this solution is more professional and solid, on the other hand it certainly feels more expensive and less flexible than using, for example, a technology that uses smartphone applications on the Web.
- Finally, it is not a centralized data management system, and without a server that stores information from heterogeneous sources, this may be a less effective solution.

12.3. RISPOSTA Reliable Instruments for Post-Event Damage Assessment (also IT system for disaster data aggregation and reporting)

12.3.1. Description

The core of the RISPOSTA damage assessment is the survey procedure for obtaining flood damage data. The procedure consists of two parts. The first one is a survey of flooded areas with assessment of extension and hazard magnitude. The second one is a survey of damage of residential buildings and industrial/commercial premises.

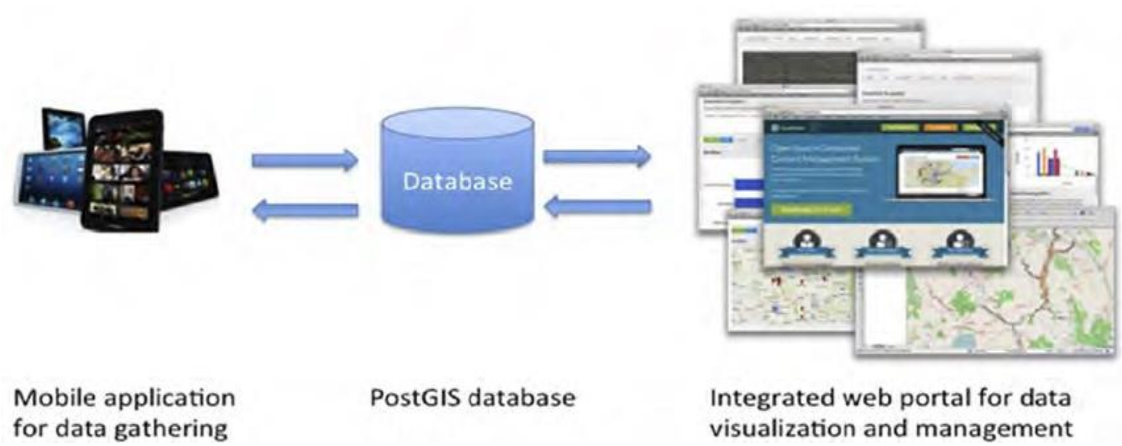


Figure 52 - Architecture of RISPOSTA: three components Information System (Ballio, 2015)

The two types of survey consist of four sections each:

- The form for residential buildings: A. General information; B. Damage to housing unit (This form must be filled in for each unit of the building); C. Damage to common areas; D. Damage to attached building (this form must be filled in for every attached building).
- The form for industrial/commercial premises: A. General information; B. Damage to building structure and plants; C. Damage to machinery, production plants, equipment, furniture, store, archive and mobile goods; D. Recovery/mitigation costs.

The RISPOSTA prototype mobile application for the Android platform has been developed on the base of the OpenDataKit (https://opendatakit.org) tools[39]. Its aim is to facilitate the field survey of buildings by enabling compilation of the forms in digital format. The surveys are filled out via handheld device and sent to the database when completed. A location can be added manually or automatically to the digital surveys using the tablet's GPS. A new version of the application is under development. It will run on Android SDK Software Development Kit.

The mobile application was tested during survey missions in 2014 in the Umbria Region[40]. The main remarks of users on useful functionalities and what should be added:

- The application manages georeferenced inputs such as delimitation of flooded area, surveyed points, and photographs on a digital map.
- Information and measurements can be electronically captured and stored.
- Mobile application provides an overview of the surveyed buildings and the missing ones.
- The completeness of the forms should be checked by an operator.
- Mobile chat among team members is required.

The Regional Civil Protection Authority of Italy is responsible for direct survey activities within the country. The trained survey teams carry out a survey on the field, while the Expertise Centre is in charge of organizing and coordinating activities.

The activities under the Regional Civil Protection Authority and the Expertise Centre are:

- Acquisition of pre-existing knowledge. Information on exposure and vulnerability of buildings is obtained via cadastral databases and/or risk maps, among other sources. The surface area, number of floors, year of construction of a building, level of maintenance, type of activity, and number of dwellers.
- Survey of damage to buildings. Selection of buildings to be surveyed on a map and distribution of survey teams on the areas using survey forms as means of data collection. Additionally, a second survey may be performed after some months with the objective of acquiring information on long-term damage.

[39] The RISPOSTA procedure for the collection, storage and analysis of high quality, consistent and reliable damage data in the aftermath of floods; Ballio et al., 2015.

[40] Flood loss assessment: Case studies, WMO, 2017

- o Acquisition of information on building damage in monetary means (number of damaged doors or square meters of damaged floors).
- o The damage value is assessed according to owners' requests on compensation by National authority funds made available by regional and/or national authorities.
- o A second survey of damage is optional for residential buildings with the aim of obtaining data on losses, such as the period when the house was in non-residential condition and loss of rental income.

Figure below represents a timeframe prescribed for procedures before, during and after an extreme event. The responsibilities and operational activities are distributed between a survey team and a Regional Civil Protection Authority. The main activities are scheduled before an event and during a one year after.

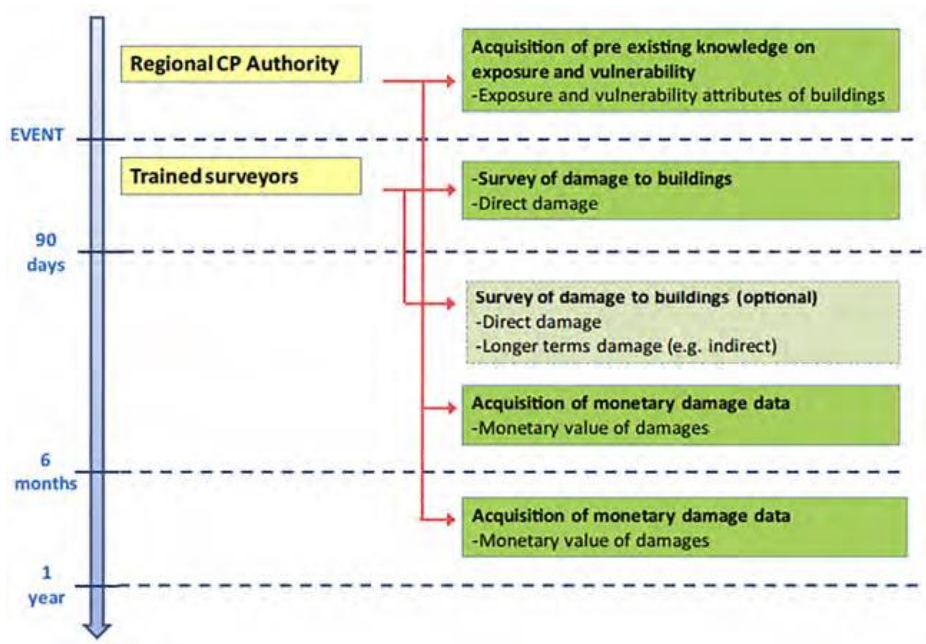


Figure 53 - Scheme of the RISPOSTA procedure for data collection on the damages at the residential sector: actions to be performed, times of actions, collected data and responsible actors (Molinari, 2014a).

The assets for assessment are categorized by sectors:

- o Residential buildings.
- o Industrial and commercial premises.
- o Farms.
- o Infrastructure.
- o Public items.
- o Emergency costs.
- o People.
- o Environmental and cultural heritage.

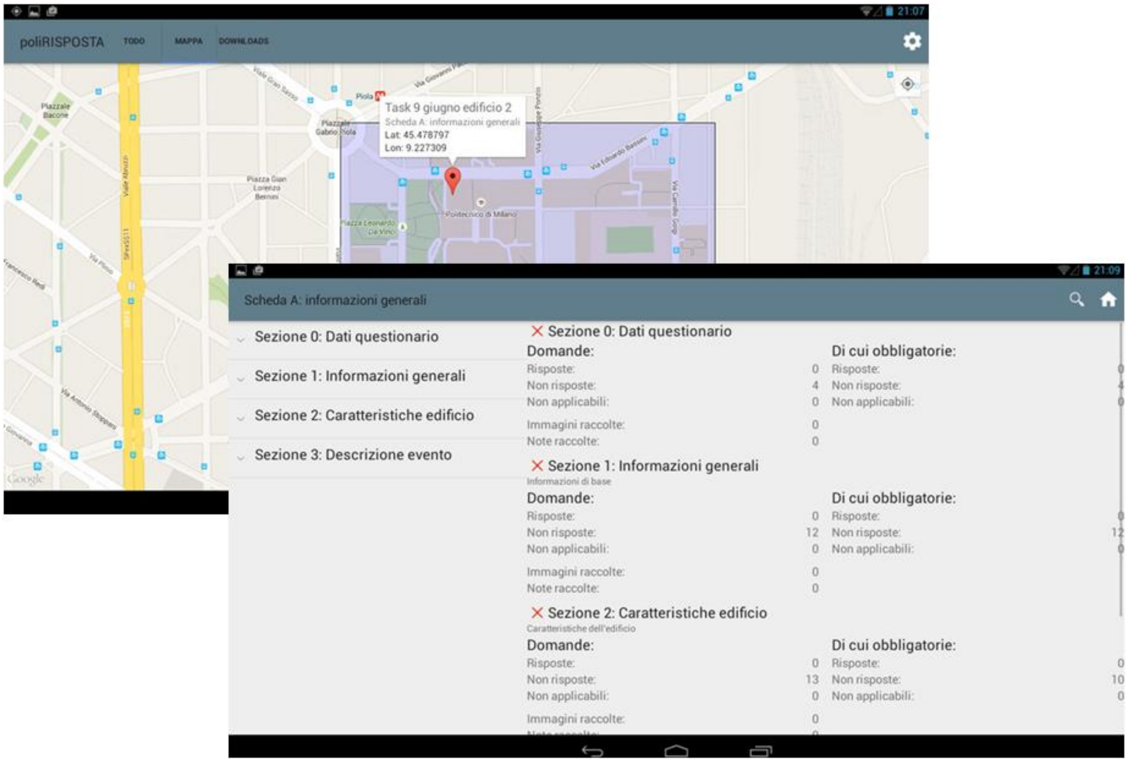


Figure 54 - RISPOSTA Mobile map and forms functionality (Ballio et al., 2015).

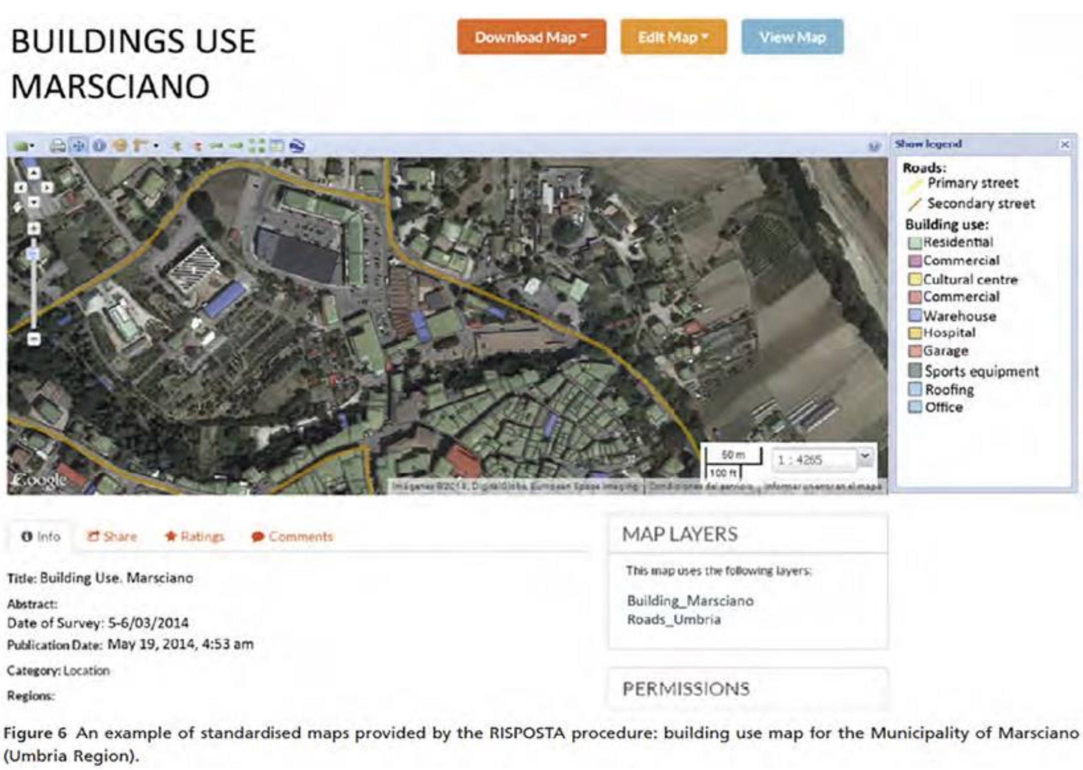


Figure 55 - Example of standardized map within RISPOSTA portal (Ballio, 2015).

The database is designed in relation to the procedures created by RISPOSTA of data gathering through surveys. The database stores all the data related to the procedure, including the surveyor teams, the exact locations of the buildings inserted and the main characteristics of the flood within the buildings (for example, water depth, presence of contaminants or sediments). It is designed under a Database Management System (DBMS) and includes GIS functionalities, such as importing and processing of georeferenced information. All data from surveys are stored in the database. The database supports multi-user approach enhancing transmission of data to stakeholders: practitioners, risk analysts, and decision makers.

The database is accessible through a web portal[41]. The web portal has several security levels that allow different users to access, visualize, and manage information acquired during the surveying phase. Through the web portal users can query the database to find, visualize and eventually export information of interest. Users can create and share interactive web maps. The web-portal offers functionalities related to georeferenced data and their browsing through maps based on GEONODE[42], which is a free and open-source geospatial content management system. Geospatial content (e.g. layers of cadastre, flooded area, survey points) in different formats (e.g. vector, shapefile, raster, GeoTiff) can be searched by category, date and keywords. Authorized users can upload and share geospatial content through standard OGC protocols such as Web Map Service (WMS) and Web Feature Service (WFS).

Software technology:

- The mobile application is designed on Android OS.
- The organization of the Database is based on the PostGIS spatial database extender for PostgreSQL object-relational database.
- Web-portal is designed on GEONODE, and uses OGC protocols such as Web Map Service (WMS) and Web Feature Service (WFS).

Disasters covered:

- River flood.

12.3.2. Overall evaluation

Strengths

- The main advantages of the methodology are: standard ways of collecting, storing and analyzing disaster data; (ii) capability to integrate data and procedures; (iii) the multi-usability of collected data; (iv) transferability to other systems and hazard achievable.
- Statistical tools for post-processing are included.
- The web-portal includes cartography tools for styling and creating maps graphically in the same way as traditional desktop GIS applications, including editing.

[41] The RISPOSTA procedure for the management of damage data, F.Ballio et al., 2015

[42] http:// geonode.org

Limitations

- The RISPOSTA technology is in pre-operational status, which was tested on a flood case in the Umbria region, Italy in the floods of 2012-2014.
- The predefined forms with questionnaire for field survey on mobile device are too detailed. Specific training for the survey team may be necessary to fill in the forms.
- The methodology does not envisage methods of estimating the monetary losses.
- A chat functionality among members of a survey team during a survey procedure is not supported.
- An interactive map is needed with the locations of assigned buildings, which is constantly updated.
- The object-relational database requires a basic knowledge of SQL language.
- This tool is not open source. The web-portal is developed for internal use by Civil Protection Department. The access of users is allowed by a personal login.

12.4. RASOR Rapid Analysis and Spatialization of risk (also IT system for disaster data aggregation and reporting)

12.4.1. Description

The Rapid Analysis and Spatialisation Of Risk (RASOR)[43] development platform performs multi-hazard risk analysis. RASOR uses a scenario-driven query system to allow users to simulate future scenarios based on existing and assumed conditions, to compare with historical scenarios, and to model multi-hazard risk both before and during an event.

The disaster data collected by RASOR system associated to a given event can be uploaded and used as a starting point to:

- Evaluate a series of second level impact indicators (social, economic).
- Evaluate the combined impact due to the occurrence of a subsequent hazardous event.

The RASOR mobile app is designed as an integral part of RASOR tool kit, which includes the RASOR web platform and the QGIS plug-in. The RASOR mobile app allows the users to create and/or characterize exposure layers during field surveys. The mobile app is available on Android devices, for both smartphones and tablets.

Technology used:

- Database: PostgreSQL, PostGIS. GeoServer is used as a data store and publisher of geographic data (static and dynamic). Spatial data infrastructure relies on the GeoServer for the publication in OGC®/INSPIRE web service standards (wms, wfs, wcs).
- Mobile application: is compatible with Android and iOS devices. Uses built-in QGIS plug-in. The application is in connection with the on-line RASOR database.

[43] http://www.rasor-project.eu/

- The source code is available at www.rasor-project.eu/wp-content/uploads/rsf/rasor_src.zip.

The full cycle of disaster management, including support to critical infrastructure monitoring and climate change impact assessment is provided by the RASOR system. For the risk management applications, the newly developed TanDEM-X Digital Elevation Model (DEM) at 12m resolution are adapted as a base layer. The near-real time very-high resolution optical and radar satellite data are overlapped and combined with in-situ data in RASOR.

A precise taxonomy of exposed elements is used in RASOR, characterized by a set of attributes[44]. The attributes describe in physical terms vulnerability of elements and economic value (importance). The attributes can also be used to perform other analyses (economic, social, functional etc.), in addition to the physical damage.

Exposed asset categories include: buildings, facilities, high potential loss facilities, road network, railway network, light rail network, lifelines, agricultural sites, areas of natural interest, population, land cover, hydraulic and geological defenses. Each category represents a class of homogeneous exposed elements, i.e. elements which could be characterized using the same family of attributes.

The significance of the attributes describing each category is defined by a color scale. The category of exposed elements depends on:

- The hazard (earthquake, flood...);
- The type of impact (e.g. physical, economic, social).

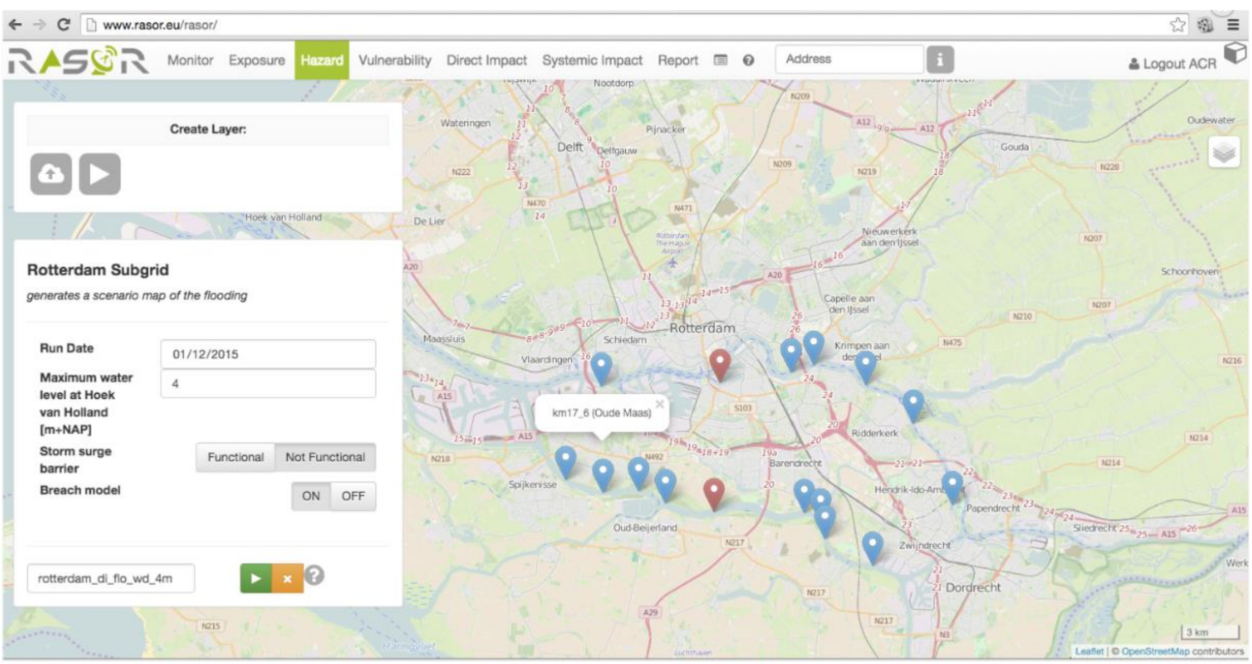


Figure 56 - RASOR interface for the Rotterdam case study.

[44] http://www.rasor.eu/wiki/index.php/RASOR_Mobile_App

The five case study areas were developed in the framework of the RASOR project:

- Haiti - a modelling chain was developed to simulate storm surge, rainfall runoff and flooding of the city of Gonaïves, as a result of a hurricane storm.
- Northern Italy - a multi-risk case study has been designed by taking into account the interaction between an earthquake and flood protection infrastructures.
- Rotterdam - flooding scenarios (coastal, riverine and combined), flooding probability, flood extent, economic quantification.
- Santorini - a simplified approach for the tsunami source has been adopted by making a few assumptions on the wave shape, length and height of the tsunami approximately 60 seconds after the impact.
- West Java - the flood risk and earthquake risk are evaluated for Western-Java. The results are validated against local observations and existing studies.

Figure 57 - The RASOR mobile app: browsing and loading an existing layer.

Figure 58 - The RASOR mobile app: function to create a new layer.

The RASOR platform uses different repositories to store data. The database and catalog are based on open source components compliant with OGC®/INSPIRE. The catalogue[45] provides search services and metadata publication. GeoServer is used for the management of both static and dynamic geographic data. Spatial data infrastructure relies on the GeoServer for the publication in OGC web service standards (WMS, WFS, WCS). A GEONODE web-based application ingests the data into the system, allowing publication on the GeoServer. It also compiles metadata in INSPIRE and OGC standard format.

Exposed asset categories include: buildings, facilities, high potential loss facilities, road network, railway network, light rail network, lifelines, agricultural sites, areas of natural interest, population, land cover, hydraulic and geological defenses. The building category are characterized through a series of physical attributes, inherited from GEM and HAZUS taxonomies. The set of attributes is related to characteristics of population present in a building.

Features of the RASOR platform include:

1. Powerful spatial search engine.
2. Federated OGC services.
3. Metadata catalogue.

The RASOR platform can be used by researchers or public and private sector technicians working in civil protection and disaster risk reduction fields.

Disasters covered:

- River flood.
- Urban flood.
- Coastal flood.
- Earthquake.
- Tsunami.
- Cyclone

12.4.2. Overall evaluation

Strengths

- The RASOR application is a web and the mobile application. It is free, open source and compatible with Android and iOS devices. For both, the source code is available for download. The application GUI is quite responsive and allows the user to rapidly reach his goals.
- Data are stored in a common geocode database GEONODE, which can be accessed by all the users, according to the defined privileges. The data owner can set the accessibility rights. Data can be retrieved with all the OGC standard services exposed by GEONODE (CSW) and Geoserver (WMS, WCS, WFS).

[45] http://www.rasor.eu/catalog

Limitations

- The RASOR application is developed for creation of impact scenarios after disasters, and is not intended for disaster loss data collection.
- The defined methodology for disaster loss data collection is not provided. Nevertheless, a detailed taxonomy for exposure characterization is implemented and is fully documented. The possibility to upload damage indicators different from physical damage is currently not developed.
- The tool is intended only for managing georeferenced data. Statistical tools are not available.
- Since the application was developed for research purpose it still has some bugs. At the moment the application does not efficiently manage the conflicts due to simultaneous users working on the same layer. In addition, internet connection is required to upload data on the GEONODE (and therefore perform the evaluation of further indicators).
- The RASOR platform is designed to allow user to perform risk assessment, thus the work necessary to adapt the data structure and the application for this purpose is very high. The mobile application is used for exposure characterization, and not for collecting of loss data.

12.5. ROVER Rapid Observation of Vulnerability and Estimation of Risk

12.5.1. Description

The Rapid Observations of Vulnerability and Estimation of Risk software was developed for FEMA under the National Earthquake Hazards Reduction Program (NEHRP) by Applied Technology Council (ATC), SPA Risk LLC, and Instrumental Software Technologies. The ROVER consists of two modules:

- Pre-earthquake module.
- Post-earthquake module.

ROVER's pre-earthquake module is designed for field inspectors. It aims to quickly compile an electronic inventory of buildings, records important structural features related to seismic vulnerability, and generates an automatic estimation of the need for detailed seismic evaluation. The typical pre-earthquake uses include:

- Inventory of buildings and critical facilities.
- Identification and prioritization of mitigation targets.
- Enhancing municipal and public communication.
- Risk assessment for emergency planning with HAZUS-MH.

ROVER's post-earthquake module is used to quickly process and manage the red, yellow, and green safety tagging applied to buildings after earthquakes. The typical post-earthquake uses are:

- Safety tagging.
- Optional tagging with ShakeCast.

- Remotely coordinate tagging.
- Documentation post-earthquake inspection efforts.

ROVER collects field data with any smartphone or tablet connected to the Internet. It allows entering the data through browser directly to the server. The server can be any PC. Optionally it provides service for data storage and a server. It runs on OS Android, iPad, Blackberry.

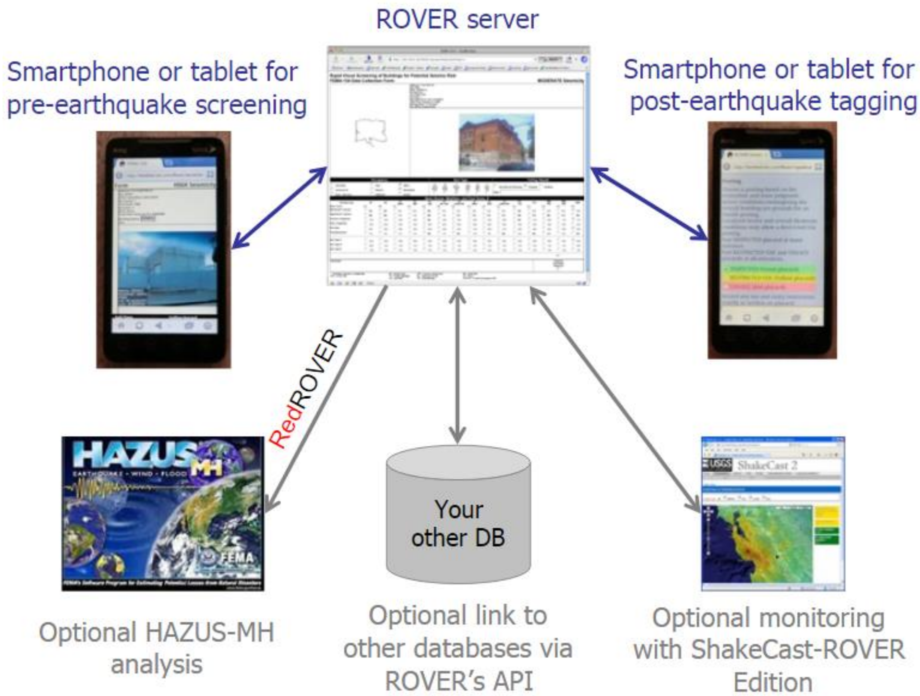


Figure 59 - ROVER architecture (ROVER for End-to-End Seismic Risk Management[46], FEMA).

The ROVER software has been announced by FEMA as a fast, free, mobile software for pre- and post-earthquake building safety screening and risk mitigation. The ROVER adds digital features to FEMA Hazus-MH 2.1 methodology. The ROVER has been successfully pilot tested in Salt Lake City by the Utah Seismic Safety Commission and the Structural Engineers Association of Utah and by the Los Angeles Unified School District LAUSD.

One of the testimonials report[47]:

- Los Angeles Unified School District LAUSD should provide to FEMA sufficient evidence of specific damage of school structures for further reimbursement.
- "Emergency Services Los Angeles Unified School District inspectors were able to assess and document building damage quickly and efficiently using ROVER. We want to expand our ROVER teams and make them part of our annual District-wide earthquake drill. ROVER, in

[46] http://slideplayer.com/slide/4576397/
[47] http://www.roverready.org/testimonials

conjunction with ShakeCast, will allow us to expedite the triage of structures." (Director of Emergency Services Los Angeles Unified School District, 18 August 2009).

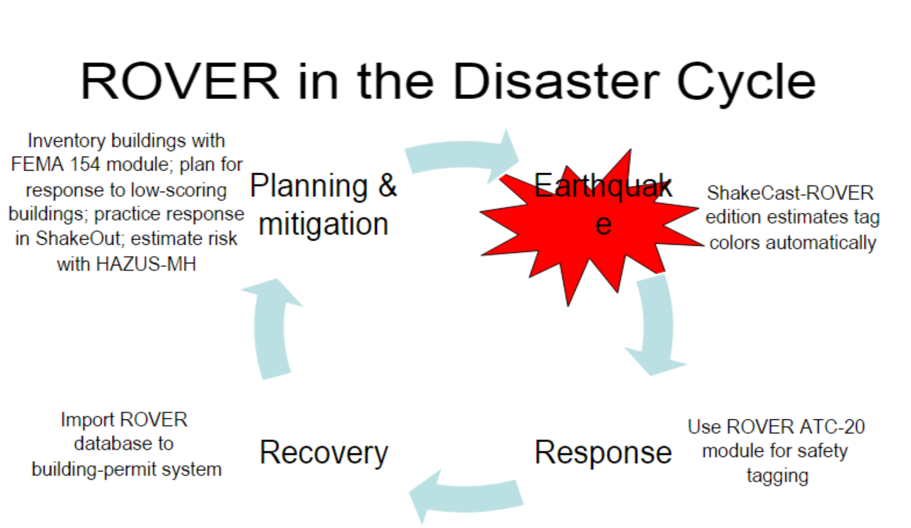


Figure 60 - ROVER application in disaster cycle (ROVER for End-to-End Seismic Risk Management[48], FEMA).

ROVER Version.2 technical characteristics are:

- includes RoverLoad, a Python program for importing customer developed building data into ROVER.
- It includes RedROVER, software for exporting ROVER pre-earthquake data to FEMA's HAZUS-MH 2.1 (HAZUS Multi-hazard models[49]).
- captures digital photos and geolocation.
- integrated with USGS ShakeCast (ROVER Edition) for seismic monitoring of buildings.
- the software operates on Android, iPhone, iPad, Blackberry, or any web-connected device with a browser.

ROVER is a free, open-source software with no licensing costs and with a user community wiki. Easy installation of downloadable mobile software and of server software is provided. Secure database on user's own Windows or Linux PC; optional secure hosted service planned. The software architecture has flexibility of working on any device with a web browser and allows for the remote management of screening. ROVER has the advantage of implementing two de facto international standard seismic safety screening procedures: Rapid Visual Screening of Buildings for Potential Seismic Hazards and Post-Earthquake Safety Evaluation of Buildings. All data can be automatically geolocated from GPS coordinates or addresses. ROVER imports pre-existing data and customer developed building data by a Python program.

[48] http://slideplayer.com/slide/4576397/

[49] https://www.fema.gov/multi-hazard-models

On the other side, ROVER is completely integrated in FEMA technology. This means that users should be professionals familiar with FEMA standards and technologies. For example, the output is strongly connected to FEMA forms for FEMA HAZUS-MH Advanced Engineering Building Module for risk analysis.

Disasters covered:

- Earthquakes.

12.5.2. Overall evaluation

Strengths

- ROVER runs on any device with a web browser and data connection. Screen layout automatically adapts to the data-entry device: smartphone, tablet, or PC.
- ROVER automates two de facto international standard paper-based seismic safety screening procedures: Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA P-154[50]) and Postearthquake Safety Evaluation of Buildings (ATC-20[51]).
- It is a free mobile software downloadable from the official website.
- Captures digital photos and geolocation. It gets latitude/longitude automatically from GPS or address.

Limitations

- The output is strongly connected to FEMA P-154 and Postearthquake Safety Evaluation of Buildings (ATC-20) forms.
- Statistical tools for post-processing are not provided.
- The software operates only on web-connected devices with a browser.
- ROVER is completely integrated in FEMA technology. The output is strongly connected with FEMA forms P-154 and ATC-20. Additional training on using the application is required. Training materials are available on National Earthquake Technical Assistance Program[52] (NETAP).

[50] Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook, FEMA, 2015: https://www.fema.gov/media-library-data/1426210695633-d9a280e72b32872161efab26a602283b/FEMAP-154_508.pdf

[51]Field Manual: Postearthquake Safety Evaluation of Buildings, Applied Technology Council, 2005: https://www.atcouncil.org/docman/other-documents/36-atc201tocv2/file

[52] https://www.fema.gov/national-earthquake-technical-assistance-program

12.6. GEM Android App Inventory Data Capture Tool

12.6.1. Description

The aim of the Global Earthquake Model (GEM) Inventory Data Capture Tools (IDCT)[53] project (2010-2014) was to develop a suite of open-source software and protocols to support participatory population of a Global Exposure Database with structural information.

GEM Android mobile application is developed to enable users to collect and modify building exposure information, which can be input into the Global Exposure Database and the Global Earthquake Consequences Database. The Android application utilizes a map interface to mark survey points, defines a number of attributes about the structural characteristics (taxonomy) and eventual earthquake damage, exports survey data and imports of offline map data. When entering building information, glossary documentation may be accessed to help attribution. Glossary information is available for most attribute types. The app can use the device camera to take photographs. These can be linked to individual survey records or captured for general reference. The list of photographs that have been linked to an individual survey record can be viewed. This allows users to check that photos and records have been correctly linked.

The Inventory Data Capture Tools suite developed by GEM consists of three components:

1. Remote sensing tools and protocols process imagery to obtain building footprints.
2. Sampling and field tools allow teams to characterize building attributes using a series of data collection forms and mobile digital apps (Android and Windows operating systems).
3. Spatial Inventory and Damage Data (SIDD) tool combines these data sources and uses a statistical approach to develop mapping schemes and exposure data for Global Exposure Database[54] (GED) and the Global Earthquake Consequences Database.

SIDD is flexible in the variety and type of data entered into it by the user. The field tools are not absolutely required to develop GEM compatible data using the IDCT tools[55]. The tools were tested by ImageCat[56] team in Greece, Italy, UK, USA and Kyrgyzstan. It was also tested in EEFIT return-mission in l'Aquila (Italy) the field tool for post-damage assessment after earthquake.

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[53] https://www.globalquakemodel.org/single-post/2017/04/21/Global-Earthquake-Model-%E2%80%93-Inventory-Data-Capture-Tools

[54] https://docs.wixstatic.com/ugd/1dcea4_18c960fd34e54b0f81db4332ab320c56.pdf

[55] https://www.globalquakemodel.org/single-post/2017/04/21/Global-Earthquake-Model-%E2%80%93-Inventory-Data-Capture-Tools

[56] http://www.imagecatinc.com/

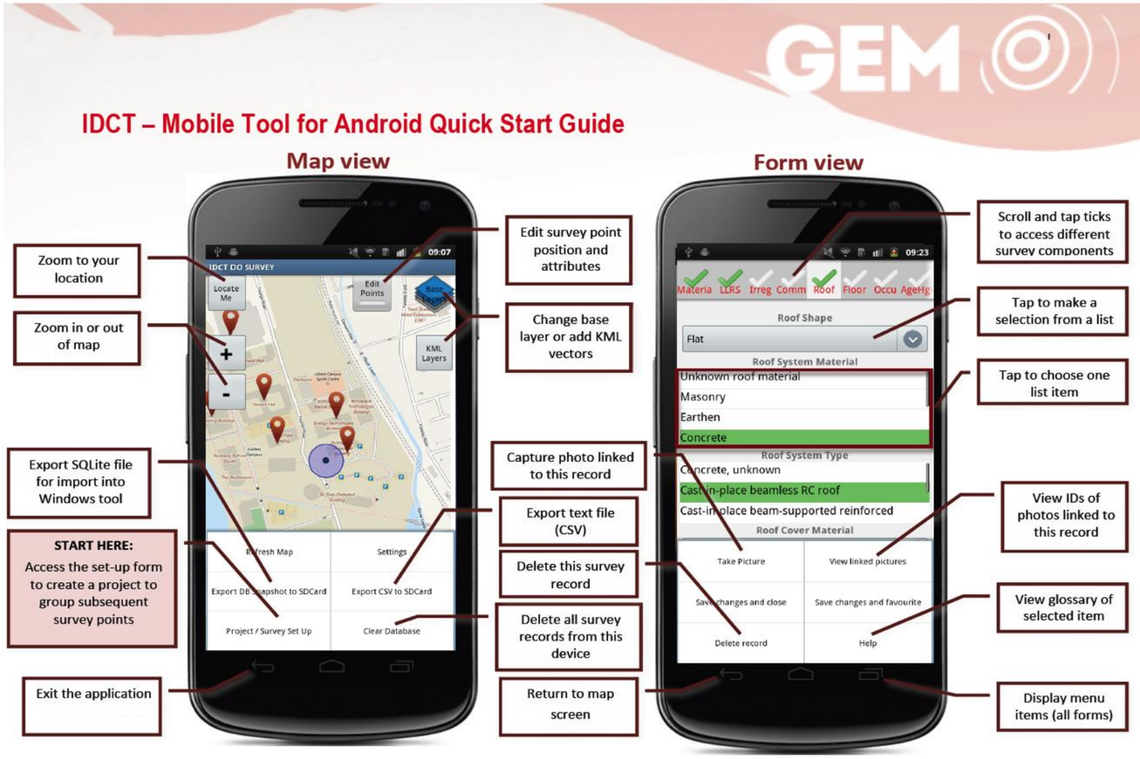

Figure 61 - GEM Mobile tool Android major interface functions.

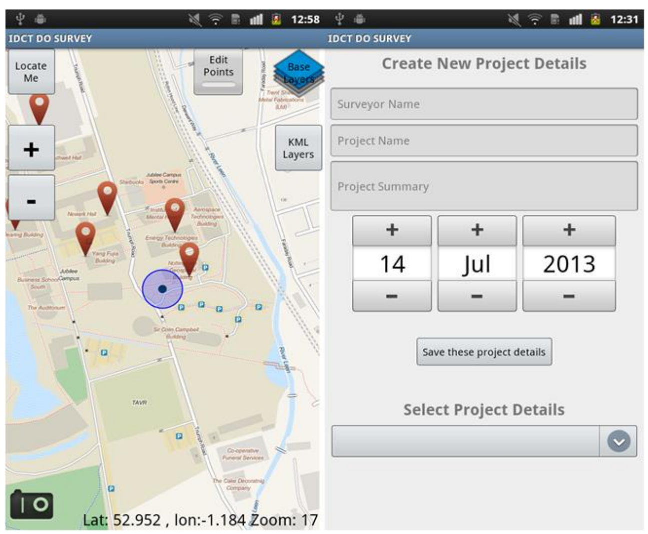

Figure 62 - Map interface and Project Survey Set Up.

The minimum device specification is defined in User Guide[57] for Android mobile tool (2014):

[57] https://storage.globalquakemodel.org/media/publication/DATA-CAPTURE-GEM-Userguide-Android-Mobile-Tool-201403-V01.pdf

- Android 3.0 or greater the best application performance will be achieved when using an Android Operating System for version 3.0 or above. The tool requires 2.3.1 as a minimum requirement.
- Minimum 7-inch screen size Data capture forms have been designed for tablet screens sized 7 inches or greater.
- Rear-facing camera Some devices such as the Google Nexus 7 only have a front---facing camera. A rear---facing camera makes capture of field photographs easier.
- 3G/4G mobile network connectivity Some devices such as the Google Nexus 7 tablet will only work on Wi-Fi. It will be preferable for many users to have the option of using mobile data connections.
- On board storage / SD Card for using offline map tiles some on-board storage or an SD card needs to be available.

Mapping tool for supporting data collection: Base map tiles (as *.png files) and KML data may be pre-loaded onto the device. This function allows to user to have a map available on device. The Mobile Tool for Android supports tile mapping systems defined by the Tiled Mercator System (TMS) and OSM/Google tile indexing, this option requires installation of tilemapresource.xml document, otherwise the tool assumes OSM / Google style indexing. The tool is available in Google Store for download.

Disasters covered:

- Earthquakes.

12.6.2. Overall evaluation

Strengths

- The open source code is provided on Github[58] web-site.
- The User Guide for the Android mobile tool (2014) provides detailed information on how to set up the application and use the map interface, capture building attribute data, import and export data. Information on preparation of basic maps and imagery for IDCT mobile tools is also available.
- The offline option for the use of the tool is supported.
- The application manages input of various type of information: layers in KML format, georeferenced information, loss data and multimedia file (e.g. photo, audio recording).
- The output data is in CSV format, which is a simple, well-known and easy format for exporting data. Otherwise it is possible to export the internal DB of the application useful backup purpose.
- Glossary information is available for most attribute types.

Limitations

[58] https://github.com/gem/DirectObservationToolsForAndroid

- Despite the smart user interface, the user should be prepared and needs introductory training to exploit all the features before using the application.
- Lack of metadata support.
- Limits the size of the data entered due to the technical characteristics of a device.
- Export of map images is not supported.

12.7. I-REACT Improving Resilience to Emergencies through Advanced Cyber Technologies

12.7.1. Description

I-REACT[59] is ongoing project (2016-2019) of H2020, which aim is integrate and disseminate data and outcomes via modeling, which based on forecasts, nowcasts and historical data, chosen specifically a region or country. I-REACT is built on the outcomes of the FLOODIS project, which ended in 2015 and was focused on implementing a crowdsourcing approach to support the emergency response in case floods[60].

The I-REACT European-wide platform (by 2018) will add value to existing data sources and methodologies enhancing the data streams and including new or existing predictive models. The platform will integrate big data with information for danger forecast services, crowdsourced information, UAVs (unmanned aerial vehicle) and wearables, satellite data and historical records. I-REACT approach is based on data combination: photographs taken by smartphones, social media capturing messages and images from Instagram and Twitter. It will collect satellite images as well as reports from wearable technologies (bands, smart glasses) worn by on-site operators. Citizens will be actively engaged through game techniques for encouraging their inputs, i.e. data and photo taken from smartphones. The gaming concepts will be used in non-gaming context. This approach has been proven effective in engaging users and keeping them active.

Below information is provided by interviewers: Claudio Rossi (ISMB[61]) and John Alexander (Aquobex[62]). The data collected from the field are disseminated by nearby devices. The field data collection will be provided by volunteers, civil protection agents and in general any professional practitioner can participate in field data collection. Moreover, the project foresees also the involvement of citizen for this task. The smart design of the tool allows low level of expertise of the users.

As a baseline data are required weather forecasts. The level of aggregation of data is municipality (Admin 3). The process of collaboration of different stakeholders is in the process of evaluation.

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[59] http://www.i-react.eu/

[60] http://www.i-react.eu/wp-content/uploads/2016/12/press-release-KO-meeting-IREACT.pdf

[61] http://www.ismb.it/

[62] http://aquobex.com/

The technology used in I-React project are BigData technologies (Hadoop, Spark, MS Azure Cloud computing), web technologies (Javascript, HTML), mobile technologies, drones, remote sensing, integrated circuits and Radio Frequencies technologies for positioning (GNSS, Ultra Wide Band). One of the advantages of the system is its multi-stakeholder and multi-user approach. Aggregation of heterogeneous data in one solution: remote sensing, positioning, crowdsourcing, social media and models.

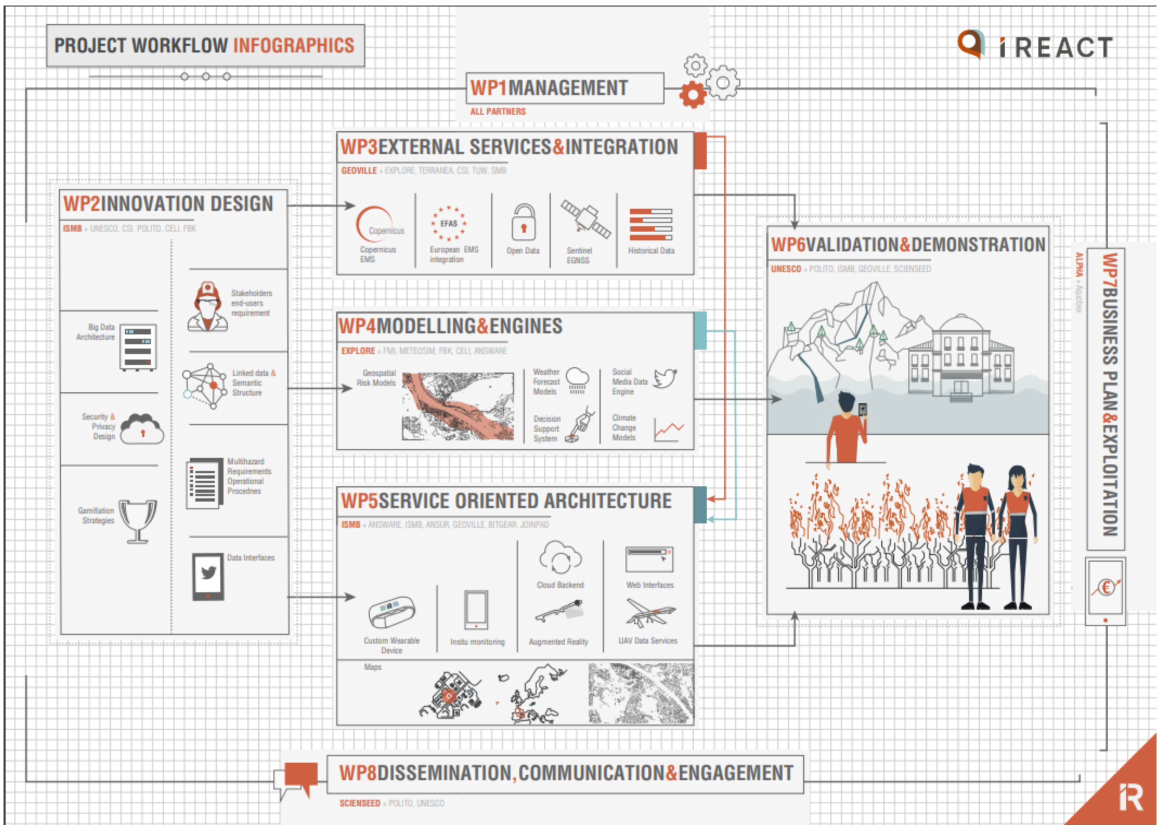

Figure 63 - I-REACT workflow infographics[63].

Disasters covered:

- River flood.
- Urban flood.
- Coastal flood.
- Earthquake.
- Landslide.
- Cyclone.
- Wildfire and other extreme weather events.

[63] Source http://52.178.145.126/wp-content/uploads/2016/10/I-REACT-descargable-blanco-2.pdf

12.7.2. Overall evaluation

Currently the information available does not allow defining the functionalities of this tool, as its development is still on-going. This tool will not be considered for the conceptual design comprised in Phase II.

12.8. MAGE - the Mobile Awareness GEOINT Environment

12.8.1. Description

The Mobile Awareness GEOINT Environment, or MAGE[64], provides mobile situational awareness capabilities. The MAGE[65] application is designed as a mobile device mainly for needs of disaster response personnel, urban search and rescue teams or enterprise. It allows to contribute to critical missions e.g., disaster response, data collection assistance.
The application creates geo-located field reports, complementing them by various media such as photos, videos, and voice recordings and sharing them promptly with a team. The GPS functionalities of mobile device allows the MAGE app to track users locations in real time. The location is automatically assigned to team members.

When disconnected from the network, MAGE will use local data layers to continue to provide relevant GEOINT. Data layers, including map tiles and vector data, can be stored on a mobile device and are available at all times to user. The mobile platform has a server, web client, Android client, and iOS client. The main operational mode is online, the operator collects the data and sends it to main server further data can be stored on a local server, and are always available.

The MAGE application is developed by the National Geospatial-Intelligence Agency (NGA) in collaboration with BIT Systems[66] company. This software aims to increase the impact of government investments by providing users with the geospatial content and analytics through commonly used, cloud-based geospatial tools.

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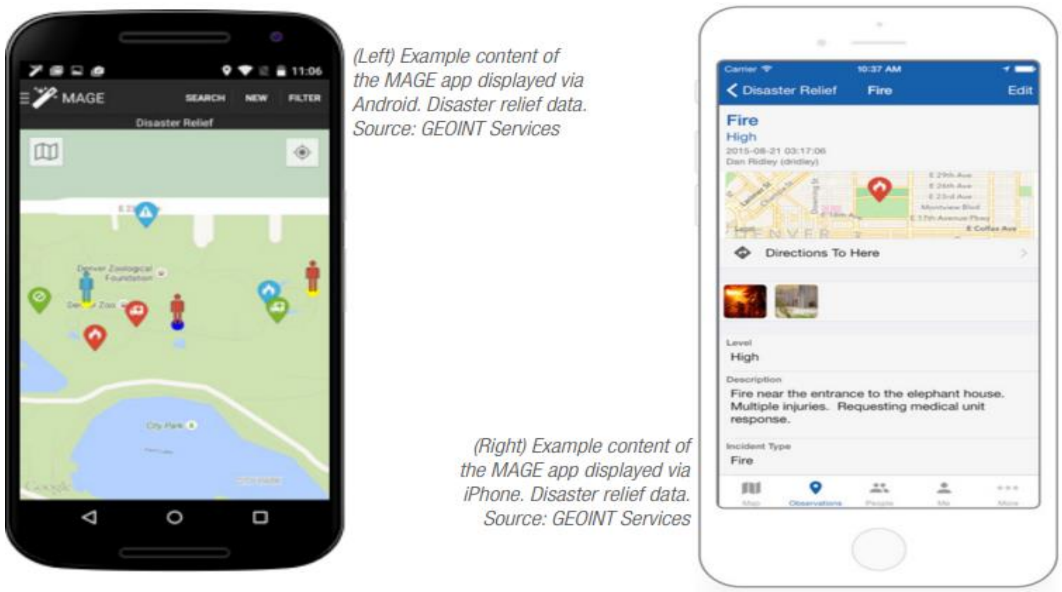
64 https://www.nga.mil/MediaRoom/PressReleases/Pages/NGA-mobile-app-allows-for-creating,-sharing-geotagged,-media-rich-field-reports.aspx

65 https://home.geointservices.io/files/59564de40bbfdd000ed9924c

66 https://www.bitsystemsltd.co.uk/



(Left) Example content of the MAGE app displayed via Android. Disaster relief data. Source: GEOINT Services

(Right) Example content of the MAGE app displayed via iPhone. Disaster relief data. Source: GEOINT Services

Figure 64 - Source GEOINT Services bulletin (Approved for public release)[67] .

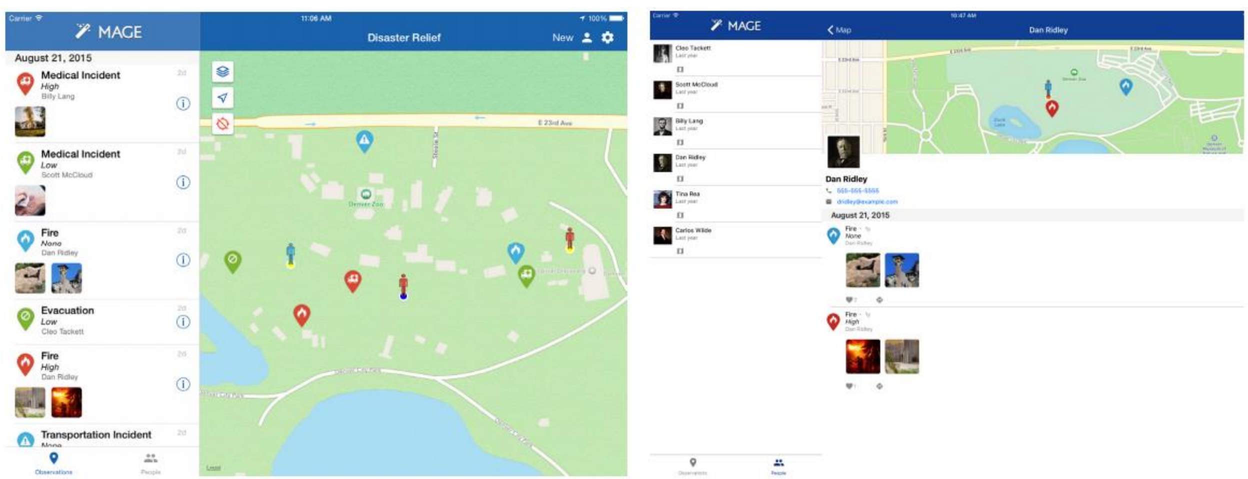


Figure 65 - Example content displays of the MAGE app displayed on an iPad. (Left) Disaster relief data. (Right) Team collaboration. Source: GEOINT Services.

MAGE is accessible through GEOINT services and some apps stores:

- NIPRnet: https://home.gs.mil
- Google Play: https://play.google.com/store/apps/details?id=mil.nga.giat.mage
- iTunes: https://itunes.apple.com/us/app/m-a-g-e/id1032815042?mt=8

Technology used (MAGE is built using the MEAN[68] stack components):

- MongoDB, a NoSQL database;
- Express.js, a web applications framework;

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[67] https://home.geointservices.io/files/59a8ac7c7a5fec000ec13532

[68] https://en.wikipedia.org/wiki/MEAN_(software_bundle)

- Angular JS, a JavaScript MVC framework for web apps;
- Node.js, a software platform for scalable server-side and networking applications.

Opensource MAGE[69] Android and iOS clients are available under the Apache License.

Disasters covered:

- Multi-hazard.

12.8.2. Overall evaluation

Strengths

- MAGE is an open-source product that NGA has enabled for use throughout the geospatial enterprise. The application is available in the Android and IOS store for download, while the source code[70] is available in Github[71] with the opportunity to inspect and extend it.
- Team collaboration chat is supported for connection among survey team members in the field.
- The app remains functional offline when a network connection is not available. The local content is uploaded when a connection is re-established.
- MAGE is easy customizable and can be tailored for a situation, survey team and various events.

Limitations

- Most users are complaining about the initial setup. The advanced skills for setup of the local server are needed. After starting the application, the user has to insert an URL of a local server, but it is not clear where to get this information.

[69] https://github.com/ngageoint/mage-server
[70] http://ngageoint.github.io/MAGE/about/
[71] https://github.com/ngageoint/MAGE

12.9. Summary

Table 11 provides an overview of the main features from the evaluation of the existing tools for disaster damage and loss data collection.

Table 11 - Summary of the tools reviewed for in field disaster damage and loss collection.

Attributes	DARMSys	FONDEN	RISPOSTA	MAGE	FiDAT	I-REACT	GEM Android	RASOR	ROVER (FEMA)
Status	Official operational system is developed and in use by Queensland Reconstruction Authority (QRA).	Official Operational system in use by Governmental institutions.	The actual status of the system components is under research and testing.	Operational application allows to create geo-located field reports complementing them by various media.	Operational system developed by Geoscience Australia.	It is ongoing project (2017-2019) under H2020. The clear data on data collection procedures and IT tool is not available at the moment.	Operational application.	The RASOR is in phase of development and test. Actually is used for research purposes.	Operational application.
Users	Queensland Reconstruction Authority (QRA). The geo-referenced information on surveys is shared in real-time among decision makers, and recovery organizations and authorities.	The Damage Assessment Committee which consists of federal and state representatives from affected agencies.	Developed for Regional Civil Protection Authorities.	The application is designed as a mobile device mainly for needs of disaster response personnel, urban search and rescue teams or enterprise.	Post-disaster engineering survey.	The platform is designed for professionals, qualified volunteers, civil protection agents, but may be used also by citizens.	Designed for participatory population of a Global Exposure Database by structural information.	Professionals in Disaster Risk Assessment and Management.	Professionals familiar with seismic monitoring of buildings.

Loss or damage assessment methodology	The procedures are clearly defined for Natural Disaster Relief and Recovery Arrangements (NDRRA) program for the funding applications.	The methodology is well described and documented by official documents on loss assessment and funding procedures.	The methodology is well described. The survey procedure consists of two parts: The first part is survey of flooded areas with assessment of extension and hazard magnitude. The second part is survey of damage of residential buildings and industrial/commercial premises.	The methodology is not described.	The procedures for data collection are documented.	The pre-defined methodology is co-designed with end-users and experts. Game based methods for citizens involvement in data gathering.	The building attributes are defined by the GEM Building Taxonomy. Glossary information is available for most attribute types.	The tool does not have a defined methodology for disaster loss data collection.	FEMA's Hazus-MH standardized methodology that contains models for estimating potential losses from multi-hazard.
Natural hazard	Floods.	Multi-hazards.	Floods.	Multi-hazard.	Earthquakes, bushfire, severe wind, storm surge and riverine flooding.	Floods, earthquakes, landslides, wildfires, and other extreme weather events.	Earthquakes	Multi-hazard risk analysis	Earthquakes

Interoperability with standards	DARMSys predefined submission forms are used for application process for NDRRA funding. ESRI services and ArcGIS standards are respected.	FINDEN standard forms are used for loss data collection in affected sectors: housing, roads and bridges, hydraulic infrastructure, urban infrastructure, education, health, etc.	OGC standard protocols such as Web Map Service (WMS) and Web Feature Service (WFS).	No standards used.	No standards are evidenced to be in use.	OGS standards, INSPIRE compliant metadata.	GEM building taxonomy.	The taxonomy for exposure characterization is implemented	FEMA's P-154 (Rapid Visual Screening of Buildings for Potential Seismic Hazards) and ATC-20 Postearthquake Safety Evaluation of Buildings forms.
Skills for use the IT solution	Skills level - Medium. DRAMSYs is populated by trained operators.	Skills level - Medium. Users familiar with FONDEN system.	Skills level- Medium. Trained operators to use SQL based database and conduct surveys with mobile device. Compilation of forms is required experience.	Skills level – Low-Medium. Some skills in connection to a local server are required.	Skills level – medium. Trained engineering survey teams.	Skills level - Low.	Skills level - Medium. The user should be prepared and needs introductory training to exploit all the features before using the application.	Skills level - Medium - High	High level of skills is required Additional training on using of application is required.

Availability of open source software	DARMSYS database and web-platform is available for authorized personal. Survey123 ArcGIS mobile software is available for download and use by public.	Not available. FONDEN is developed as an internal governmental system.	Not available. The web-portal is developed for internal use by Civil Protection. The access of users is allowed by personal login.	Opensource MAGE Android and iOS clients are available under the Apache License. Apps Stores (GooglePlay, NIPRNet, iTunes).	Not open source software.	Not open source software. The I-REACT project currently is under development.	The source code is provided on Github web-site.	Freely available app (source code is provided for download).	Free for download, mobile software for pre- and post-earthquake building safety screening and risk mitigation.

IT infrastructure	-Survey123 for ArcGIS software for field data collection; –GPS tracking of affected assets; – MS SQL-based database (available only for internal use).	Software: OS Windows XP or higher; Silverlight Plugin; Internet service; Compatible Browsers: Internet Explorer, Chrome, Firefox Mozilla. Mobile tool: GPS device with integrated camera and Windows Mobile OS 6 or higher; or GPC device and separate camera.	RISPOSTA prototype mobile application for the Android platform has been developed by exploiting OpenDataKit. The new mobile application will run on Android SDK Software Development Kit. The RISPOSTA database is based on PostgreSQL. We-portal is based on GEONODE geospatial management system.	The MAGE web client can be accessed over the internet and is optimized for desktop and mobile web browsers. The server supports the MAGE Android and MAGE iOS mobile clients.	System components: Field Data Analysis Tool (FiDAT) a desktop information processing platform; Handheld computers with GPS functionalities; RICS transportable system for images capture. FiDAT platform is developed in Python using the following libraries: PyQT; GDAL; PROJ4; PySHP.	BigData architecture (Hadoop, Spark, MS Azure Cloud computing), web technologies (JavaScript, HTML), mobile technologies, drones, remote sensing, integrated circuits and Radio Frequencies technologies for positioning (GNSS; Ultra Wide Band).	Android OS for version 3.0 or above. The tool requires Android version 2.3.1 as a minimum requirement. On board storage / SD Card for using offline map tiles. Rear camera.	Compatible with Android and iOS devices.	Runs on OS Android, iPad, Blackberry.

Summary of strengths and limitations	The DARMSys post-disaster assessment consists of three phases: I. The initial response phase; II. The damage assessment phase; III. The reconstruction monitoring phase. Survey123 mobile tool and web-portal database are used during II. and III. Phase of the DARMSys assessment.	In the case of Mexico's FONDEN, the requirement for geo-referenced photographic images to be provided to the Damage Assessment Committee has helped FONDEN to efficiently record and manage financial resources for the reconstruction.	The Risposta system consists of main component: Database for data storage; Mobile application for in-field data collection; and Web-portal for data visualization. The methodology on data collection is in place. The components of the system are tested on the case study and actually are under evaluation.	MAGE provides users the ability to create and share observations (including attached videos, photos, and audio recordings) in the field using a mobile device.	FiDAT tool is used to collect and extract data on the nature and damage to a structure. It provides access to NEXIS (National Exposure Information System) database and RICS (Rapid Inventory Collection System) imagery. It incorporates data from both databases along with elevation data (if DEM exist) and fundamental spatial datasets such as cadastre.	The I-REACT is ongoing project. Specific information on developed tools is not available at the moment.	The GEM Android tool was designed basically to feed GEM's Global Exposure Database and the Earthquake Consequences Database in the framework of the IDCT project (2014). The field tools are not absolutely required to develop GEM compatible data using the IDCT tools.	RASOR is not a loss data catalogue but a tool allowing - among other functionalities - to upload and use disaster loss data. The RASOR can run also on mobile devices. The mobile application is not designed for loss data collection.	The output is strongly connected to FEMA P-154 and Post-earthquake Safety Evaluation of Buildings (ATC-20) forms. Users should be professionals familiar with FEMA forms P-154 and ATC-20.

13. Appendix C: IT systems for disaster data aggregation and reporting

This section provides an in-depth review of existing IT systems for the aggregation, storage and reporting disaster damage and loss data, including the main strengths and limitations.

13.1. DesInventar Disaster Loss Accounting System

13.1.1. Description

DesInventar is a Disaster Loss Accounting System which was beginning at 1994 by LA RED (Network of Social Studies in the Prevention of Disasters in Latin America). The current development is supported by UNDP and UNISDR, which have sponsored similar systems in the Caribbean, Asia, Africa and Europe. The DesInventar database was adopted by many countries for loss data collection and currently 92 countries (Africa, Americas, Asia, Europe, Caribbean, Oceania) are publishing disaster loss data through the DesInventar system.

The DesInventar methodology is based on IRDR standardized classification and definitions of natural hazards. The description of an event defines the cause and consequences. According to the methodology, the information must be spatially disaggregated in order to show the effects of disasters at the level of administrative unit of minimal resolution — at least municipality level (NUTS2) or district level (NUTS3). The Sendai Framework loss indicators[72] on loss data were implemented into the system in the end of 2017. The losses collected are concordant with the Sendai Framework indicators: human losses (disaggregated by gender and age), physical damage (houses, infrastructure elements, affected sectors), economic loss (disaggregated by economic sectors) and loss of cultural heritage. The DesInventar system is automatically reporting to the Sendai Framework Monitoring System[73] and Sustainable Development Knowledge Platform[74].

DesInventar provides conceptual tool for the construction of databases on loss, damage, or effects caused by emergencies or disasters. It is based on:

- Methodology with concrete data collection concept.
- Administration module for data entry and modification of data cards.
- Analysis module for consultation of data with selection options for search criteria, creation of thematic maps, basic statistical analysis, graphic, charts and download data.

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[72] https://www.preventionweb.net/publications/view/54970

[73] https://sendaimonitor.unisdr.org/

[74] https://sustainabledevelopment.un.org/

The basic criteria guiding DesInventar are:

- All datasets must use the same variables to measure the effects (damage) and the same homogeneous and basic classification of events (IRDR).
- The information compiled and processed must be entered in a scale of time and at a geo-referenced spatial level.
- The information comprising DesInventar datasets must be spatially disaggregated in order to show (and later analyse) the effects of disasters at local level. For country level disaster inventories it is recommended a minimum disaggregation level equivalent to Municipality, usually one or two levels below the first administrative/political division (Province/State/Department, depending on each country).
- The datasets can then be analyzed following a number of existing and emerging methodologies, starting with the Preliminary Analysis Methodology, which give users an immediate understanding of the impact of disasters in a country or region, the possibilities of comparative research and support to decision-making processes related to risk reduction actions (including Risk Assessments) and risk management as a whole.

Administration module contains predefined Data Cards with fields on loss indicators corresponding to Sendai Framework loss and damage indicators. Functionalities allow the addition or deletion of loss indicators, disaggregation criteria or sectors of accounting. The administrative module also allows the definition of different categories of users with different level of access to the data and administrative privileges.

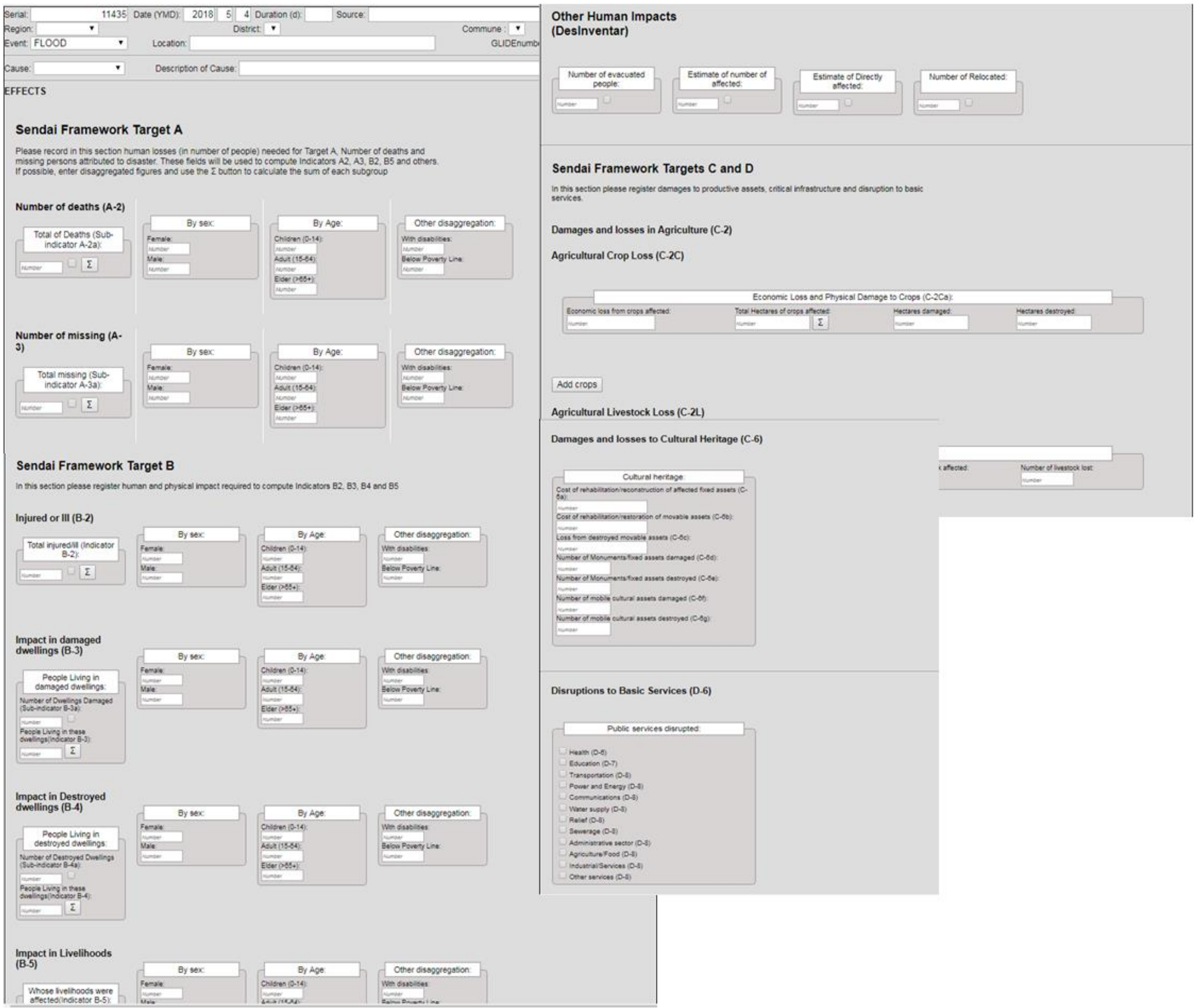

Figure 66 - DesInventar Data Entry Card with Sendai Framework disaster loss indicators.

The analysis module contains tools for data querying, visualization through creation of thematic maps, graphic and charts, tabulation, and data processing. It allows SQL language commands for data management and querying. The data can be downloaded in Excel format, CSV and KML layers.

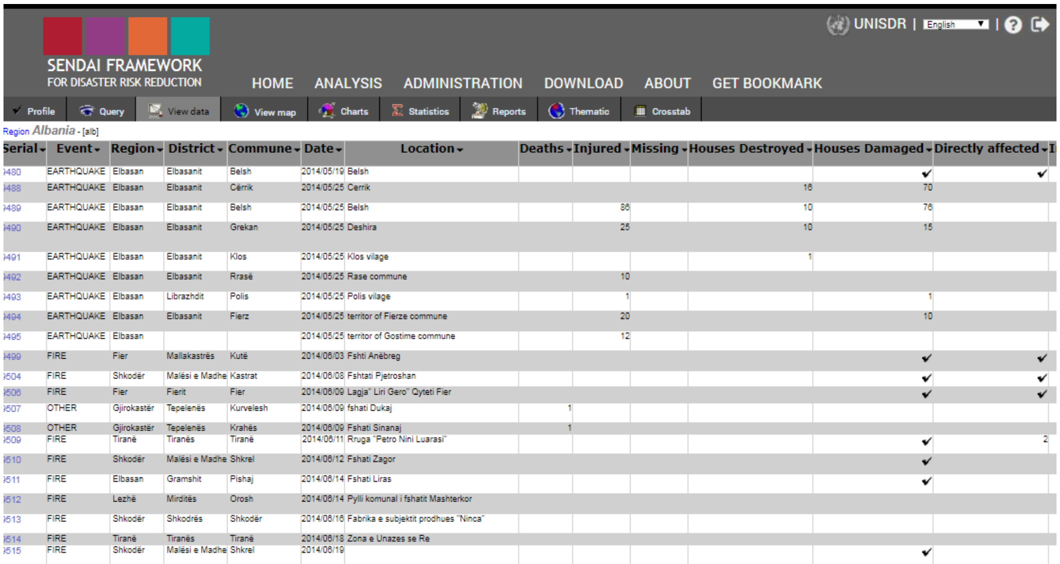

Figure 67 -DesInventar data query and visualization in table.

The analysis module with a preliminary analysis profile is provided by the DesInventar system automatically for each country. The preliminary analysis visualizes the content of a country database, and temporal and spatial trends in losses distribution.

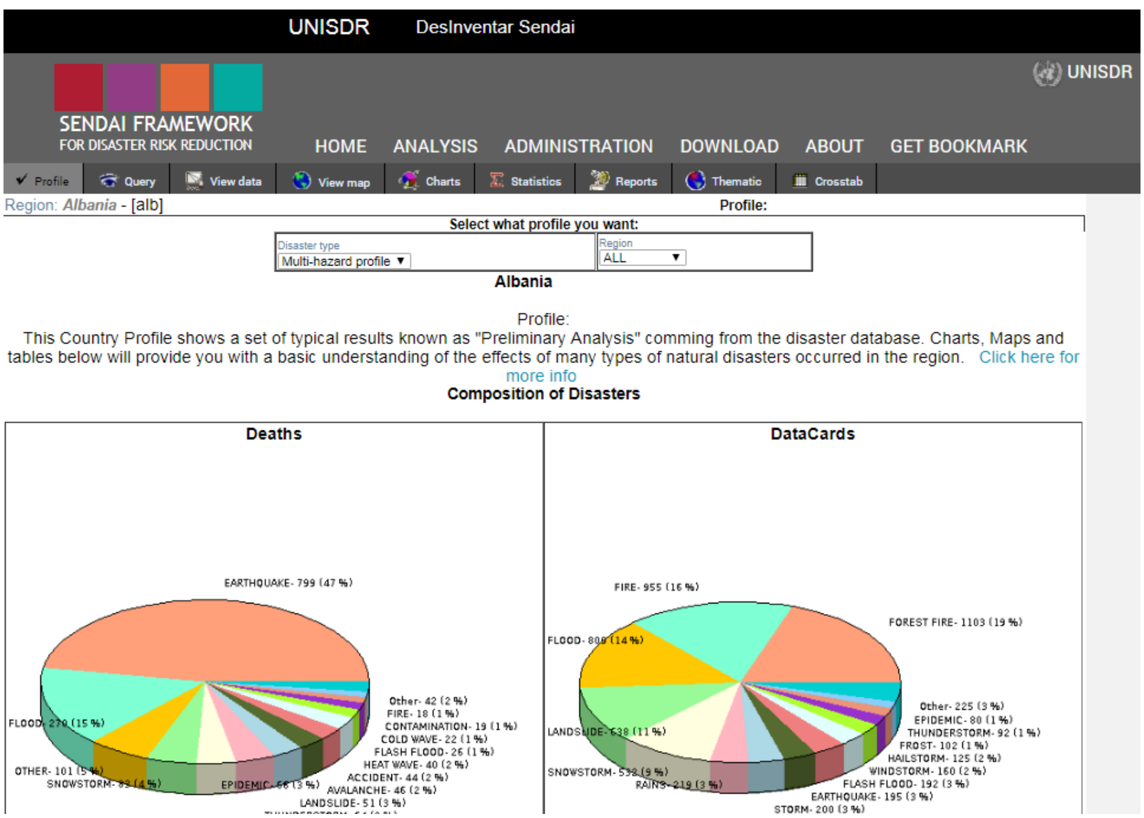

Figure 68 - DesInventar Analysis module Country Profile preliminary analysis.

The DesInventar software products support many international IT standards such as OGC, XML, GLIDE and Google API. The interface can be customized and adapted to national needs. The open access to data are provided through Analysis module. The data are downloadable in most common formats CSV, Excel, XML, and MS Access, what ensure compatibility with other databases, that use the same standards. The open source code is developed in Java/JSP.

Sendai Server 10.1 is an official UNISDR project initiative. The DesInventar Sendai software is open-source and is free of charge for commercial and non-commercial use. It is distributed under an "Apache-2" license. DesInventar Sendai is a new version of the widely used and already tested by many countries software. From 2018 it implements all the loss Indicators and data required for the Monitoring of Targets A to D of the Sendai Framework for Disaster Risk Reduction, which correspond to parallel Sustainable Development Goals (SDG's) indicators from Goals 1, 11 and 13. DesInventar supports the reporting of loss indicators to both the SDG's process and the Sendai Framework Monitoring system. Among new features of the system are: definition of Sendai Framework metadata for description of several loss indicators; and finer disaggregation of loss data.

Disasters covered:

- Natural disasters.
- Some technological disasters

13.1.2. Overall evaluation

Strengths

- DesInventar provides an open source platform for the systematic collection, documentation and analysis of data about losses caused by disasters associated to natural hazards and technological disasters. This system is currently used by almost 90 countries (the number of users has increased). It runs as a distributed tool, potentially deployed on countries.
- The tools of Analysis module for statistical analysis, tables designed by query, visualization in form of charts, graphics, thematic maps are available for data visualisation.
- The methodology proposes loss data collection in a systematic and homogeneous manner. Data must be collected following a set of standards and is time-stamped and geo-referenced and disaggregated to a relatively small geographic unit, usually a low level administrative unit.
- The system was updated in 2017 in accordance to the Sendai Framework. The indicators in DesInventar are currently in line with Sendai indicators. The outputs can be used for reporting to Sendai Monitoring System and SDG knowledge platform. System DesInventar is seamlessly integrated to Sendai Framework Monitoring system as an integrated SUB-SYSTEM.
- The open source code allows system configuration and setting according to user needs.
- The manuals, methodology description are provided on the official website. An operator should be familiar with documentation.

- Allowing from minimum data recording up to recommended data sets (including disaggregation) and metadata.
- Simple data exchange formats (Excel, DesInventar XML/JSON).

Limitations

The basic limitations are related mainly to technological functionalities. Amongst the main criticisms from end-users are:

- The current IT technology should be updated. There is an incomplete JSON functionality.
- The platform does not provide a responsive layout.
- The database should be installed on PC, or local server. The data updates are carried out online.
- The database does not support data at the asset-level.

13.2. AJDA, Slovenia

13.2.1. Description

The AJDA information system for Damage Assessment on Agricultural Products and Objects has been developed by the Administration for Civil Protection and Disaster Relief of Slovenia. It has been used since 2003 as a centralized electronic aggregation system of applications coming from owners affected by natural disasters and other disasters[75].

The system facilitates data entry at the municipal level and control data at the regional and the state level. After the compilation and checking the forms on damages, the final assessment of damage to crops and property is carried out and the procedure on fund allocation is started. The procedures for allocating funds to affected owners have been significantly accelerated, thanks to this technical tool.
The assessment procedures are applied on the national, regional and municipal level and strongly based on national legislation:

- The Decree on the Damage Evaluation Methodology (2003, 2006, 2008) specifies the eight damage assessment forms and it follows a bottom-up approach. Detailed price lists are published annually on the ACPDR website.
- The Act on Protection Against Natural and Other Disasters (2003, 2006, 2010).
- The Act on the Recovery from the Consequences of Natural Disasters (2003, 2007).

There are eight predefined input forms on damage data collection:

- Form 1 - Damage assessment on agricultural land.
- Form 2 - Damage assessment on agricultural products.
- Form 3 - Damage assessment on buildings destroyed.
- Form 4 - Assessment of partial damage on buildings.
- Form 5 - Damage assessment on civil engineering facilities.

[75] Decree on the Damage Assessment Methodology (consolidated text no. 2)

- Form 6 - Assessment of damage on animals.
- Form 7 - Assessment of damage on fixed and current assets.
- Form 8 - Assessment of damage on fixed and current assets.

The information system uses external data sources from the national records as baseline data: the register of buildings; cadastre recording Surveying and Mapping Authority of the Republic of Slovenia, the central public database on all business entities AJPES, farm register of Ministry of Agriculture, Forestry and Food (MAFF), etc.

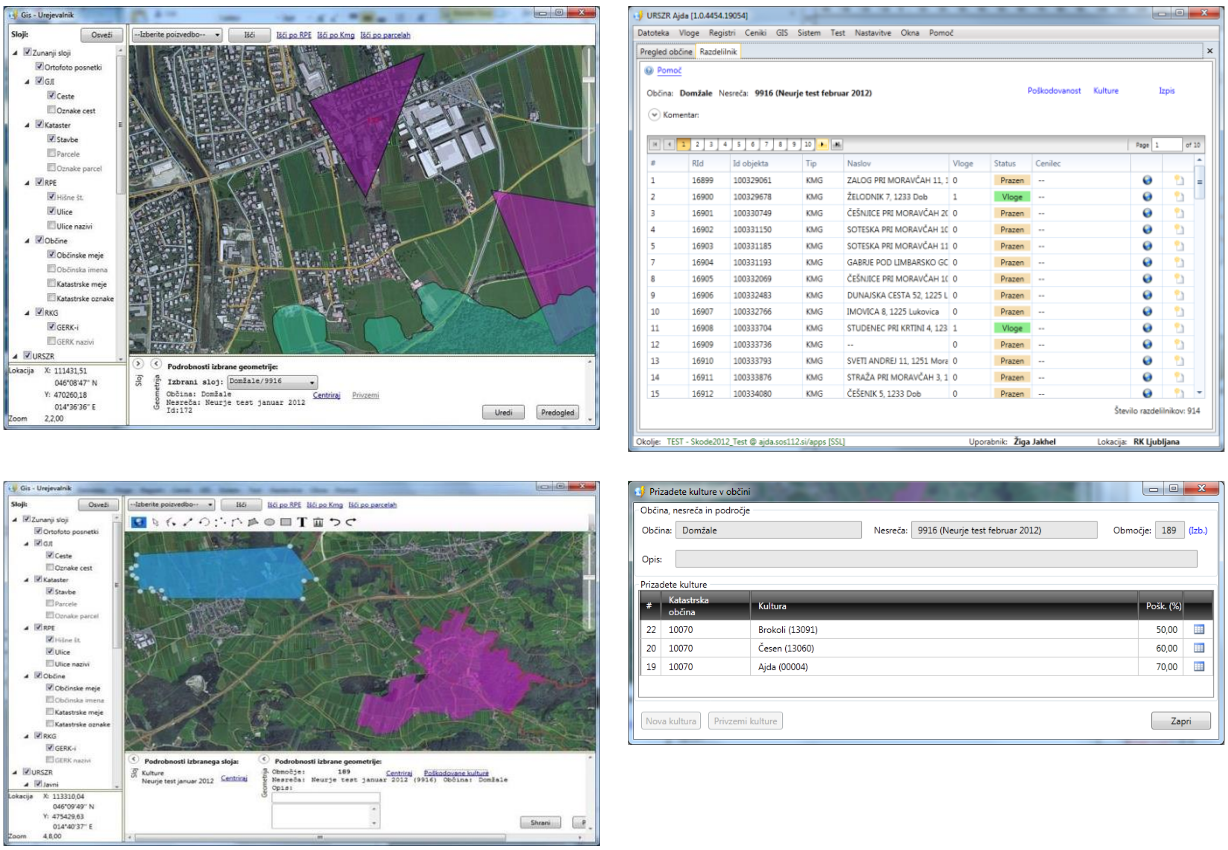

Figure 69 - AJDA Information System database (source Technical note Assessment of Damage After Natural and Other Disasters in Slovenia, Ministry of Defence Repubblica Slovenia).

The software is a "client - server" style application, which is installed on PC. The database is SQL based. The processing of individual data at the primary level is executed through input forms. The information system also includes an analytical and graphic part (a part of the geographic information system, developed especially for such needs).

After the damage assessment and decision of the Government of the Republic of Slovenia, input forms are transferred to Ministry of Agriculture, Forestry and Food in digital format for the planning of mitigation measures. In addition to damage assessment to crops and property, the collected data are used by governmental organizations for development of new agricultural policies and fund allocation; and by research institutions for of forecast modeling, risk modeling.

Disasters covered:

- Earthquakes.
- Irruption of gas.
- Floods.
- Landslide and avalanches.
- High snow and frost.
- Drought.
- Storms and hail.
- Industrial accidents.

13.2.2. Overall evaluation

Strengths

- Ad-hoc methodology is well organized and transparent. The methodology presents a clear method of estimation of monetary losses on reported damage.
- Many statistical tools are included, for example: type of damaged roof, where crops are damaged more than 60%.
- The mapping tools are available for supporting the in-field assessment.
- AJDA is a centralized web system that provides its users with a friendly, easy-to-use and unified working environment. The system facilitates the transfer of verified records on damage among various institutions, in particularly among Ministry of Agriculture, Forestry and Food (MAFF) and Ministry of the Environment and Spatial Planning (MESP).

Limitations

- The AJDA is official internal system for loss data collection of Administration for Civil Protection. The access to the database is allowed for authorized stakeholders.
- The methodology is strongly based on national legislation, insurance system and cadastre data.

13.3. FloodCat (Italy)

13.3.1. Description

FloodCat is a web-GIS platform officially used by the Italian Civil Protection Department. The system was established by Italian government under Directive of the President of the Council of Ministries, Dir.P.C.M. 24 February 2015) that fulfils the function of catalogue of floods to address the requirements of the European Floods Directive 2007/60/CE. The Civil Protection Department manages and makes available to Regions and River Basin Authorities (Floods Directive Competent Authorities) the catalogue FloodCat as the official technological platform for reporting historical and potential future floods according to the EU Floods Directive.

The Floods Directive is focused on the assessment and management of flood risks and specifically addresses the need of having a catalogue on past events. The FD describes a precise schema in which data should be recorded and reported from each EU Member State.

FloodCat[76] presents a specific architecture, in accordance to the Floods Reporting Schema, that allow for each significant flood the collection of the following data and information:

- Location (name of locality, river basin, sub-basin and/or coastal area or other areas associated with past floods); category of flood (past flood or potential future flood).
- Type of flood.
- Extent (area of land inundated, or length of river stretches or coasts).
- Probability of flood event (frequency, recurrence).
- Date of commencement and duration (days) for each flood.
- Type and degree of adverse consequences for:
    - Human health.
    - Environment.
    - Cultural heritage.
    - Economic activity.
    - Other relevant information.

FloodCat is a Disaster Loss Database designed to fulfil the Floods Directive Reporting schema. The FloodCat data model has been conceived with the element required by the Floods Directive, taking in account some details that allow recording and consulting the database elements efficiently and effectively. Among the main data collected are the geographical location of an event, description of phenomenon, loss and damage data. The collected information is used to build a plan of actions for reconstruction of public services (roads, public buildings, river bed, etc.). The following diagram shows the UML Diagram of the FloodCat Data Model.

[76] FloodCat User Manual http://www.mydewetra.org/wiki/images/f/f4/FloodCat_manuale.pdf

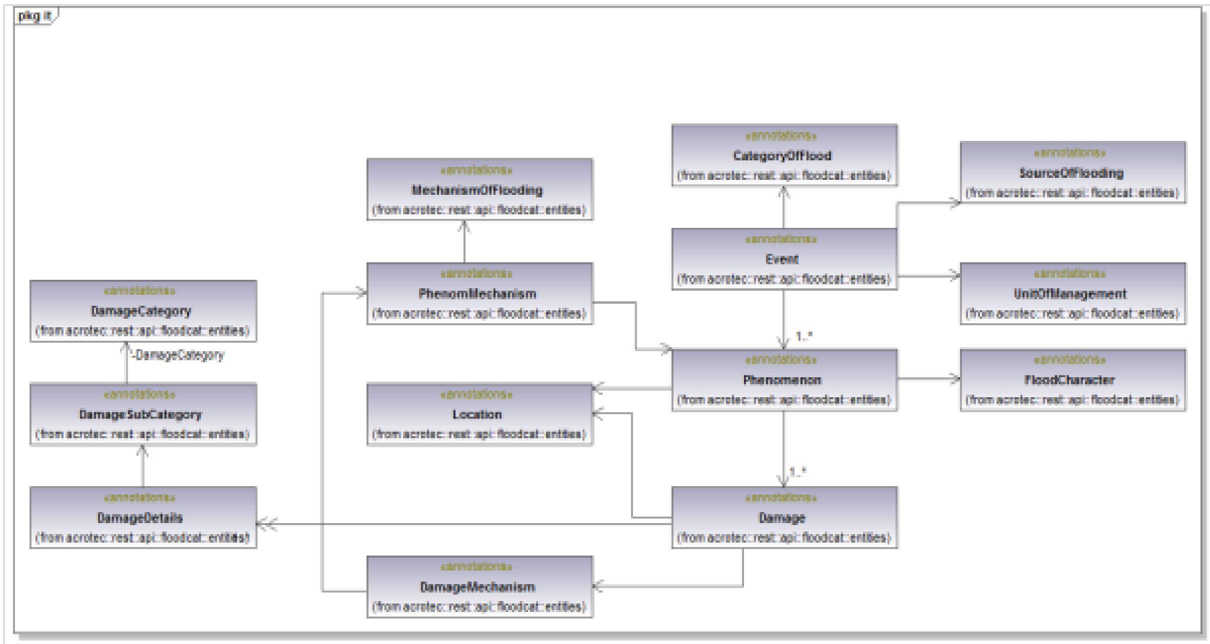

Figure 70 - FloodCat Data Model UML Class Diagram.

Following the Flood Directive Schema, the Data Model of the platform system is organized into three main levels: Event, Phenomena and Damage. The main class is the Event Class. The event is a flood occurred at a certain time in a specified area. Each event is characterized just by one type of flood origin (fluvial, pluvial, etc.) and by having impacted only one Unit of Management. This means that, if a given area was subjected to a fluvial and a marine flood, this will have to be inserted as two different events in FloodCat. Each Event Class has a list of related Phenomena. A single Phenomenon can be caused by one or more Mechanisms of Flooding, which are related with a Phenomenon class. The phenomenon has also the Characteristic of Flooding as required by the Floods Directive. Under the Phenomenon class is the Damage class. A single Damage is characterized by Damage Details. The Damage Detail is characterized by a Damage Category and a Damage SubCategory. The user interacts with the application through a web-interface (see Figure 71).

Figure 71 –Grafical user interface of FloodCat.

The main tools are divided in three categories:

- Geographical search of events.
- Data export and reporting.
- New event insertion.

Among specific functionalities of the system are the following:

- Querying the system.
- Importing of existing data (The import of existing data can be done via Excel files or Shapefiles with specific predefined fields).
- Downloading of data at different levels: event, phenomenon or damage.
- Reporting functionality allows a choice among preloaded schema (Floods Directive, JRC Minimum requirements).

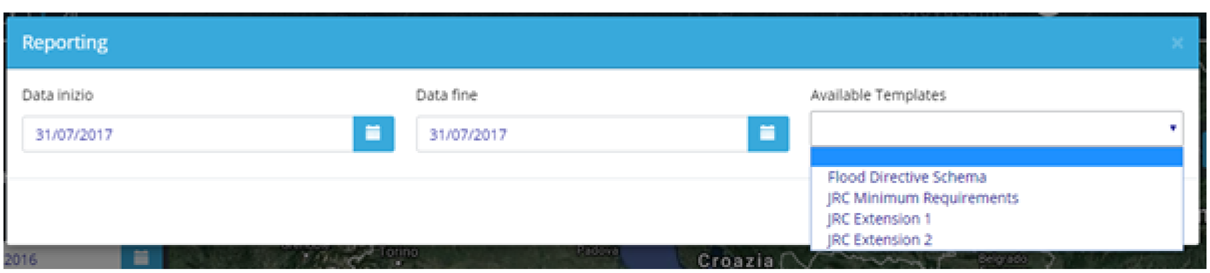

Figure 72 - FloodCat Reporting tool.

The Event Card form requires the main elements for the definition of an Event: Category (past/future, according to Flood Directive), date and time frame, Unit of Management, Source of flooding, extent, probability (expressed as frequency or recurrence). For each event associated, Phenomena are described by a specific card with characteristic of flooding (e.g. flash floods), mechanism of flooding, geographical localization of the affected area. The damage is registered in association with the related Phenomenon, with the following attributes: category and sub/category of damage, geographical localisation, date, damage class and economic damage.

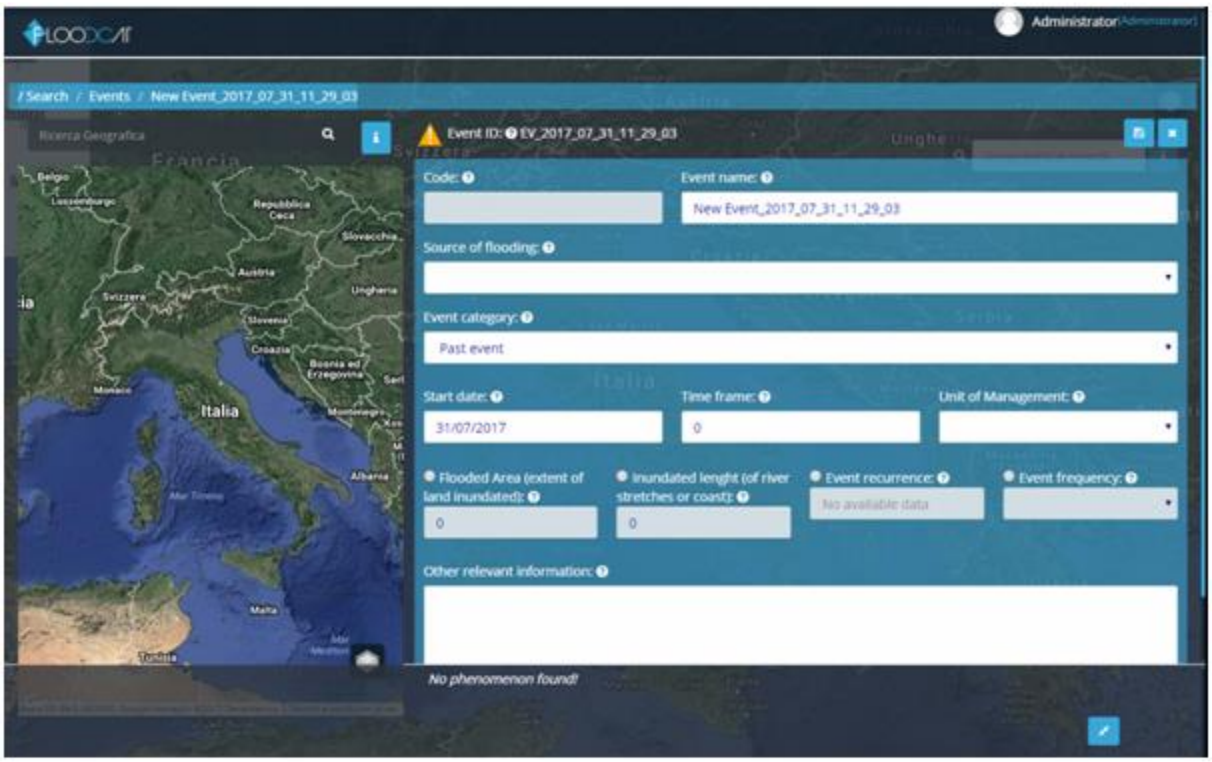

Figure 73 - FloodCat Event card.

Technological characteristics:
FloodCat is developed as a client server three-tier application following the MVVMC (Model View-View Model-Controller) pattern. The high level architecture can be represented by the schema in Figure 74.

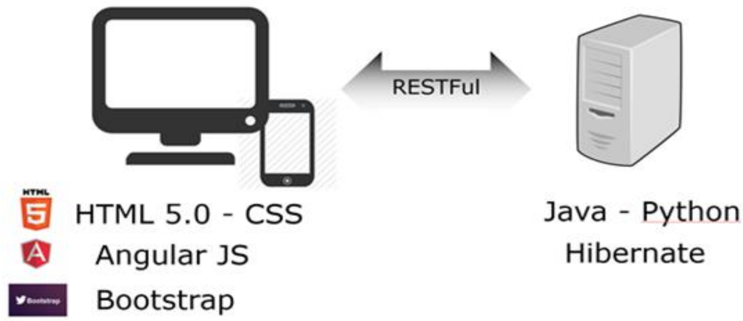

Figure 74 -FloodCat Architecture.

It is a Restful Web 2.0 application. On the server side Java is used, with Jersey as a REST library. PostgreSQL and PostGIS are used as Database Management System. On the client side the system is a pure HTML5.0 + CSS application written using the Open Source AngularJS framework. All rights on the source code are under the licence of the Italian Civil Protection Department. Access to data is restricted to authorities with the necessary credentials.

Disasters covered:

- Riverine floods.
- Urban floods.
- Landslides.

13.3.2. Overall evaluation

Strengths

- FloodCat is an Institutional system established by the Italian government under the Directive of the President of the Council of Ministers. The Italian Civil Protection Department manages the system. Each Region and Basin Authority has the responsibility for registration of data on flood events and landslides.
- Ability to create automatically files and reports on past floods for further preventive measures and structural planning. The data collection is in line with EC Floods Directive 2007/60/EC. The platform can also provide reports according to some templates indicated by JRC in matter of Disaster Loss Data Collection
- The Google map tools used by FloodCat platform have functionalities that allows users to search flood events by drawing geographic areas or to localize damages by interacting with map tools or uploading ESRI shape files.

Limitations

- FloodCat is an Open Source platform, but all source code is owned by the DPC, which grants as Open Source resources only for Civil Protection purposes.
- The accessibility to the platform is restricted to authorized users.

- The tools for statistical processing of data are not yet available in the platform. Reporting according to Sendai indicators is not yet available.
- There is need for harmonization and standardization of the different methods for collecting data among the Regional authorities at national level. Regional authorities should include in the database information on past floods in accordance with the requirements of Floods Directive, which in some cases has become an issue, due to different disaggregation of information collected previously on the river basin level, municipality or regional level.

13.4. National Disaster Observatory Information System NDOIS, Moldova

13.4.1. Description

The National Disaster Observatory Information System NDOIS was developed for loss data collection for the purposes of the General Inspectorate of Service of Civil Protection of Emergency Situations (CPESS) of the Republic of Moldova. The data on emergencies is gathered in collaboration with police service, Hydro-meteorological center, Statistical bureau and other national authorities. The direct access and management of the NDOIS database is reserved exclusively to the General Inspectorate of CPESS.

The information is collected at municipality scale, asset level. Emergency situations are assessed by Civil Protection teams under local CPESS commissions in collaboration with police, fire brigades, rescue units and other official authorities. The gathered information from paper forms are transferred into the NDOIS system. The NDOIS system generates reports in one of the predefined standard forms. There are eight standard forms in digital format of report on emergency situations of different character.

The type of the form depends on an emergency situation:

1. Report on transport accident (catastrophe).
2. Report on explosion.
3. Report on detecting the ammunitions (explosive substances).
4. Report on chemical damage (radioactive).
5. Report on technogenic breakdown.
6. Report on emergency situation of natural character.
7. Report on emergency situation of biologic-social nature.
8. Report on fire.

The criteria on assessment of an emergency situation contain more than 40 parameters officially defined in Order No.139 dated 4th September 2012 of CPESS on the approval of the Statute on the statistical recording of emergency situations (fires) and their consequences in the Republic of

Moldova; and in Government Decision No.1076 dated 16th October 2010 on the Classification of emergency situations and the order of gathering and presenting information in the field.

The NDOIS system collects information on all emergency situations according to Order No.139 of 4th September 2012: Emergency situations of man-made character, Emergency situations of natural character, Emergency situations of biological and social character. Among emergency situations of natural character registering by NDOIS are river floods, urban floods, earthquakes, landslides, wildfires, heavy rains, heavy snow, wildfires and many others.

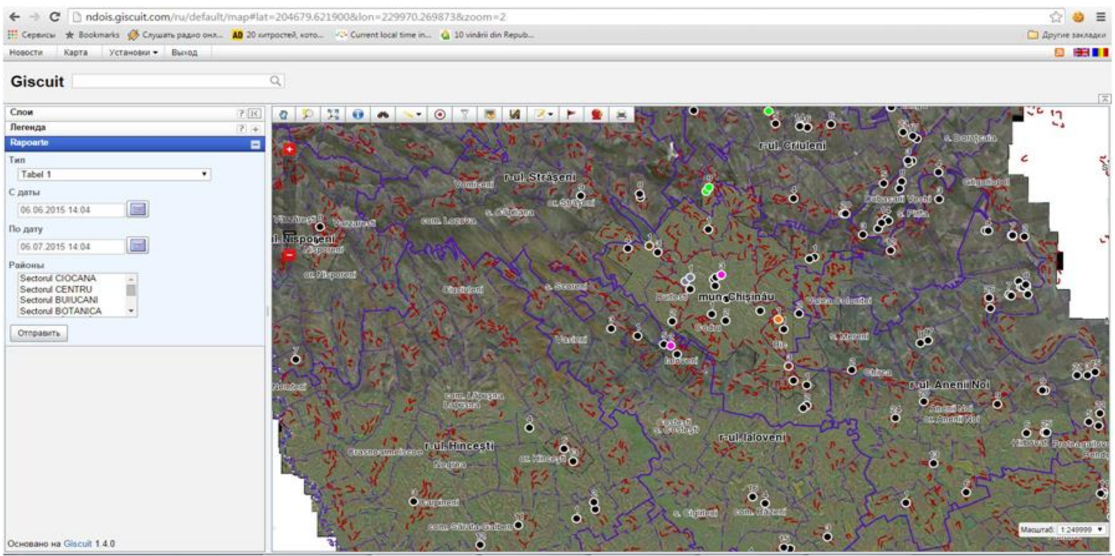

Figure 75 - The NDOIS database with emergency situations marked on the map (Source: presentation of main specialist Planning and analysis division CPESS, First lieutenant Alexandr Tatarov, , 2015).

The NDOIS system is developed on the base of the GISCUIT[77] geographic web-platform built on open source geospatial components. The GISCUIT is compliant with the OGC Open Geospatial Consortium standards through Open Layers / PHP Map Script supporting several OGC standards like WMS, WFS, WMC, KML, GML, CSW etc. Giscuit provides a scalable GIS server platform that can be deployed on a single Linux or Microsoft Windows machine, it can be distributed across multiple servers or deployed on cloud infrastructure. The web-mapping platform runs also as a mobile application. The mobile application version is not used by CPESS Moldova. GISCUIT mobile layout is browser based which allows users to work on a wide variety of platforms like iOS, Android, BlackBerry OS, Windows Phone 7, webOS, Bada and Symbian. The layout is detected automatically using the information sent by the browser. It supports as well Offline mode which enables a user to take and edit raster and vector data when internet connection is not available. In Online mode most of the operations are doing by the server. Offline mode is more resource demanding since operations rendered by the device. All the vector features are loaded into RAM (minimum required of 256MB RAM). A GPU unit is desirable to accelerate SVG feature rendering, CSS3 transitions and transformations.

[77] http://giscuit.com/documentation

Technology required:
- Ubuntu Server 8.04/10.04.
- CentOS 5/6.
- Red Hat Enterprise Linux 5/6.
- SUSE Linux Enterprise 11.
- openSUSE 11/12.
- Debian 6.

Supported Microsoft Windows operating systems: Windows Server, Windows 7, 8, XP. Minimal hardware requirements: CPU: 600Hz; RAM: 256MB.

GISQUIT components are provided on the fee basis under various software licenses[78] (or packages). The basic license is proposed for new customers., then the system can be upgraded to another license to enable additional features. All information on the GISQUIT software is well documented[79] and provided on the website. The GISCUIT script supports several Open Geospatial Consortium (OGC) standards such as WMS, WFS, WMC, KML, GML, CSW, what facilitate of data processing.

Disasters covered:
- Natural and technological disasters.

13.4.2. Overall evaluation

Strengths
- The NDOIS database is designed to collect a wide range of damage data related to: human health loss, physical damage of buildings, objects, technical equipment, loss in agriculture, infrastructure, communication sectors, disruption of vital services, direct economic loss to buildings, constructions, economic sectors, forest etc.
- The tools for basic statistical analysis are provided. The mapping tools functionalities allow to draw an affected area and put geo-referenced markers on emergencies. Google Maps API are integrated and allowing geolocation of emergencies.
- Among loss indicators there are indicators relevant to Sendai Framework (official modification of indicators in the Sendai Framework of Sendai is ongoing), plan of prevention measures and other official procedures.
- High level of skills are not required to work with the system. It provides standard forms for data gathering from place of an emergency situation and produces official reports.
- The system and application can be used offline.

Limitations
- The assessment of indirect losses and detailed economic loss evaluation is not foreseen by the system.

[78] http://giscuit.com/features
[79] http://giscuit.com/documentation

- Data is generated by print and download. It does not generate charts, graphics and thematic maps. The reports are generated in standard official format approved by the Law.
- The procedures of loss data collection are based on the national legislation.
- The access to the system is reserved exclusively to General Inspectorate of CPESS. It is strictly an internal official database under Ministry of Internal Affairs. The NDOIS system does not support access by multiple stakeholders from different institutions. It is an internal platform managed and used exclusively by CPESS.

13.5. HOWAS21, Germany

13.5.1. Description

The HOWAS21 is a flood damage database developed by German Research Center for Geosciences (GFZ) in 2007. The database is designed for damage accounting resulting from pluvial and fluvial floods in Germany. It is focused on direct tangible damage. The main purpose of the database is development and validation of the loss estimation models and support forensic analysis. HOWAS21 contains about 6,000 object-specific damage data sets on flood events in Germany from 1978 to 2011.

The GFZ manages the database compiling, reviewing and maintaining consistency of data. As administrator it assigns access rights and verifies user requests. The technology of the HOWAS21 is based on PostgreSQL object-relational database management system. User interface is provided through a website, and to use the system, no specific technical skills or expertise is required.

A community-based concept underlies the core of HOWAS21. Three user groups[80], have varying degrees to access the database:

- World: The interested public can search the database and access general information and evaluations. The user interface has an option to search in the database according to selected criteria. These include a structured query, filtered by catchment area, regions (provinces and municipalities), periods (event year), sectors, collection methods, campaign, and a combination of these criteria.
- Registered user Group I: This group includes all institutions that provided a dataset with appropriate quality to HOWAS21. There is unlimited access to the entire data collection in the database.
- Registered user Group II: Users from academia and non-commercial projects, who did not provide data, can apply for a restricted project-specific use. As feedback, this group of users reports on their project results, particularly results based on HOWAS21 data, and in case the user collects flood damage data later on, these data have to be included in HOWAS21.

[80] www.howas21.gfz-potsdam.de/

Users of Group I and II are required to agree to the terms of usage which define the scope of use, reporting requirements and prohibition of data dissemination. The users from science, insurance, authorities and engineering consultancy are registered to HOWAS21.

The minimum content data for damage cases to be reported into HOWAS21 is defined as follows: information about the economic sector of the affected object, monetary loss, inundation depth, the flood event and spatial location of the affected object at least on the level of zip codes or municipalities. HOWAS21 data are collected in an anonymous format respecting personal rights according to data privacy regulations.

In HOWAS21 the damage cases related to individual objects are classified into six damage sectors:

1. Private households particularly residential buildings and contents.
2. Commercial and industrial sector for including public municipal infrastructure (administration, social issues, education etc.) as well as agricultural buildings.
3. Agricultural and forested land.
4. Public thoroughfare, including roads and transport infrastructure.
5. Watercourses including flood defense structures.
6. Urban open spaces.

All attributes of the damage cases are grouped into three main tables per sector, as described in Table 12.

Table 12 – The HOWAS21 main damage information tables for private households.

Flood characteristics at the location of the affected object (table is used for all sectors)	**Object characteristics and damage information (specific table per sector)**	**Damage mitigation (table for private households and commercial/industrial sector only)**
Start, end, duration of inundation at object	Location of the building	Knowledge about hazard maps
Name of river causing the inundation	Building type and characteristic (no. of stories, age, quality, net dwelling area, intrusion paths and intake sill, , building material, use of the cellar etc.)	Precautionary measures
Max water depth	Value of the building, building loss, loss ratio	Early warning, lead time
Max flow velocity	Contents value, contents loss, loss ratio	Emergency measures
Contamination, flotsam		Effectiveness of measures

Local return period		
Hazard peculiarities, description of hazard at object		

The HOWAS21 methodology on data collection is based on standard catalogue of items. The definition of catalogue of items was implemented via a multi-step online expert survey using the Delphi-approach. To cover the requirements of different professional fields, 55 experts from governmental agencies, re-insurance companies, science and engineering consultancy were included in the survey panel.

For floods occurred in 2002, 2005, 2006, 2010, 2011 and 2013 HOWAS21 contains a substantial amount of damage data from computer-aided telephone interviews with private households and companies who suffered flood damage. For loss data collection via computer-aided telephone interviews shortly after a flood event, lists of all affected streets are compiled possibly with the help of flood masks derived from radar satellite data, or publicly available information like official reports and press releases. The social institutes and marketing research are usually engaged in conducting interviews with affected private household or company.

In HOWAS21 database there are few loss datasets on affected infrastructures and water management sectors such as the road infrastructure in the City of Dresden affected during the flood in 2002. The data were collected via on-site expert inspections. Physical characteristics including length, width, sidewalks, etc., the road classifications and some other features documented. The flood damage was recorded in two ways: (1) the absolute loss was derived from archives of the city administration, that contain reconstruction costs; (2) experts from the city administration assessed the physical damage immediately after the flood by a six-point scale and the condition of the road before the flood on a five point scale (Kreibich et al. 2009).

The HOWAS21 system consists of two major software components: the database and the web application. The data are stored in different tables with a well-structured relationship. The HOWAS21 web application provides a user-friendly data access interface on the Internet. Via the web application the data can be visualized, analyzed and downloaded using standard web browser functionalities.

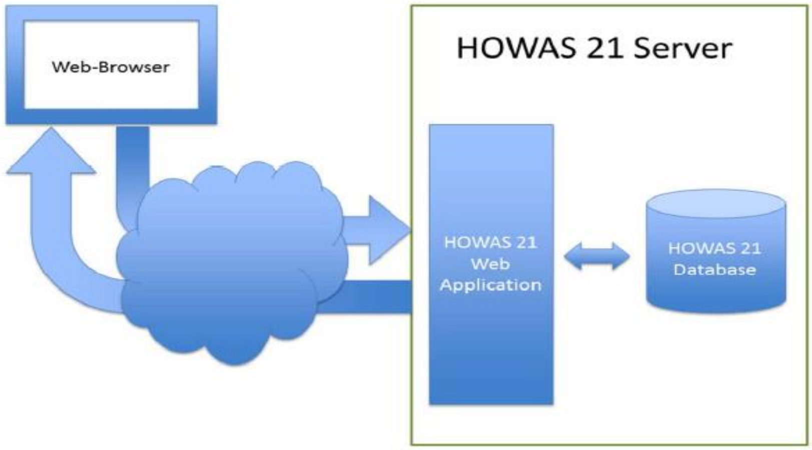

Figure 76 - Structure of HOWAS21 - database and web application.

The HOWAS21 manual outlines the theoretical framework for flood damage assessment and suggests criteria for damage documentation. The core attributes for each sector are supplemented by evaluation methodologies (e.g. measurement units, check lists). The suggestions for metadata, general event documentation and aggregated damage reports are presented in the manual (H.Kreinich, A.Thieken, et al. 2017[81]).

The HOWAS21 database was implemented on the base of the object-relational database management software PostgreSQL, which runs as a database service at the German Research Center for Geosciences, GFZ. The database can be queried using criteria such as catchment areas, damage sectors or data collection campaigns. Users must be register to use HOWAS21 on the web portal. After registration a “contract of using data” is provided to the user. Login credentials are assigned to the new user after this registration procedure.

Disasters covered:

- Pluvial and fluvial floods.

13.5.2. Overall evaluation

Strengths

- Various institutions can integrate flood loss data into HOWAS 21. All organisations which integrate data get access to all datasets. Many data come from data collection organised jointly by GFZ & University of Potsdam & Deutsche Rückversicherung. GFZ is monitoring users access.
- It is an online database. The system can be accessed via web by login.
- The tool provides different user level access to meet the different actors’ needs.

[81] Flood Damage Survey and Assessment: New Insights from Research and Practice, AGU book, 2017

Limitations

- Various methodologies are used, because the phone interviews are conducted by various data collection campaigns. That can lead to uneven data.
- The HOWAS21 platform is not intended for distribution of technology used. All entities that contribute the data to HOWAS 21 database have unlimited access to all contained data, other organizations can get project specific access for governmental funded projects.

13.6. CDTE Catalog of Earthquake Damage in Spain/ CNIH National Catalogue of Historical Floods in Spain

13.6.1. Description

Spain has several databases of damage and loss recorded after natural disasters, including:

- National Catalogue of Historical Floods in Spain (CNIH).
- Catalog of Earthquake Damage in Spain (CDTE).
- National database of Compensations in Spain (INDEMNIZA).

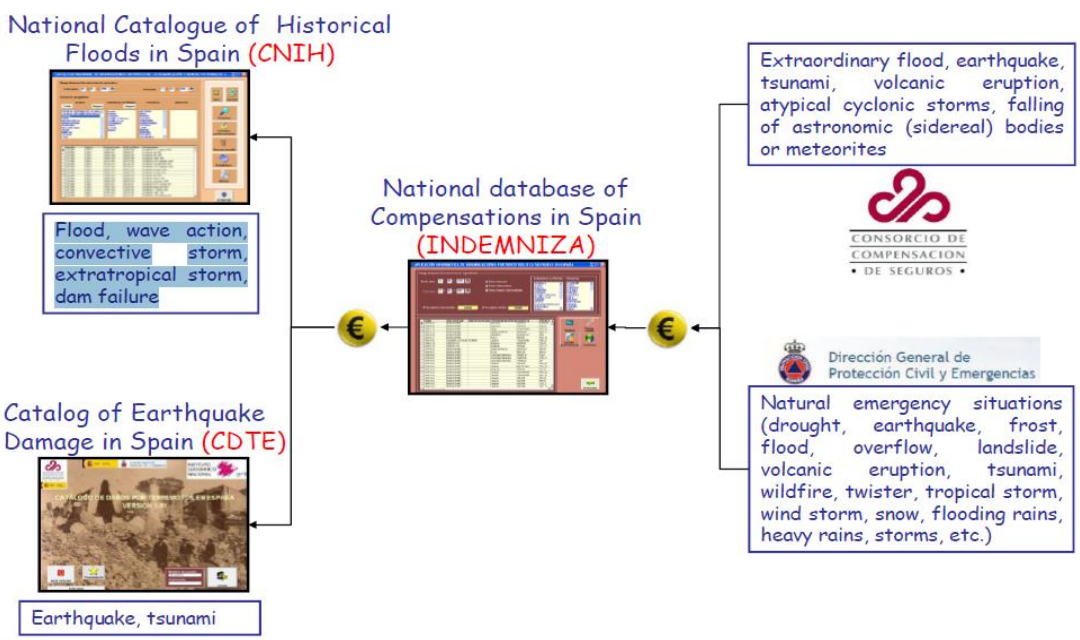

Figure 77 - General scheme of official databases on loss accounting in Spain (Source: Presentation of Cid Javier (CiVilis); Fernández, Javier (Centro Nacional de Información Geográfica), 2016, ISPRA).

CNIH is a national flood database for storage information on floods that have occurred throughout the national territory and that have had an impact on the population and its physical assets. The CNIH Data Card includes fields on loss in human health, economic loss for different economic and industrial sectors, and damage to infrastructure.

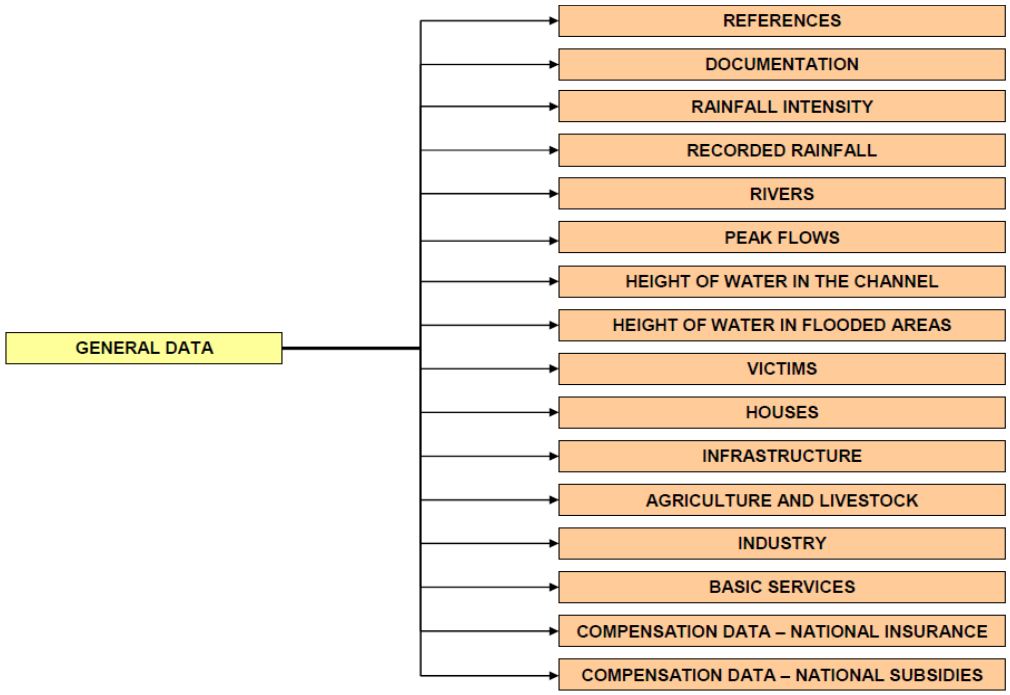

Figure 78 - CNIH data structure (Source: Presentation of Cid Javier (CiVilis); Fernández, Javier (Centro Nacional de Información Geográfica), 2016, ISPRA).

The methodology of National Catalog of Historic Floods (CNIH) was used for the design of the CDTE, adapting the methodology to seismic risk and including aspects related to the recording of data on damages and losses in case of an earthquake catastrophe. The Guide published by the expert working group on disaster loss and damage in the EU led by the JRC also was used.

The complete methodology is available for characterization of all the elements in the earthquake damage database. The main functionalities of the CDTE catalogue are:

- Registration of damages and economic losses caused by earthquakes in Spain.
- Editing data.
- Querying data.
- Data analysis by statistics tools.
- Visualisation of maps using QGIS technologies.

The CDTE is a project that has been in development since March 2015, as a result of a collaboration agreement signed between the Insurance Compensation Consortium, the General Directorate of Civil Protection and Emergencies, the General Directorate of the National Geographic Institute and the National Center for Geographic Information. Its purpose is to develop an earthquake damage database that collects the information that is dispersed in various sources, applying the guide prepared by the working group on disaster losses and damages in the European Union.

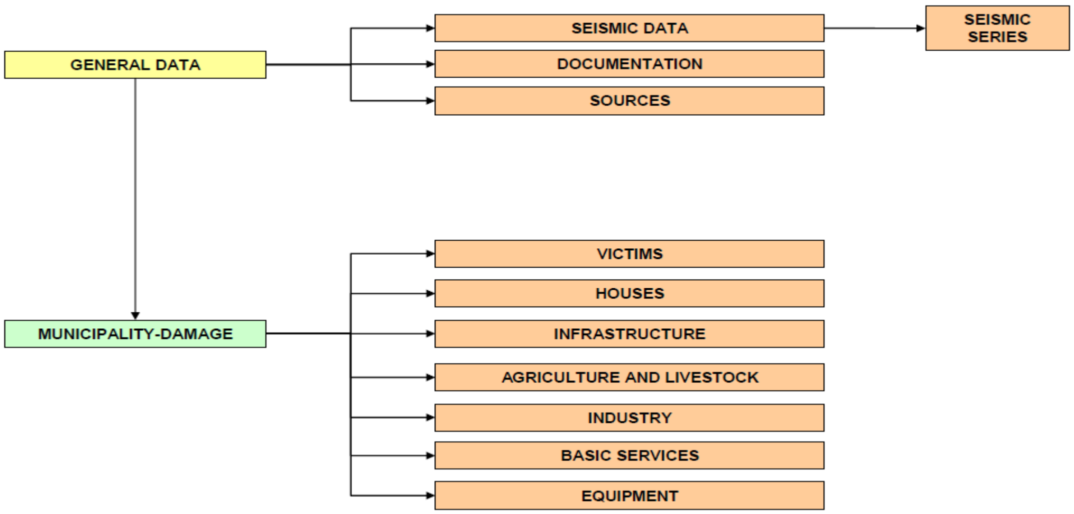

Figure 79 - CDTE data structure (Source: Presentation of Cid Javier (CiVilis); Fernández, Javier (Centro Nacional de Información Geográfica), 2016, ISPRA).

Earthquakes with the epicenter out of Spain are registered in CDTE, but the damage data is collected only in relation to Spain. The baseline data includes episode event number, date, IGN number of the event, damage to human health, housing, hydraulic infrastructure, transport infrastructure, agriculture, industry, basic services and equipment.

The studies on historical flood of the Technical Commission for Flood Emergency (CTEI) ended between 1983 and 1985. These studies were the basis for the General Directorate of Civil Protection for the preparation of the National Catalog of Historic Floods (CNIH). The CNIH catalogue aims to systematize and homogenize the collection of data on historical floods at the national level, as well as facilitate and ensure their updating in the event of new flood episodes. The web application is available on http://www.proteccioncivil.es/cnih for public access, where a selected portion of the records is available for public use. The data available on the web platform is from 1908 till 2007. The data card of an event reports the date, location, affected municipios, loss in human health, economic loss for different economic and industrial sectors, and damage to infrastructure.

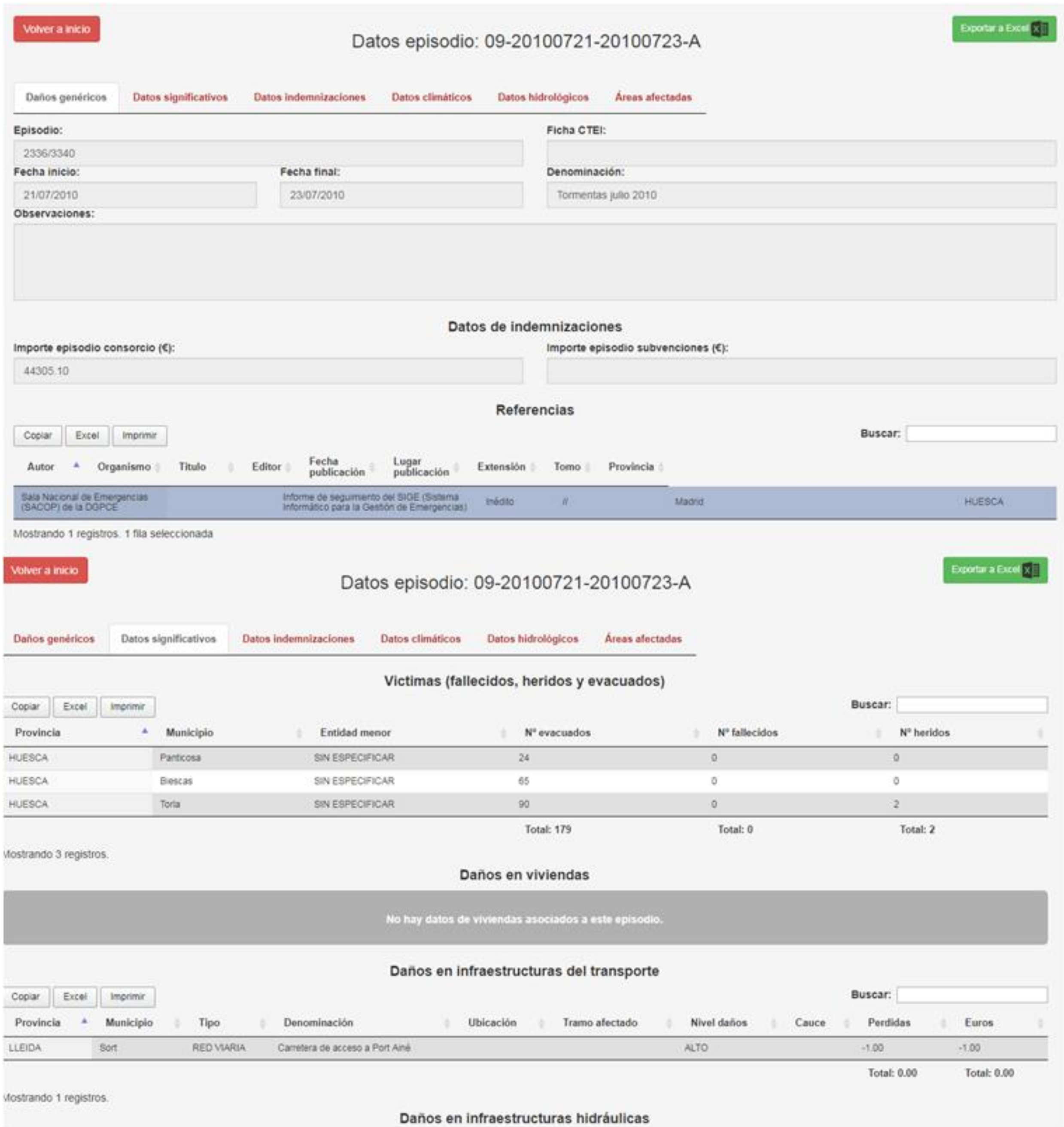

Figure 80 - CNIH database data cards (Source CNIH webportal http://www.proteccioncivil.es/cnih).

The various data sources are used for CDTE catalogue population:

- Seismic Catalog of Iberia o Historical seismicity of the Granada Kingdom.
- Seismic Database from the IGN (localization, intensity, magnitude, macro-seismic information, acceleration, seismic moment tensor etc.).
- IDNDEMNIZA catalogue.
- Reports from Emergency Management System (SIGE) of the DGPCE (Directorate-General for Civil Protection and Emergency).
- Reports from Civil Protection Sub-delegations and delegations of the Government.

- Official Publications from the Congress, the Senate and the parliaments of the Autonomous Communities.
- Official Reports from the State (BOE) and the Autonomous Communities.
- Specific studies, doctoral theses, scientific articles and other.

INDEMNIZA is correlated with CNIH database by temporal information, geographic location, floods and storms.

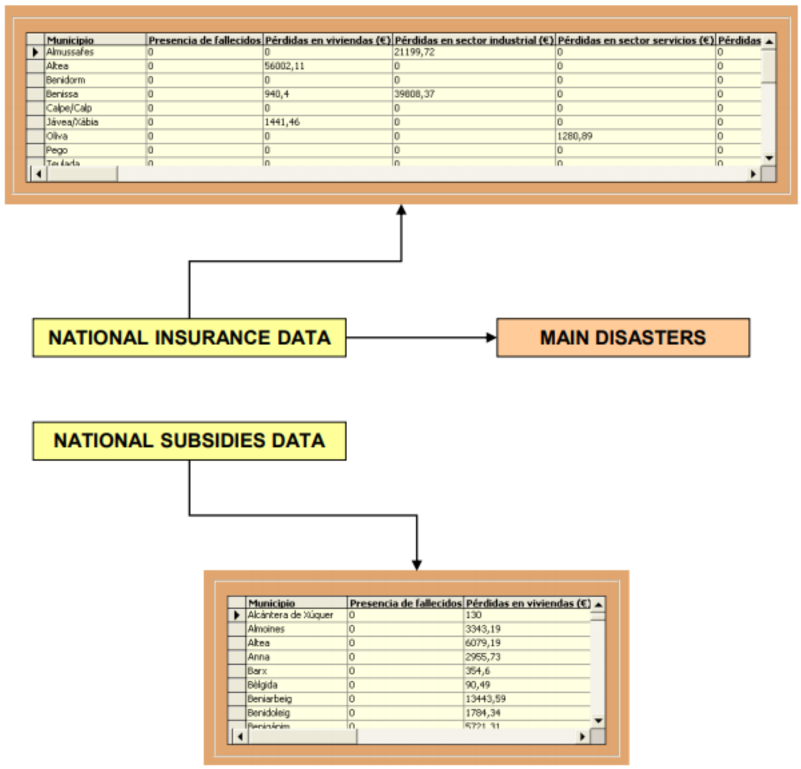

Figure 81 - Structure of INDEMNIZA database.

The National Database of Compensations in Spain INDEMNIZA (Access based) aggregates information on economic losses for multiple sectors:

- Health facilities.
- Education centers.
- Government buildings.
- Commerce.
- Tourism.
- Emergency Services.
- Environment degraded.
- Cultural heritage.
- Vehicles.

Technology used:

The technology used for CDTE and CNIH databases design are Access, MS SQL Server, and QGIS tools.

The application client interface is developed on Visual Basic and Access Database engine. The data are loaded from SQL Server and published through QGIS client desktop. QGIS system provides visualization of information and layers from SQL server database.

Disasters covered:

- Floods.
- Convective and extratropical storms.
- Dam failure.
- Earthquakes.
- Tsunami.

13.6.2. Overall evaluation

Strengths

- The main purpose of CNIH and CDTE databases is collection, sorting, recording and querying data on natural disaster events related to floods and earthquakes. The CNIH and CDTE recorded direct losses that can be used further by different national authorities through an official request for different purposes.
- The official methodology is well organized and clear. Direct losses on human, housing, industry, agriculture and infrastructure in the databases are registered. The output is generated on the basis of predefined for registration damages and losses.
- CNIH and CDTE web-platforms provide public access to common data stored in databases. Web-platforms support visualization of information of episodes at a defined geographical level in a given period of time referring to a significant level of damage to the population; and help generate thematic reports and maps automatically from the selected study level.
- The manual on use of the CNIH web-application system is available for general public.

Limitations

- The CDTE catalogue aggregates information from multiple sources such as official and scientific. The specific procedures on data quality are necessary. The different data sources provide multilateral view on the earthquake event and enrich event episodes with details, but should be controlled on data content and quality.
- The access to CNIH and CDTE databases is limited for the public. Web-portals provide general information on registered events.

13.7. Summary

Table 13 provides an overview of the main features from the evaluation of the existing tools for disaster damage and loss data collection.

Table 13 – Summary of the tools reviewed for in aggregation and reporting of disaster damage and loss data.

Attributes	DesInventar	AJDA, Slovenia	NDOIS, Moldova GISQUIT based	HOWAS21, Germany	FloodCat, Italy	CDTE/CNIH, Spain
Status	Operational Disaster Information Operational System.	AJDA is an official centralized web system developed and operated by Administration for Civil Protection.	Official operational platform developed and operated by Civil Protection and Emergency Situations Service (CPESS).	Operational flood damage database managed by GFZ University of Potsdam.	Official operational platform operated by Civil Protection Department.	Official operational databases managed by General Directorate of Civil Protection.
Users	DesInventar is used by 89 countries worldwide. Usually operated by official authorities on Disaster Risk Management, decision makers authorities.	Administration for Civil Protection, various governmental institutions, in particularly among Ministry of Agriculture, Forestry and Food (MAFF) and Ministry of the Environment and Spatial Planning (MESP).	NDOIS is an official web system (designed on the base of GISQUIT web-mapping platform).	Community based use concept is implemented. The data providers to the database have access to the all data collections.	Exclusively Civil Protection Department, regional functional centers, River Basin Authorities.	General Directorate of Civil Protection.
Methodology	Well defined methodology on data collection based on Sendai loss indicators and Sendai Framework Monitoring System.	The assessment procedures are in line with national legislation and cadastre. There are eight predefined input forms on damage data collection.	The methodology (based on Order No.139 of 4th September 2012 of CPESS) defines detailed instructions for filling out standard forms on disaster events.	The HOWAS21 methodology on data collection is based on a standard catalogue of affected items.	Methodology is based on European Floods Directive 2007/60/CE.	CDTE/CNIH methodology is based on recording of data on damages and losses in case of a catastrophe. In the databases are registered direct losses on human, housing, industry, agriculture and infrastructure.

Natural hazard	Multi-hazard Sendai, including technological disasters.	Multi-hazard, including technological disasters.	Multi-hazard, including technological disasters.	Floods.	Floods, landslides.	Floods, Earthquakes
Interoperability with standards	Sendai loss indicators; Sendai Framework Monitoring System and Sustainable Development Goals Knowledge platform compatible.	National standards on loss data collection defined by legislation.	OGC standards like WMS, WFS, WMC, KML, GML, CSW etc. National legislation.	No standards are implemented.	European Floods Directive 2007/60/CE, INSPIRE specification metadata.	JRC standards on loss data collection are envisaged.
Skills for use the IT solution	Skills level – Medium. The manuals, methodology description are provided on the official website. An operator should be familiar with the documentation.	Skills level – Medium. The database is populated by trained employees, who are experts in procedures.	Skills level – Low. Used by qualified operators.	Skills level- Low. Database is designed with user-friendly web interface.	Skills level – Low. The database is populated by trained employees, which are experts in procedures.	Are not indicated.
Availability of open source software	DesInventar is an open source software.	AJDA is an official internal database. No open source code, or open access is provided.	GISQUIT is open source code software can be installed on desktop or mobile device.	HOWAS21 is an internal database. The registration and official request for data use and upload is required. User access through web-interface.	FloodCat is an open source code platform.	CNIH/ CDTE are official internal databases. User access through web-interface.
IT infrastructure	DesInventar database is developed on Java/JSP technology.	The database is SQL based "client - server" application.	The software is a scalable GIS server platform. It can be deployed on a single Linux or MS Windows machine, or distributed across multiple servers, or deployed on cloud infrastructure. It runs also as a mobile application (don’t used by CPESS).	Object-relational database management software based on PostgreSQL DBMS.	Restful Web 2.0 application. Server side: Java is used, with Jersey as a REST library. PostgreSQL and PostGIS based DB. Client side: pure HTML5.0 + CSS application written using the Open Source AngularJS framework.	CNIH database is designed on the base of MS Access and SQL Server. The technology used for CDTE design are SQL Server, QGIS tools.
Summary of	DesInventar platform	AJDA is an official	The NDOIS database is	HOWAS21 is an object-	The platform	The main purpose of CNIH

strengths and limitations	provides tools for systematic collection, documentation and analysis of data about losses caused by disasters associated to natural hazards and technological disasters. Unique database for official reporting losses in line with Sendai Framework for DRR.	centralized web system which facilitates the transfer of verified records on damage among various authorities and simplifies the procedures on treatment of funding applications coming from owners affected by natural disasters and other disaster.	designed to collect a wide range of damage data related to: human health loss, physical damage of buildings, objects, technical equipment, loss in agriculture, infrastructure, etc. It provides standard forms for data gathering from place of an emergency situation and produces official reports.	specific (at building level) flood damage data database. He data is used for following loss estimation modelling and support forensic analysis.	automatically creates files and reports on past floods for further preventive measures and structural planning in line with official legislation requirements.	and CDTE databases is: collection, sorting, recording and querying data on natural disaster events. The CNIH and CDTE recorded direct losses that can be used further by different stakeholders for different purposes.

14. Appendix D: Evaluation of the case studies

14.1. 2010 - 2011 Queensland floods, Australia

14.1.1. Description of the impact

During the wet season of 2010/2011, Eastern Australia and especially the states of Queensland and Victoria suffered from devastating flooding. For the state of Queensland, the year of 2010 was the wettest year since 1974. In the period between November 2010 and April 2011, Queensland was hit by an extensive series of heavy rainfall caused by storm cells including Cyclone Tasha, Cyclone Anthony, followed by the category 5 tropical Cyclone Yasi, and followed by monsoonal flooding. The total rainfall in the most affected regions of Queensland was in the range of 400-600 mm. The cities of Brisbane (capital) and Ipswich were the most affected, where approximately 2/3 of all impacted properties and buildings were located in these two areas. Very high levels of inundation in Queensland were also experienced in the areas of Rockhampton and Lockyer Valley, while the latter suffered from severe flash flooding. The total flooded area was equivalent to the total area of France and Germany combined.

The consequences of these tremendous events were devastating. All the local government councils in Queensland declared the state of emergency, where the 3/4 of the state area were declared as disaster zones. Overall, around 90 towns were affected and more than 70 towns were evacuated, over 200,000 people were affected, and 35 people lost their lives. The floods inflicted significant damages and losses to residences, private properties, businesses, public infrastructure and services. The events washed away roads and railways, destroyed crops, and brought Queensland's 20 billion USD coal export industry to a near halt. The direct damages were estimated at US$2.38 billion, and the indirect losses exceeded the 10 billion USD. It was one of Australia's largest and most expensive natural disasters and one of the major international disasters of the decade. The impact of the event is summarized below:

- Over 30,000 residences and 6,000 businesses were affected.
- Around 12,0000 properties were fully flooded and about 15,000 partially flooded.
- Approximately 4,500 governmental and public buildings were affected.
- Power supply disruptions to over 450,000 residences and businesses.
- Damages to more than 9,100 km of state road network and approximately 4,800 km of the rail network. In total, 300 major roads and highways, and 89 bridges were damaged.
- Damages or disruptions to 54 coal mines, 11 ports, 411 schools and 139 national parks.
- Estimated losses of 875 million USD to primary industries, in the agriculture sector, particularly.
- 97,000 insurance claims for damaged private assets, of which 50-60% were for private residential properties. The total insured losses exceeded US$2.5 billion.

- The estimated reduction in Australia's GDP was about 30 billion AUD (2.25%).
- The Australian and Queensland Governments committed approximately 7.0 billion USD for the reconstruction and recovery process
- According to the World Bank, the total damages and losses exceeded 15 billion USD.

14.1.2. Damage data collection procedure and primary use

On February 21 of 2011, the Queensland Government assented to the Queensland Reconstruction Authority Act 2011 and established the QRA. The main purpose was to ensure the rapid and efficient recovery of Queensland and its communities from the impacts of the 2010-2011 disasters, by assigning QRA the coordination and administration of the reconstruction and recovery of the impacted areas. The Queensland Reconstruction Board (QRB) was set to manage the operations of the authority, and oversee the reconstruction of public infrastructure and private properties, including flood mitigation measures.

In the immediate aftermath of the events, the Department of Natural Resources and Mines (DNRM) coordinated the capture of high resolution aerial photography and satellite images over the flooded areas in collaboration with the Emergency Management Queensland (EMQ), QRA and local authorities. DNRM supplied spatial data about the extent and range of the evolving disasters, where aerial photography was acquired for 187 towns and suburbs in Queensland. The compiled information was fundamental for the emergency response operations, but also to assist the planning of the damage assessment phase.

After the satellite imagery and aerial photography became available, the Department of Environment and Resource Management (DERM) attempted to produce flood extent maps and floodlines for the worst affected areas, to serve as a decision support tool for the allocation of resources and financial assistance.

As mentioned in Section 2, the DARMsys™ system was developed by QRA, in collaboration with the Department of Housing and Public Works and Queensland Building Services Authority (QBSA). This system can be used to carry out rapid damage assessments and monitor the reconstruction process of Queensland. The system was introduced as a pilot in May 2011, three months after Cyclone Yasi struck Queensland, when the first field surveys and damage assessments were carried out in conjunction with Queensland Fire and Emergency Services (QFES) and QBSA. The former provided trained staff with experience in damage and loss assessment at the asset-level, while the latter provided valuable expertise in assessing the level of damage and required repairs.

Recognising the high potential of this system, QRA decided to acquire additional hardware and improved the procedures for data collection. This additional equipment (DARMsys™ hand-held devices) and its distribution across the affected areas of the state increased substantially the rapid damage assessment capabilities. Subsequently, in June and July 2011 the new developed system was implemented, and QRA cooperating with QBSA and QFES assessed around 11,500 properties in the

Brisbane and Ipswich areas covering all non-industrial properties within the defined floodline. For this field mission, 26 DARMsys™ assessment teams were deployed and carried out daily asset-by-asset damage assessments, with daily verification of the collected data.

Throughout the damage assessment phase, the collected data (including photographs) were sent to the QRA's GIS database, which allowed developing a map with the spatial distribution of the damage. This map enabled the identification of the areas in greatest need of assistance, and initiation of the reconstruction process. The information provided by DARMSys™ was integrated with information from other sources such as census data from the Australian Bureau of Statistics, and land use information from the local and state governments. This provided detailed damage information, which enhanced significantly the reconstruction activities by key recovery agencies. Additionally, the Queensland Premier's Disaster Relief Appeal (PDRA) provided financial and material assistance to numerous residents by combining the DARMSys™ data with specific financial, insurance, and social information from the individual PDRA applications.

During the reconstruction phase in the Brisbane and Ipswich areas, QRA along with the Building Services Authority conducted audits in July 2011, October 2011, February 2012 and May 2012 to monitor the reconstruction progress, with each assessment targeting properties identified as under-repairing in the previous surveys (see Figure 82). Reconstruction monitoring assessments were also carried out for the areas in the north Queensland affected by the Tropical Cyclone Yasi in June 2011, September 2011, November 2011 and March 2012, and June 2012 (see Figure 83). In other less impacted areas, such as Emerald and Roma, reconstruction audits were conducted in September, August and November 2011.

By undertaking periodic damage assessments every three months, the QRA managed to monitor the progress of reconstruction of the residential and business sectors. Because the state was impacted by further disasters in the summer of 2011, the reconstruction activities were continued for the affected areas. Overall, since the initiation of the DARMSys™ procedure in May 2011 and for 18 months, approximately 35,000 assessments at the asset-level were carried out.

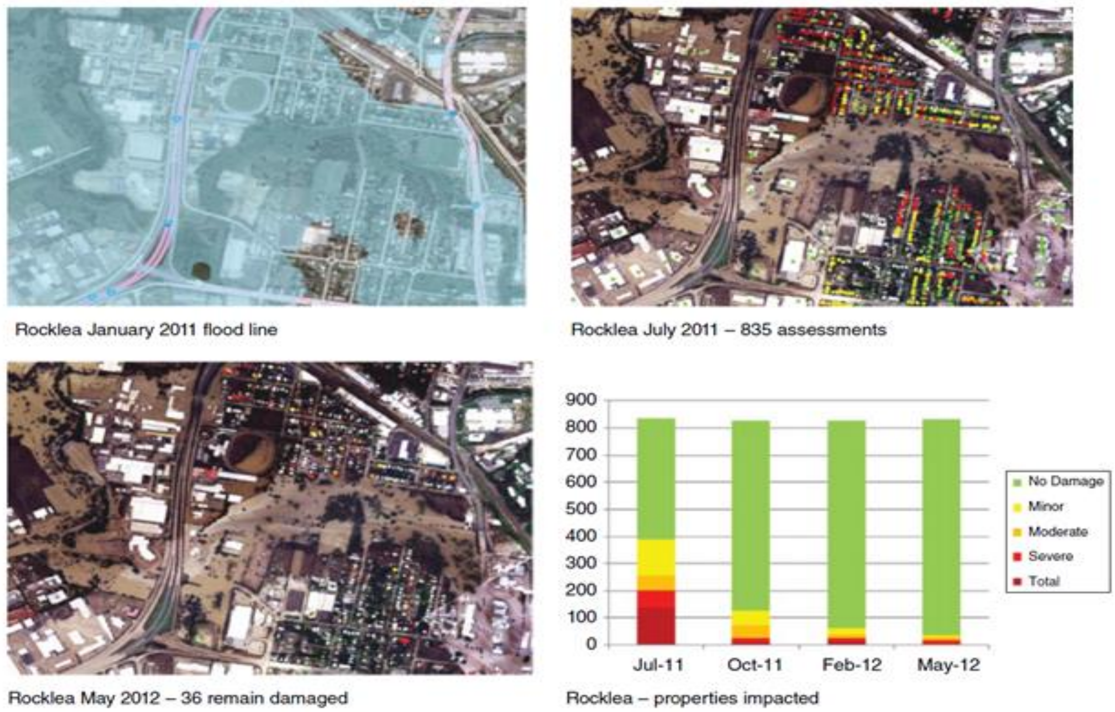

Figure 82 - Data collected in different times during the damage collection and reconstruction phases of Rocklea in Brisbane[82].

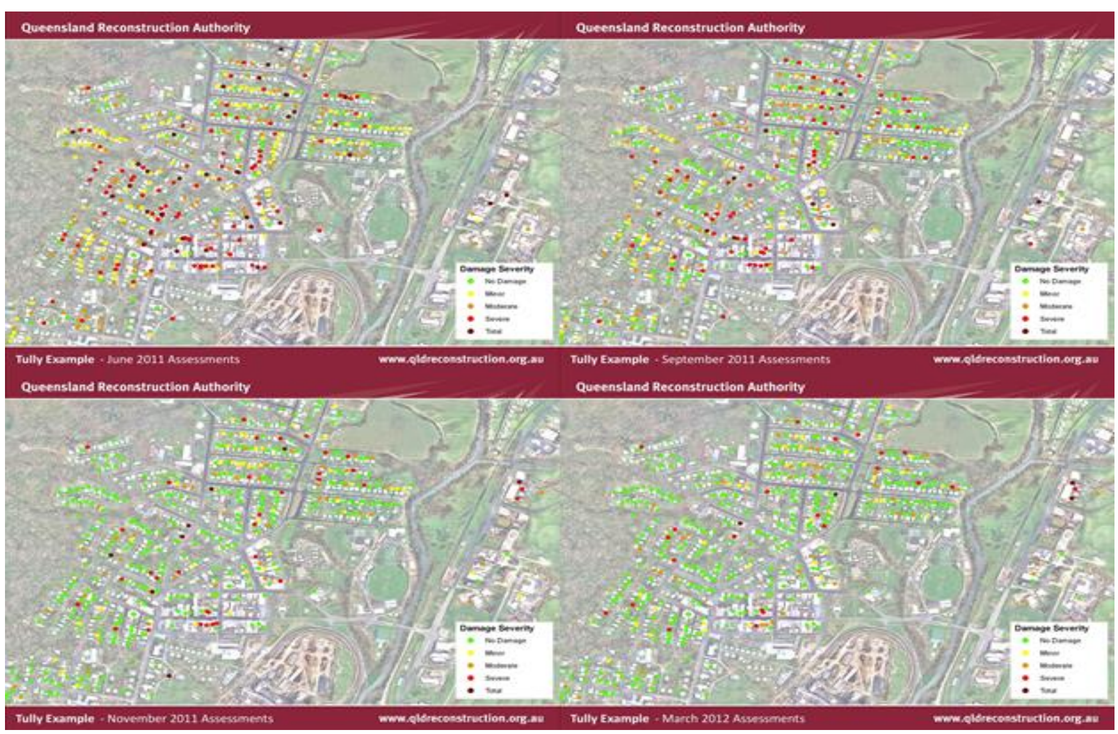

Figure 83 - Data collected in different times during the damage collection and reconstruction phases of Tully.

[82] Source: Flood Damage Survey and Assessment (2017): "New Insights from Research and Practise".

The recovery and reconstruction activities of QRA were operated under the guidance of a comprehensive and integrated plan, the Operation Queenslander, which was the state's community, economic and environmental recovery and reconstruction plan for 2011-2013. Its purpose was to rebuild and improve Queensland's communities, infrastructure, and economy towards a more disaster resilient environment. Sub-committees were formed for each line of reconstruction that drew membership from across the non-profit organizations, industry, the private sector and tiers of government.

In order to understand the consistency and success of the DARMSys™ system, a list of aggregated data from the surveys carried out during the reconstruction monitoring phase is provided:

- September 2011: In Emerald, from the 1630 inspected properties 97.1% were no longer damaged. In the Cassowary Coast and Hinchinbrook regions affected by the Cyclone Yasi, 2658 were inspected and 1882 were repaired or reconstruction had started.
- October 2011: In Brisbane and Ipswich, 11,364 properties investigated and 10,626 were no longer damaged or under repairing.
- November 2011: In Roma 76 properties audited and 96 % were reconstructed.
- February 2012: In Brisbane and Ipswich from the 11,364 properties the 11,098 were repaired.
- March 2012: In the Cassowary Coast and Hinchinbrook regions, from the 2658 properties 93.8% were no longer damaged.

Prior to the development of the IDARM system, the Transport Network Reconstruction Program managed the recovery and reconstruction of Queensland's integrated transportation network and infrastructure. Input from the public and private sectors from all regions across the state was used to schedule and prioritize works, and provide access for communities and industry during the reconstruction process. This included the reconstruction, stabilizing and improvement of roads, highways, culverts and bridges across Queensland. The investment by the Australian and Queensland government exceeded 4.2 billion USD.

14.1.3. Further use of the collected data

The Queensland government established the Queensland Floods Commission of Inquiry (QFCI), with the primary objective for the preparation, mitigation, planning and response to flooding in Queensland. The QFCI collaborated with QRA, the Department of Local Government and Planning, Building Codes Queensland (BCQ), DERM, and the Department of Community Safety (DCS) to undertake the Queensland Flood Mapping Program (QFMP).

The QFMP's mission was to ensure that Queensland learned from the recent natural disasters, and assist local government authorities to deliver a plan towards greater resilience and understanding of Queensland floodplains. The QRA provided valuable information from the DARMSys™ assessments to this initiative. The developed maps give an indication of the likely extent of Queensland's floodplains, but they do not intend to represent a specific flood event. Essentially they indicate areas where flooding had previously occurred or where it may occur. During the January 2013 floods, the mapping proved to be remarkably accurate across many affected regions of Queensland.

Prior to the 2010-2011 events in Queensland, the state departments were making steady and gradual progress towards opening up and sharing their spatial datasets for access both internally and externally. However, there was only limited public access and only on a viewing basis. A few interactive mapping systems existed, in a prototype stage, and were mainly designed for accessing departmental collected data and managed to meet jurisdictional and statutory obligations. Nevertheless, only a portion of these datasets were available for public access. Due to the large amount of data collected in the 2010-2011 events, a rapid evolution of these systems in terms of sharing data was achieved.

In the same context, the Department of Transport and Main Roads (DTMR) developed an interactive mapping system, based on an earlier prototype created by QFES, to display hazard data. DTMR recognized the potential of interactive maps to access corporate knowledge, under the primary aim to consolidate relevant information for supporting rapid decision-making during future disaster events. Furthermore, DARMsys™ information has been critical to plan the recovery efforts for the floods that hit western Queensland in the following years. Particularly, the Department of Communities is using DARMsys™ for targeting vulnerable people and those needing assistance.

In January 2013, Queensland was impacted by another significant flood. The Tropical Cyclone Oswald developed in the Gulf of Carpentaria crossed the western coast of Cape York Peninsula and moved south producing extremely heavy rainfall and damaging winds in the region between the towns of Rockhampton and Bundaberg. The Gladstone Town, the Burnett catchment, and Brisbane received a higher amount of rain compared to 2011 and 2012 events. The reported damage included over 2,000 homes assessed as uninhabitable, 5,845 km of state roads and 2,800 km of state rail network temporarily closed, and the natural gas supply disrupted. On this occasion, decisions were made with a greater degree of confidence based on spatial tools that had been developed and tested during the flood events of 2010-2011. Although no action could prevent these damages, the reliability of the spatial data promoted a more comprehensive decision making process among all stakeholders during the initial disaster response stage, damage assessment and recovery phase. The majority of insurance and NDRRA flood claims were processed and affirmed in a considerably reduced time span compared to the 2010-2011 flood events, as decisions could now be made using spatial datasets. The damage data collected by DARMsys™ devices had been expanded to include 21 items compared with a basic set of 6 items included in the 2010-2011 events.

14.1.4. Lessons learnt and recommendations

The lessons learnt from the Queensland experience in the 2010-2011 floods can be summarized in the following:

- The State Disaster Management Group and the Department of Community Safety (DCS), recognizing the need for continuous improvement, revised its disaster management arrangements in late 2010. The events in 2010-11 demonstrated that the fundamentals of the revised disaster management arrangements introduced in November 2010 were efficient. Through the Queensland Reconstruction Authority Act 2011, the QRA was able to establish a regulatory framework for the local government authority that ensured proposed rebuilding efforts and approval processes were fast-tracked, including the facilitation of development application approvals with relevant agencies.

- Due to the large geographical extent of the events, the flooding data collection required a large number of surveyors on the ground, which significantly stressed the response capabilities of Queensland. Even though the data collection and damage assessment acted within its limits, the streamlining and introduction of DARMsys™ guidelines and the approval of funding applications has more than halved the time taken for reconstruction works to be approved compared to the past events.
- The coordination and planning of the activities were the significant factors for the success of the operations. By focusing on a comprehensive value-for-money framework, QRA delivered cost-effective reconstruction programs that were easily tracked.
- The surveyors using the Trimble devices to carry out the RDA, had to return to a docking station in order to upload the collected data back to a local computer. This was a major setback (time consuming) of the data collection tool considering the scale of the impacted areas, which resulted into people delivering USB drives across South-East Queensland and created issues with data duplication. Nevertheless, in the current practice, the introduction of the Survey123 application and its real-time data upload capability tackled these issues.
- In contrast to the experiences of 2010–2011, QRA now hosts a sophisticated grants management system that provides the automation of briefing documentation, a single repository for data storage, digital capture with immediate retrieval and access to documentation, and a unified structure to manage funding application phases.

Several lessons were learnt concerning the usage and limitations of spatial information during and in the aftermath of the Queensland flood events, and its role as a driver for building community resilience. The importance of the creation of an authoritative spatial record of the event as ‘point-of-truth’ was highlighted, for supporting a coordinated, equitable and timely decision-making throughout all phases of a post-disaster situation. The spatial datasets should include high-resolution imagery for floodplain mapping, and future inundation predictions.

14.2. 2013 Yolanda Typhoon, Philippines

14.2.1. Description of the impact

The Category 5 Yolanda (Haiyan) typhoon that hit the Philippines in 2013 is one of the strongest tropical storms ever recorded in history. The typhoon entered the Philippine area in November 6th, it intensified within the next day and continued moving west towards Eastern Visayas (see Figure 84). The typhoon made the first landfall at the far eastern island of Samar on November 8th, and within the following 24 hours made 5 more landfalls over Tolosa, Leyte, Daanbantayan, Cebu and Bantayan islands. With winds up to 250 km/h, a storm surge of up to 5 meters, and significant flooding, the typhoon caused massive casualties and damages across multiple islands in the Eastern, Central, and Western Visayas.

The typhoon affected 9 out of the 17 regions of the country (IV-A, IV-B, V, VI, VII, VIII, X, XI, and Caraga) including 12,193 barangays (smallest administrative division), 591 municipalities and 57 cities. The inland areas of Leyte, Eastern and Western Samar, along with parts of Cebu, Capiz, Iloilo, Aklan and Palawan provinces, were the most affected areas. Though less severe, damage was recorded even beyond the 100 km storm track. As reported a month after, Haiyan typhoon caused approximately 6,300 fatalities, 28,689 injured, and affected a total of 16 million people. In addition, over 550,000 houses were destroyed and about 589,000 sustained heavy damage, causing 4.1 million people to be displaced. Information and communication access was severely impeded for weeks with 90% of the affected people having no access to electricity. Humanitarian agencies also faced significant challenges in sharing lifesaving information and assessing community needs during the emergency response activities.

About 5,898 classrooms were destroyed and 14,508 partially damaged in 2,905 public elementary and 470 public secondary schools in the most affected areas. Furthermore, the infrastructure was heavily damaged, including provincial and local roads and bridges, ports, power and water supply systems.

According to the National Economic Development Authority (NEDA), the total damage and loss from Typhoon Yolanda was estimated at PhP570 billion (equivalent to US$12.9 billion), representing approximately 3.8% of the GDP of 2013. About PhP424.3 billion of the total damage represents the value of destroyed physical assets, while the remaining represents reductions in production, sales, and income. Eastern Visayas experienced the highest amount of damage and losses, estimated at around PhP 50 billion, which represents 17.4% of the GRDP for 2013. Overall, approximately 90% of the total loss was due to damage on private assets and loss of income.

The national government, the local governmental units, NGOs, relief teams from more than 20 countries, and the UN launched a large humanitarian response to the disaster. Although the affected communities had already begun their own recovery efforts with the limited resources available, the magnitude of the disaster was so severe that it took several years to recover.

Source: DROMIC Report, 22 November 2013

Figure 84 - Map indicating the Yolanda typhoon path and affected areas.

14.2.2. Protocols, tools and IT system used for the disaster data collection

The President declared a state of National Calamity 3 days after typhoon Yolanda struck the country. The emergency response was managed mainly by the National Disaster Risk Reduction and Management Council (NDRRMC), the Office of Civil Defense (OCD), and NGOs. The NDRRMC and OCD conducted several meetings for the planning of rapid estimation of damages and aerial assessments. The immediate deployment of assessment teams led by the provincial governors also resulted in rapid damage assessment reports and provision of emergency assistance to the severely affected areas. A large number of domestic and international organizations, including many other countries, were actively involved in the immediate response operations, providing both financial resources and humanitarian assistance.

The framework for disaster risk management in Philippines was established in 2010 and it is managed by the NDRRMC, which is composed by 44 members from governmental agencies, local governmental units (LGU), the private sector, and the civil society organizations. The structure of the NDRRMC is mirrored at the local level (i.e. provincial and municipal levels) where the Local DRRM Councils (LDRRMC) are formed and managed by their respective local chief executives, while the Regional DRRM Councils coordinate, integrate, supervise and evaluate the LDRRMC activities. The National Disaster Coordinating Council (predecessor of the NDRRMC), institutionalized the Cluster Approach in the Philippine disaster management system in 2007, and the Department of Social Welfare and Development (DSWD) was appointed as the administrator of the system.

The NDRRMC is chaired by the Secretary of the Department of National Defense (DND), and is supported by the Office of Civil Defense (OCD) and the National Economic Development Authority (NEDA). Among the various functions and responsibilities, the OCD formulates standard operating procedures[83] for the deployment of rapid Damage Assessment and Needs Analysis (DANA) teams, and provides technical assistance in mobilizing the necessary resources to increase the capacity of LGUs.

The DANA is a rapid damage, repair and rehabilitation needs assessment, conducted within 24 to 48 hours after the disaster. The data collection is carried out through interviews and field surveys by the DANA teams. Standardized format and criteria for DANA are prepared by the relevant national agencies and disseminated to the local authorities of the affected regions. The purpose of DANA was to suggest the required activities within a certain timeframe. In the aftermath of Yolanda typhoon, sector-level damage and loss assessments were carried out and the outcomes were used for the preparation of the Reconstruction Assistance on Yolanda (RAY) plan.

In the week following the disaster, in response to requests from the National Economic Development Authority (NEDA) and the Department of Public Works and Highways (DPWH), a team of 10 specialists from the World Bank was mobilized to advise and support the government in developing a reconstruction and recovery plan. The team was formed by members from the East Asia and Pacific (EAP) Disaster Risk Management, GFDRR, the Indonesia Country Office, and specialists from California, Japan, and New Zealand. The team collaborated closely with NEDA and developed guidelines for the RAY plan. This plan was developed in five weeks and launched by the government on December 18th, which provided a recovery framework based on the early estimates of damages and losses, and informed the initial funding requirements and priorities for reconstruction of the affected areas.

[83] http://ocd.gov.ph/attachments/article/144/OCD_Operation_Manual_for_Response.pdf

Furthermore, approximately a month after the typhoon hit Philippines, the President appointed a Presidential Assistant for Rehabilitation and Recovery (PARR) to unify the efforts of governmental agencies and other organizations involved in the recovery efforts. For this purpose, a Comprehensive Rehabilitation and Recovery Plan (CRRP) was established, which required coordination of the different stakeholders (i.e. governmental agencies, LGUs, private sector, development partners, and NGOs) in the planning and implementation of the activities. Under PARR, 5 clusters at the national level were established to support and interact directly with the provincial governors and municipal mayors. The clusters and LGUs formulated the plans and programs for the CRRP, which was approved by the President ten months later (August 2014).

The OCD, under NDRRMC, initiated a Post Disaster Needs Assessment (PDNA) in the end of December 2013, which included DaLA and HRNA assessments, and proposed a sectoral recovery and reconstruction framework. The PDNA training for OCD employees and selected RDRRMC members was conducted after the tropical storm Sendong (Washi) hit Northern Mindanao in December 2011, with the assistance from the World Bank. In addition, similar training sessions were done after typhoon Pablo (Bopha) in Eastern Mindanao in 2012 and after Zamboanga Crisis in September 2013. OCD led the process, in collaboration with a total of 536 personnel from governmental agencies, LGUs, civil society organizations, NGOs, and local authorities. Four broad sectors were included in the PDNA: social, productive, infrastructure, and cross-sectoral areas. The procedure provided guidelines describing the common data templates, assumptions and parameters to be estimated.

Due to time constraints and the extent of the damage in the affected areas, the selection of the region covered by the PDNA was based on the following criteria:

- All areas within a 50 km radius of the typhoon track, identified by the Department of Science and Technology (DOST) (see Figure 85).
- Heavily affected areas based on the NDRRMC reports (DANA).
- Areas validated by the OCD regional directors and the RDRRMC.

Seven teams were formed to cover the areas of Tacloban City, Leyte, Samar (Eastern and Western), Aklan, Cebu, Biliran, Leyte, and Capiz. In total, 155 municipalities, 7 cities, and 11 provinces were covered in the 4 most affected regions within 5 months. In May 16th 2014 the results of the PDNA was submitted to the government.

Figure 85 - Affected areas covered by the PDNA.

The data collection included field visits and damage assessment by experts and professionals. Using the locally adopted version of PDNA, the multi-sectoral assessment teams gathered the information in paper forms. Many challenges were faced related to logistical issues and limited manpower. Several development partners supported the data collection by the LGUs, by providing tablets to capture the observed damage. However, this assistance was provided in certain scattered municipalities and the collected data were not reported into a single IT system. Finally, when no adequate information could be found during the field visits, professional estimates were used by the experts.

The National Community Driven Development Program (NCDDP) under the Cultural Center of Philippines (CCP) has building information in a provincial and regional level. Its members were trained to conduct national household targeting (pre-disaster), so they assisted in the damage assessment, using templates provided by the Department of Social Welfare and Development. However, this assessment took place in the areas where the staff was available, and did not cover all affected areas.

The development of the RAY program before the initiation of the PDNA caused some initial confusion amongst governmental agencies, LGUs, and international development partners. The governmental agencies and LGUs were required to submit several documents and to collect data on damage, losses, and urgent needs. Different templates (with distinct deadlines) were required by the RAY, PDNA and CRRP. This caused some confusion amongst the national and regional agencies and LGUs, and triggered delays in the preparation of the reconstruction and recovery plan. The Philippines

Statistics Authority under the National Economic and Development Authority (NEDA) was the central authorized agency for the data collection. However, there were gaps in the implementation of the data collection from the national level to the local (municipal) level. For this reason, scattered data collection from different agencies and with different mandates was observed.

The RAY plan was a centrally-driven procedure, as NEDA mobilized the respective central agencies to undertake their own separate assessments, using the DaLA approach. To this end, several workshops were organized to experts on the DaLA procedure. The purpose of RAY was to assist the government in development of policies and allocation of resources to reduce the social and economic cost from the disaster. On the other hand, the PDNA was a bottom up process that collected information from the affected LGUs. OCD mobilized teams composed of representatives from the national governmental agencies and local governments to collect and verify information on disaster impacts at the local level. The PDNA accounted only for the public sector damage and losses, while the RAY included damage and losses for both the public and private sectors (see Table 14).

Table 14 - Comparison between RAY and PDNA.

ITEM	RAY	PDNA
Lead Agency	NEDA	OCD
Date Completed	December 2013	May 2014
Approach	Top down	Bottom up
Data Set	• Recovery and reconstruction needs based on the application of ratios (derived and benchmarked against those used in comparable post-disaster assessments in the Philippines and other countries) of public to private ownership and medium-term recovery and reconstruction needs by sector	• Data collected are field validated and assessed by experts and professionals with cost valuation based on standard costing, local assessment, and agreed assumptions
Output	• Initial calculation of the overall recovery and reconstruction needs for further refinement • Accounted for damages and losses of both the public and private sector	• DaLA • HRNA • Recovery and Reconstruction Framework • Accounted for damages and losses of public sector
Estimated Amount of Damage	PhP 424.260 Billion	PhP 89.598 Billion
Estimated Amount of Losses	PhP 146.848 Billion	PhP 42.760 Billion
Reconstruction and Recovery Needs	PhP360.895 Billion	PhP 104.644 Billion

Around a year after Typhoon Yolanda hit Philippines, the activities of the CRRP, under PARR, were integrated with the regular activities of the NDRRMC though a national institutional mechanism for monitoring the rehabilitation and recovery of the affected areas, under NEDA's supervision. For this purpose, NEDA established the Yolanda Project Monitoring Office. Finally, there was a major contribution from UNDP to the recovery and reconstruction programs.

14.2.3. Lesson Learnt and recommendations

The impact of Typhoon Yolanda has forced the Government of Philippines to reconsider its post-disaster institutional framework in order to effectively deal with large-scale disasters in the future. The primary lesson is that establishing a permanent framework whose capacity and knowledge can be built over time is definitely better than creating ad-hoc procedures after the occurrence of a disaster. In addition, the existing regulatory gaps in the cooperation of the various involved stakeholders, governmental agencies, LGUs, and organizations that needed to be addressed after the disaster, undermined the damage data collection and the effective implementation of recovery activities. The lessons learnt from the Philippines experience are summarized in the following:

- Multi-agency coordination and cooperation is fundamental in all phases of a post-disaster situation (emergency response, damage assessment, and recovery). Avoiding duplication of efforts especially in the damage data collection will benefit decision-making and reconstruction.
- The government's leadership and ownership of the post-disaster activities planning is essential. Adhering to external mechanisms is not sustainable because they do not build local and national capacity. Also, the need for a single central body from the key stakeholders to interface with government is crucial.
- There should be a predefined national agency responsible for the planning and monitoring of the recovery and reconstruction process.
- It is crucial for the government to establish post-disaster damage assessment methodology, standard templates and data collection tools. This system should be shared among all governmental agencies, LGUs and relevant stakeholders before the occurrence of the disaster, and should be designed towards recovery and reconstruction implementation.
- The data collection was launched by national governmental agencies, but coordinated and implemented by each LGU. The process was not centralized and this seems to have been a source of inefficiency.
- The availability and granularity of baseline data is necessary for all the post-disaster activities. Quick access to baseline information will enable the effective allocation of resources for the response, damage assessment and recovery phases.
- There is a need to establish a transparent and unified system for monitoring, evaluation and reporting (across agencies and LGUs) the recovery and reconstruction. It is important that all stakeholders can refer to a unified platform that provides consistent information.
- The multiple layers of recovery plans that emerged caused initial confusion and delays in finalizing the overall plan. The information from RAY, PDNA, and CRRP, built on each other to

ensure consistency in policies, strategies, and priorities. However, better quality of data was needed for the reconstruction.

- In 2012, another typhoon hit the Philippines and affected a few provinces only. At the time there was an attempt to develop a common platform to facilitate all the data from all the relevant stakeholders, but the negotiations between the agencies and the coordinating organization were not efficient. The main reason was that different and incompatible database systems are used by the various agencies in combination with different templates and data collection tools. Nowadays, there is an attempt to establish the standards for the datasets to be collected pre- and post-disaster by each LGU. In this way, the data would be compatible and transferable to a common platform.
- Remote damage assessment using innovative technologies can overcome some of the challenges associated with field-based assessments of large-scale disasters. Satellite and aerial images, and crowdsourced mapping, can be used to estimate disaster impacts rapidly and boost considerably the damage assessment that rely on field visits, such as PDNA.
- A PDNA core team from different agencies should be formed and be ready to conduct assessments immediately after a disaster. This will strengthen the capacity of governmental agencies to conduct PDNA from the national to the local level.
- A technical team at the national level should be formed and manage an IT system application to estimate values for damage, losses and needs at the asset level.

14.3. 2015 M7.8 Gorkha earthquake and landslides, Nepal

14.3.1. Description of the impact

On the 25th of April 2015 Nepal was struck by a 7.8 moment magnitude (Mw) earthquake with the epicenter located at the Barpak Village in the Gorkha district, 75 km north-east from Kathmandu (capital), and with a hypocentral depth of approximately 8.2 km. This event, which was estimated at a maximum Mercalli Intensity of VIII, was followed by a strong sequence of more than 300 aftershocks greater than Mw 4.0, mainly in the central part of Nepal. Four of these aftershocks were higher than Mw 6.0 with one shock in the Kathmandu Valley reaching Mw 6.7 on the 26th April. However, the strongest aftershock was recorded on the 12th of May with Mw 7.3 and an epicenter located to the east of the initial shock, near Mount Everest. This aftershock occurred on the same fault as the previous event and caused significant damage in Dolakha and Sindhupalchok districts, north and northeast of Kathmandu.

While the earthquakes caused tremendous damage and casualties, mainly due to ground shaking, a considerable portion of losses were due to secondary hazards (ground failure), and especially landslides (2,000+ mapped landslides). Seismically triggered landslides occurred on many steep slopes, in general in the mountainous areas of Nepal, and caused substantial damage to roads and residences. These landslides also isolated many villages for weeks. The mainshock alone triggered a huge landslide in the Langtang valley which killed hundreds of people, and a landslide and subsequent avalanche on Mount Everest. Triggered Landslides mainly affected the rural areas in the central and western districts of Nepal, where the rural road network and main highways were blocked. Rock falls and land slips were frequently observed outside the Kathmandu valley, and in particular the Singati Township in the Dolakha district was significantly affected by rock mass failures. In addition, localized liquefaction and associated lateral spreading was observed in the Kathmandu Valley, which caused foundation distress, and structural tilt and settlement. The greatest damage due to liquefaction was observed in Mulpani, northeast-east of Kathmandu.

Of Nepal's 75 districts, 31 were affected, of which 14 were struck extensively (see Figure 86). The hardest hit districts were located around and north of the Kathmandu Valley. Overall, approximately 9,000 people lost their lives and more than 23,000 people were injured. The damage to buildings and infrastructure was extensive, covering residential and government buildings, schools, hospitals, rural roads, bridges, water supply systems, agricultural land, and hydropower plants. Damage was more severe in rural areas outside of Kathmandu, where houses were commonly poor constructions from mud mortar. More than 600,000 residential buildings were destroyed or required demolition, and approximately 300,000 were damaged. Hundreds of thousands of Nepalese become homeless with entire villages flattened, across many districts of the country, and centuries-old historical buildings were extensively damaged, at UNESCO world heritage sites in the Kathmandu Valley. According to the government of Nepal, the total estimated economic loss from the events is US$7 billion, while according to the Institute of Housing and Urban Development (IHS) the total cost of reconstruction is US$5 billion. The economic losses were massive considering that Nepal's GDP in 2014-2015 was approximately US$20 billion, and its economy relies primarily on agriculture and tourism.

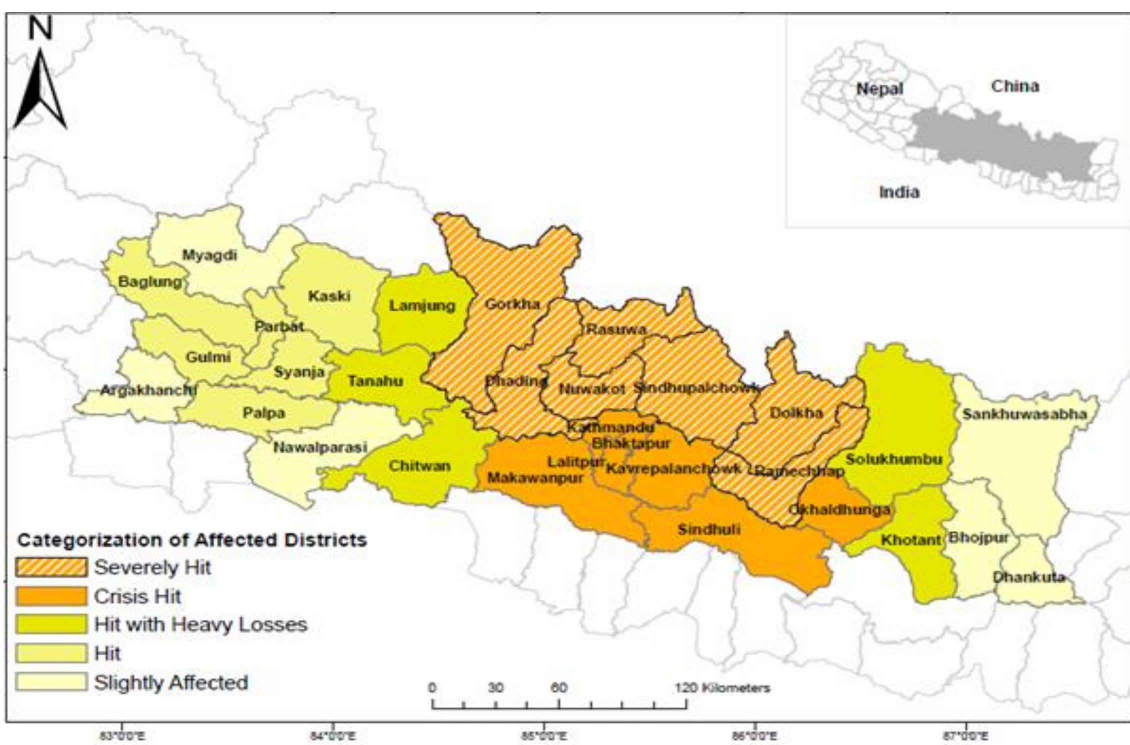

Figure 86 - Post-disaster categorization of Nepal's affected districts. Reproduced from PDNA volume A.

Furthermore, there was severe damage to the power distribution system with estimates of about 800 km of distribution lines and 365 transformers out of service immediately after the mainshock. Power was mostly restored in Kathmandu within 24 hours, and in other urban areas within a week. Although in the most severely affected districts and rural areas (e.g. Gorkha, Sindhupalchowk, and Rasuwa), the power was restored only up to 50% a month after the earthquake, mainly due to difficulties accessing the damaged equipment in those areas. The total damages are estimated at NPR 210 million, which is about 25% of annual operating expenditures. Except for around NPR 50 million damage that occurred to a reservoir above the hydroelectric plant, most of the losses are related to building and distribution equipment damages. In addition, the earthquakes and landslides damaged many pipelines (especially house connections), leaking mechanical couplings, and caused silting of wells. As for the telecommunication system, approximately 250 of the 1,240 mobile towers in the eleven most affected districts were down, and that number was reduced to 100, two weeks after the mainshock.

The earthquake sequence and landslides occurred 2 months prior to the seasonal heavy rain associated with the South Asian summer monsoon. Due to the ruptured and destabilized slopes and surfaces, the vulnerable areas became even more susceptible to flooding and further landslides that occur during the monsoon, especially in the mountainous areas and villages in the most affected districts. Moreover, the geodetic network centers, including horizontal and vertical control points, were damaged in a way that affected the reconstruction planning and mapping procedures.

Nepal had not experienced a natural disaster of similar magnitude since the Bihar earthquake in 1934. It was a disaster which largely affected rural areas, with the poorest and vulnerable disproportionately impacted. These series of events tested the nation in many ways and highlighted aspects of inequities in Nepali society, as poorer rural areas were affected way more than cities due to their inferior quality of houses. The extent and pattern of damage exposed the weaknesses of houses, which did not have any seismic design features or were not in compliance with the building code's guidelines. In summary, due to the earthquake sequence and associated landslides:

- Around 9,000 fatalities and 23,000 injuries occurred.
- Approximately 8 million people were directly or indirectly affected, while 3.7 million received humanitarian aid.
- Over 600,000 houses were destroyed and more than 300,000 were damaged.
- Around 200,000 families lived in high-altitude temporary shelters through the following winter.
- More than 27,000 classrooms were destroyed and another 26,000 classrooms were severely damaged, and nearly 1 million children left without school. The reconstruction and retrofit cost of the education sector is estimated at US$415 million.
- Nearly 6,500 governmental buildings, and 960 hospitals and clinics were damaged.
- Approximately 700,000 (2.5-3.5% of the population) people were pushed below the poverty line.

- Total estimated economic losses were around US$7 billion, which corresponds to 33% of the GDP of the previous year.

14.3.2. First days-weeks after the event – RVA – RDA

The Department of Mines and Geology is the Ministry of Industry agency responsible for disaster management and land zoning. The disaster management activities have been traditionally deficient in Nepal, as different organizations collect various data related to damages and casualties, mainly focused on rescue and immediate response. Also, far less attention has been paid to disaster preparedness in a country characterized by high risk to natural disasters, and especially earthquakes. Under this scope, mainly two instruments contribute: the first is the building code which was introduced in 2002 and specific sections were revised after the 2015 earthquake sequence; the second is represented by the building bylaws, established by the Ministry of Federal Affairs and General Administration (formerly the Ministry of Local Development). The latter were adopted by the local governments to simplify the provisions of the building code in order to ensure its implementation in the regions of the country where capacity is limited. Many houses collapsed and were responsible for thousands of fatalities, due to the poor construction techniques and non-compliance with the building code. In addition, the land zoning in Nepal is inadequate and combined with the very limited information about the soil conditions, constitutes a problem for Nepal's constructions.

The National Society for Earthquake Technology of Nepal (NSET) was founded in 1994 after the consequences of the 1988 earthquake. NSET was heavily involved in the establishment of the building code, although its primary focus is earthquake risk management. Many senior members from various governmental offices collaborated and established NSET, as a non-profit and non-governmental organization (NGO). Even though it is not officially responsible for post-disaster emergency response, it participated heavily in the emergency operations due to the high needs and expectations of the community. In the first hours after the mainshock, NSET contacted USGS for preliminary prediction of damages and casualties based on the recorded local intensities. In this way the places in need of immediate response and rescue were identified, and the activities were better planned.

Within the first hours after the mainshock, NSET established an emergency operation center, where almost all the staff gathered, divided into teams, and mobilized in the Kathmandu Valley for rapid visual damage assessments (RVA). This activity was not at the building level, but instead it represented a fast investigation of the impacted areas. The goal was to derive an overview of the situation and identify the most affected areas within the Valley. The teams did not use formal tools or paper-based damage assessment forms, but the affected areas were marked on a map. Simultaneously, rescue squads were formed and mobilized in collaboration with security and local authorities, and carried out rescue operations. The security and local authorities of each municipality and administration unit collected the data about human casualties (fatalities, injuries) and communicated them to the central government.

After the first day, the RVA was more organized, as NSET collaborated with engineers and other organizations and stakeholders, who had initiated similar activities from their side as well. Due to the numerous aftershocks, the population was not willing to enter their houses and stayed outside for several days, so the responsible organizations and agencies were under pressure to inform the public whether the buildings, and especially the residences, were safe to enter or not. There was a concern about the safety of existing buildings due to minor or major cracks, and appropriate information about the actual damage sustained was fundamental for removing the pressure from the relief personnel. Therefore, the first task towards the public was to assess the damaged buildings by conducting rapid damage assessments (RDA). For this purpose, the government adopted the method of tagging (marking) the public buildings (schools, hospital, governmental premises) as *red*, *yellow*, or *green*, representing the severity of damage and the overall condition of the building.

The Department of Urban Development and Building Construction (DUDBC) under the Ministry of Urban Development collaborated with NSET, the Institute of Engineering (IOE), and the Nepal Engineers Association (NEA), and conducted training sessions in order to mobilize mass survey teams for RDA. For this purpose, students and fresh graduates from the civil engineering department were recruited and trained. Meetings were held among the involved stakeholders, including various NGOs involved in the socio-economic assessment of the community for relief activities.

In the decade before the 2015 earthquake, the government in cooperation with other stakeholders made gradual progress in disaster management by developing certain policies and guidelines. Detailed damage assessment (DDA) guidelines were designed by NSET in conjunction with DUDBC and finalized in 2009. These guidelines and paper-based damage assessments forms were utilized, after some revisions and updates took place, and all the organizations agreed to use them for conducting the RDA. Afterwards, training sessions were carried out in multiple phases, and the assessment teams were deployed and mobilized in different areas within the Kathmandu Valley. Different RDA tasks were assigned to each team, covering governmental buildings, residences, schools, hospitals, and public buildings. NSET was primarily responsible for the assessment of important buildings, governmental offices, and schools, while 2-3 NSET experts were deployed in each other RDA team, because of their broad experience in post-earthquake damage assessment.

The RDA initiated 2-3 days after the mainshock and continued for the next 2-3 weeks, and mainly took place within the Kathmandu Valley, where around 60,000 individual buildings were assessed. The primary objective was to facilitate the population to return to their homes and to assess the safety of important public buildings. The information from these damage assessments still remain on paper forms today.

Overall, the cooperation among the various stakeholders for the RDA was successful, but initially there were some regulatory gaps, especially in the agreement of tools and damage assessment forms. Additionally, there were communication gaps in the deployment strategies, assigning the areas of responsibilities and the types of buildings to be assessed by each organization. The leadership by the government (DUDBC) was efficient, coordinating all the stakeholders and avoiding potential duplication of efforts.

Even though the guidelines and damage assessment forms were based on existing ATC guidelines, and adapted in Nepal's context, they proved to be efficient for the RDA. However, it should be noted that they was no legal act regarding which authority or organization was responsible to tag the assessed buildings. The fact that some surveyors tagged the buildings without proper investigation created confusion among the RDA teams. It was the first time that this system was applied in Nepal and the participants did not have experience in conducting large scale damage assessments. Moreover, a more sophisticated system to report the real-time data could have been very beneficial for rapid decision making, for example, so that the local governments and authorities could had been rapidly informed about the number of destroyed, damaged, and usable buildings in order to estimate the required temporary shelters and relief resources.

Despite the fact that the training of surveyors was quick and effective, the main constraints during the RDA was the lack of skilled manpower, which in some cases led to wrong and misleading assessments. In addition, due to the extent of damages to building and infrastructure the time was very limited to conduct the surveys and inform the responsible agencies to initiate the required relief activities.

Approximately 3 weeks after the mainshock, a Post-Disaster Needs Assessment was set in motion by the government, where different clusters were formed for the assessment of each affected sector, each cluster involving many stakeholders. For example, the educational cluster was composed by the Ministry of Education, UNICEF, and Save the Children, while NSET was the technical advisor. NSET prepared the damage assessment guidelines and questionnaires, and provided training to engineers to conduct the damage assessment of schools. Each party was responsible for the sectoral buildings of each district. The PDNA was completed 1-1.5 months later and provided essential information for the post-disaster relief activities, which was combined with the data from the RDA to estimate the needs of temporary shelters for housing and education, and resources allocation. Furthermore, the guidelines and standards of the SPHERE[84] project were also followed for the humanitarian assistance, especially for the education cluster, since it was the most affected sector.

14.3.3. Detailed Damage Assessment (DDA)

Subsequently, after the completion of the RDA and PDNA, NSET consulted the government to initiate a more detailed damage assessment initially in the 14 most affected districts. The central government approved and established the damage assessment guidelines, where different forms (checklists) were used for the various types of buildings, such as residences, public buildings, schools and hospitals.

[84] http://www.sphereproject.org/

In the census survey of 2011, NSET advocate the Central Bureau of Statistics (CBS) to formulate certain questions regarding the residential buildings, such as building typology, material of construction and number of storeys. These data were utilized by NSET to derive exposure information and fragility functions about the building classes of the residential building stock. The fragility functions along with the spatial distribution of ground motion intensities, provided by USGS, were used to estimate the damage in the affected districts prior to the field DDA. The spatial resolution of these estimates was at the Village Development Committee (VDC) level, which corresponds to a municipality level. In addition, based on building typology, number of storeys, the floor area, the unit cost of the building class, and the extent of damage, preliminary monetary losses were estimated for each building typology (not each individual building). PDNA used this rough estimate of damage and losses for the residential sector, such as percentages of damaged buildings.

The DDA carried out by NSET was guided by engineering and scientific interest, and had three main objectives:

- To understand the scale of the disaster and advice the government on a robust basis.
- To study the building performance for calibrating the analytical fragility functions using empirical data, and for enhancing building code provisions.
- To work with local governments (municipalities) for the local level reconstruction and retrofitting, and to support the implementation of central policies.

NSET trained and mobilized around 500 fresh graduate civil engineers for the building-by-building DDA, and the training was conducted by a specific group of instructors. The sessions consisted by three days of training and one-day field visit, before the engineers were sent for the DDA. This expedition was funded by the U.S Agency for International Development (USAID). For the planning of the DDA surveys, various map data such as google images were used to collect the building footprint in combination with the census data of 2011. Moreover, the data from an ongoing long term project of NSET called Building Code Implementation Program in Municipalities of Nepal (BCIPN) were utilized. Under this project, NSET planned and mobilized large building inventory and building code compliance surveys and the georeferenced data were stored in a GIS database.

The existing knowledge and capacity from the tools used in the BCIPN was transferred, and an android application for mobiles and tablets was developed by NSET and used for the DDA. The application was based on the *KoboToolbox* tool, which was modified to incorporate the 2-3 pages of checklists of the damage assessment forms. The tool was able to capture the following aspects:

- Building information: such as the structural system, material of construction, number of stories, shape in plan and elevations, and overall dimensions.
- Structural member information: including the typical size of columns, beams and walls.
- Structural damage part; such as the extent of damages (minor-major) and the identification of damaged elements, the length of damages, and the width of cracks.
- Social information and casualties of the residents.
- The GPS location including the building footprint.
- Minimum 4 and maximum 10 photographs per building were required.

Subsequently, the data were uploaded to a KoboToolbox mirrored server database, which was originally developed for organizations working in the data collection for humanitarian purposes. Due to the high cost of providing real-time data through internet and due to the limited access of internet at the rural areas, the application was operating in an offline basis. Every evening the scattered assessment teams gathered and uploaded the data in 2 systems (including the back-up), where the collected information was verified and post-processing took place. The monitoring of the data collection, including reassessment when was necessary, was carried out in the NSET offices. Within the server, the data were presented as statistical graphs (e.g. pie charts) indicating the location of the buildings with the level of damage, including the analysis report. After the completion of the surveys, the data were aggregated and the *KoboToolbox* databases along with the report and the GIS mapping were shared with the local government servers, as NSET collaborated with them during the DDA.

NSET carried out DDA not only in the 14 most impacted districts, but also in some of the remaining 17 affected districts in order to capture the range of intensities (low to high) for the purpose of fragility function modelling. The assessment teams were mainly composed of trained engineers, but also by geographers and GIS experts. The districts were divided into different sectors and assigned to the assessment teams. Approximately 20-24 people were mobilized per district and divided in assessment teams for 3 weeks to 1 month, while on average one team conducted 20 DDA per day. More than 200,000 buildings were inspected in the following 6-7 months. NSET was responsible for the residential buildings, while for the public buildings DUDBC was in charge.

Internally in NSET offices an advisory group planned and supervised the DDA surveys, while another body was the volunteer management and selection group. In every district there was one coordinator responsible for the daily planning and mobilizing of the assessment teams.

Four to five months after the mainshock, NSET had completed DDA surveys in several municipalities, while simultaneously the Chief District Officers (CDO) and local authorities were collecting non-technical damage data. This data collection was mostly based on the relief operations provided to the people, such as the number of people and families affected. The central government was preparing the reconstruction strategy based on these data, which initially was planned for 200,000 NPR per residence.

By analyzing the damage data, NSET advocated the central government for the importance of the damage assessment in order to assist decision making for the reconstruction reimbursement. NSET compared their damage data with the corresponding from the CDO and advised the government that the reconstruction grants should be based on DDA data rather than on the relief activities. For example, at one municipality the data collected for residences by CDO presented 98% complete damage, in contrast with NSET's 50% complete and 20% partial damage.

Based on this inference the CBS initiated a damage data collection expedition, and the National Reconstruction Authority (NRA) was founded approximately 9 months after the mainshock. This damage data collection expedition had both socio-economic and technical characteristics, but primarily was conducted to inform decision making regarding the government grants for reconstruction and retrofitting. This survey was guided by the NRA and carried out by CBS, while NSET provided the damage assessments guidelines and trained the engineers. Even though this data collection was not as detailed as the DDA conducted by NSET, the same guidelines were used to conduct damage assessments, with some additional field for socio-economic information. During the CBS data collection survey, the DUDBC developed guidelines for mobilization and training of the surveyors at the headquarter and district level.

Nevertheless, some issues arose because many decisions were taken on behalf of NRA before its establishment. More specifically, the CBS which is under the National Planning Commission Secretariat (NPCS) was the official responsible agency for any type of data collection, processing, analysis and publication. Since CBS had already initiated the data collection prior to the formation of the NRA, a steering committee was formed and administered the data collection procedure, despite the fact that the owner of the data was the Ministry of Federal Affairs and General Administration (MOFALD). The steering committee, which was under NPCS, continued administering the data collection until the end, while various stakeholders were involved such as local contractors and UNOPS personnel. Essentially, the real owner of the collected data was NRA, but at the initiation of the procedure NRA had not been established yet.

Subsequently, the government formed the Central Level Project Implementation Units (CLPIU) for each affected sectors (residences, schools, public buildings, etc.) under the NRA. The data collection was facilitated by a tool developed with the assistance of the World Bank: an application for tablets able to capture the occurred structural damage including photographs, socio-economic information about the residents, and the location of the buildings. The enumerators were provided tablet devices for data collection, and the information was uploaded to the CBS servers. The internet connection limited the real-time uploading of data, and in many cases the enumerators had to bring the tablets to the headquarters to upload the data. All the quality control and data verification took place at the CBS, and the information was used to estimate and approve the beneficiary for reconstruction or retrofitting. A sample of 10,000 damaged buildings from the NRA were used for a data quality assessment by NSET, and the estimated error was less 10%. Finally, the processed data were sent back to the respective local governments and village development committees.

The data collection took place initially at 11 out of the 14 most impacted districts, where the census method was applied, covering every household. However, this would have been extremely time consuming for the remaining districts, including the Kathmandu Valley, where the damage was not so significant as in other districts, but the number of residences is enormous. Therefore, for the remaining 20 districts (3 heavily hit and 17 less affected) the data collection methodology was modified which led to some discussion between the steering committee and the NRA. In the first 11 districts the data collection procedure was funded by the World Bank and the overall system was efficient. When this funding ended, there were insufficient resources to carry out the data collection in the remaining 20 districts. Ultimately, the United Kingdom Department for International Development (DFID) funded the data collection survey and the program was mobilized for the remaining 20 districts. Despite the fact that there was a lack of trained enumerators for the damage data collection, the guidelines were effective and kept improving during the process, which was completed approximately 7 months after the establishment of the NRA.

In hindsight, the DDA could have been conducted in one phase with the cooperation of all stakeholders. Since the governmental data collection for reconstruction decision making was initiated only 7 months after the mainshock, the recovery process was delayed. The main problem was that there was no predefined framework, even though the technical guidelines were developed and Nepal had the capacity to carry out large scale damage assessment. It was not initially clear to all concerned that a DDA with clear roles among the involved stakeholders is required for further reconstruction and retrofitting activities. This combined with fact that the NRA was founded 9 months after the disaster, constituted a major gap in the post-disaster recovery process.

14.3.4. Use of the data

The reconstruction and retrofitting activities were initiated before the completion of the governmental damage data collection. As soon as the processed data for a municipality were adequate, policies were formulated and the reconstruction emerged based on these policies, and this procedure was continued for all the affected districts. Every reconstruction decision should pass through the executive committee of the NRA for approval. NRA along with CBS administered the reconstruction of private residences, while the respective ministries are responsible for the reconstruction of their sector. For example, the Ministry of Education manages the educational sector and the Ministry of Tourism administrates the heritage building retrofitting. The reconstruction is an ongoing process, and due to the enormous number of damaged buildings, it has not been completed yet.

NSET consulted NRA in drafting several reconstruction policies at the national level, which are applied to all 31 affected districts. The damage classification for masonry buildings according to the EMS-98 were utilized to categorize each individual building damage based on the collected information. This system classifies 5 grades of damage, and the reconstruction and retrofitting grants were based on these grades. More specifically, between damage level I (slight) to III (substantial) a retrofitting grant of 100,000 NPR was entitled, whilst for damage level IV (heavy) and V (very heavy) demolishing was enforced and a reconstruction grant of 300,000 NPR was granted.

NSET, using the data collected from the DDA, advocated NRA to establish new standards for the reconstruction and retrofitting, based on the building codes guidelines and towards disaster resilience. Hence, the NRA decided to inspect the reconstruction process in three stages and allocate the compensation funds accordingly. Hence, the 300,000 NPR were transferred in three phases of 50,000, 150,000 and 100,000, after inspection, based on the criteria that the reconstruction followed the building code, otherwise the government did not fund the next phase. This is the structure of the Reconstruction Disbursement System and the house inspections are conducted by trained engineers. Adopting this system, the government ensured that the new buildings comply with the Build Back Better concept and will perform better in future earthquakes and other perils. Furthermore, the collected socio-economic data were used to identify the social vulnerable people in order to provide additional support by the government.

The overall procedure from the data collection until the reconstruction was successful and ultimately it was accomplished within a reasonable timeframe. In addition, the IT system was efficient and enhanced the reimbursement process, allowing the multiple stakeholders to verify the information in a transparent manner. Nevertheless, there were several deficiencies. The crucial information for NRA in order to make decisions was to know whose house was damaged, what was the degree of damage, and finally the location of the building. However, the questionnaires which were implemented in the tablet application were designed before the establishment of the NRA, and a large amount of information regarding the socio-economic conditions was required. As a result, the surveys took too long time (1-2 hours per building), and in the end NRA used a subset of the collected data for the compensation funds. None of the detailed socio-economic information has been used so far, which resulted in a large quantity of information that required long time to process, without clear objectives.

Another issue with the damage assessment forms was that the different damage characteristics were not linked directly to the final verdict (damage grade I to V). There were also discrepancies in the engineering judgment that in certain cases created problems, such as repeating the surveys and mobilizing additional resources. Moreover, the assumption that the local governments were present and functioning was not always true, because many governmental buildings were damaged and the governmental personnel were absent. Key roles and responsibilities were assigned to the local governments, which occasionally created problems in the data collection process, as there were lack of authorized staff to facilitate the damage assessment surveys.

From June to September 2015 NSET conducted training sessions (6 mason + 3 engineering), where around 100 engineers and 200 masons were trained for the upcoming reconstruction phase. NSET also developed a mason training curriculum, which was acknowledged and enforced by the government in all districts. The training provided orientations for existing and new masons, in various levels, associated with the construction technique, towards the Build Back Better concept. During the reconstruction phase, NRA formed a Housing Reconstruction and Recovery Platform (HRRP) composed by NGOs, including NSET, to support the procedure in a local level (VDC) in collaboration with the CLPIUs.

The reconstruction technical assistance provided by NSET was coordinated with the Baliyo Ghar Program for Safe Reconstruction. This program was initiated in October 2015 and will continue until September 2020 using funding from USAID. The short-term goal is to ensure safer earthquake construction, while the long-term objective is to achieve disaster-resilient communities in Nepal. It was introduced as a pilot in the Dolakha district, where a District Reconstruction Technology Center was established, and since November 2015 the program was mobilized in the districts of Kathmandu, Nuwakot and Dhading. The program utilizes the DDA collected by NSET, the information from the PDNA, and the data collected from the District Disaster Response Committees (DDRC). As of today, approximately 30,000 buildings have been reconstructed in the areas of responsibility of NSET in those four districts. Because one-time training is not adequate, NSET provides door-to-door reconstruction support and technical assistance in each of the four districts. Also, NSET provides technical assistance and training to masons and engineers at a VDC level in all districts, to support the reconstruction by the NRA.

As of June 2017, the NRA published the following information regarding the damage assessment and reconstruction process:

- In the 14 most impacted districted 876,520 buildings were damaged between grade I and V, while 626,696 reconstruction grants and 19,886 retrofitting grants were approved.
- In the rest of the 17 affected districts 176,428 buildings were damaged between grade I and V, and 100,043 reconstruction grands were approved.

14.3.5. Lessons learnt and recommendations

The Disaster in Nepal represents an excellent learning opportunity, as despite the limited resources, rapid and detailed damage assessment was performed in thousands of structures, and the results were used for the purposes of decision making, in particular in the allocation of funding for reconstruction. Some of the lessons learnt and recommendations are summarized below:

- The damage assessment should be performed at many levels, along with the corresponding training of the surveyors. At a high level level, staff without an engineering background should be training for RVA in order to rapidly assess the safety of the damaged building. At a more rigours level, a detailed damage assessment carried out by technical expert should be performed for estimating reconstruction cost and designing strengthening techniques.
- It is important to adapt the common guidelines and tools (or forms) to the different types buildings and infrastructure, but the same tools should be used by all parties. These tools should be endorsed by the central government in order to facilitate acceptance by all parties.
- It is critical to level some level of verification of the raw data before submitting them to a centralized system. Unverified data could mislead and ill-inform the decision making process. Such verification may cause some delays in the process, but it will enhance the quality of the final results, and consequently increase the efficiency of the recovery process.
- In the aftermath of a strong disaster with a large geographical extent it is likely that some of the existing mechanisms for damage assessment might not be entirely appropriate. For example, NSET had the expectation that the trained engineers would also assist in the training sessions in other regions, in order to deploy a large number of teams for RDA. In reality, this plan did not work due to the lack of available engineers and volunteers with a technical background. Moreover, some of the villages were isolated due to landslides or the access was too dangerous.

- Real-time satellite imagery and remote sensing data are essential in the immediate aftermath of a disaster, and it was a serious drawback that such data were not available in 2015 events. These data can provide useful information about the affected areas, which is critical for mobilizing staff during the emergency response and for planning the damage assessment.
- All the potential stakeholders for the damage assessment should have a predefined area of responsibility (AOR), and potentially be responsible for the data collection of specific sectoral buildings (residences, governmental buildings, schools, commercial buildings).
- Specific information regarding the event such as the magnitude, epicentre, extent of the damage and number of casualties should be announced and shared by a single agency. The government should have a clear plan to inform the public, in order to avoid misunderstanding, discrepancies, and misuse of information by the media.
- The government of Nepal did not have a defined framework for data collection and reconstruction before the 2015 events, and since then has spent significant efforts in developing such system. The gaps in the existing policies and regulations created trust issues in sharing the information among the stakeholders. Since the NRA was a new organization, some roles and responsibilities were not clear. This part of the process provided several learning experiences and eventually the NRA became functional and had a satisfactory collaboration with the other organizations and local governments. It is fair t assume that if the NRA and these regulations existed before the disaster, the damage assessment and financial compensation of the population would have been more efficient.
- The responsible organizations, agencies, and stakeholders for the data collection and reconstruction should be identified and have a clear role before a disaster occurs. Even if immediate relief and response operations are taken into account and planned properly, the next phases are equally important and should be planned in detailed. Furthermore, when a government drafts guidelines and policies after a disaster, it is not possible to address all the post-disaster issues, and therefore there will be some setbacks in the procedures.
- The lack of skilled and trained manpower for the damage assessment was definitely an issue for all the involved organizations. If the damage assessment guidelines are not clear, then the damage assessment is affected by subjectivity and individual judgment. For this reason, the data collection tools and questionnaires should be quantitative, and avoid qualitative metrics. Moreover, the social-economic conditions of the communities where the damage assessment takes place is also important. For example, during the DDA coordinated by NSET, in some cases the residents tried to influence the surveyors to "increase" the level of actual damage in order to be entitled to a greater grant. It should also be noted that in situations where the population was grieving, the expectations for government support were high and influenced the data collection.
- The capacity of the local (non-governmental) civil society is fundamental for the emergency response and relief activities, but more importantly for the reconstruction phase. High capacity conditions can accelerate the reconstruction progress at a lower economical. This capacity should be created or improved as part of preparedness plans.

- All the disaster prone countries should include information in the census database related to the building characteristics to enable multi-hazard risk assessments. This information can be critical for the estimation of the occurred damages immediately after a disaster, but also to monitor and evaluate risk mitigation and reduction activities. Furthermore, pre-disaster information from all sectoral buildings and not only residences, including the geographical location, is very important for the post-disaster data collection.
- The existence of a legal mechanism and disaster preparedness framework are equally important with the existence of efficient and up-to-date damage assessment guidelines, tools and IT systems.
- Scattered settlements across the country with limited building information may complicated the identification of the high risk areas. A detailed framework with an efficient GIS system should be developed, and used also for other activities such as land zoning, urban planning, and multi-hazard assessments.
- For decision making, different data and information are required at different times after the occurrence of a disaster. Therefore, there should be existing policies that define how and when the information will be shared amongst the relevant stakeholders after the occurrence of a disaster.
- Even though the tools for the data collection were efficient, the fact that they were not completely open source created problems in modifying or change certain features during the damage assessment. Initially, NSET attempted to utilize Open Mapping Tools, but since there was a lack of control in the design of the tool, they decided to develop their own based on the *KoboToolbox*. However, the map of the affected and investigated areas should had been integrated in the application, be accessible by all surveyors, and include the basic information of the assessed buildings.
- There should be a clear connection between the data captured by the tools or assessment forms and their end use. Particularly, the tools and questionnaires should be developed based on the needs of the various stakeholders and end users, in order to avoid the collection of unnecessary information, that might consume precious time.
- Before the occurrence of a disaster, the records of house ownership should be available to the agencies responsible for data collection and reconstruction. More specifically, there should be a disaster management authority which manages a database with the necessary data in interconnection with other agencies that acquire or need similar data for other purposes (e.g. socio-economic). The disaster management authority should have this information nationwide and in advance, including the location of the buildings. This way, the damage data will build on the existing information, and the local governments can carry out the data collection and share the information with the respective authority.
- The training of key members for the damage data collection should take place at a local government level and identify engineers in the local authority system, as these experts can lead the data collection at the local level. Therefore, a better hierarchy in the data collection should be achieved, as the local authorities can collect the information and then share it with the central agencies.

- Clearly disaster preparedness is the key for every activity in a post-disaster situation. In particular, the funding mechanism for the expedition of the damage data collection should be identified before the occurrence a natural disaster.

14.4. 2016 M6.2 Central Italy earthquakes

14.4.1. Description of the impact

The earthquake sequence that occurred in Central Italy in 2016 started with a mainshock on the 24th of August and concluded with the last aftershock on the 18th of January 2017. Numerous events with a moment magnitude greater than 4.0 occurred, from which 9 had magnitude above 5.0, and 2 reached 6.0 and 6.5 (Mw) within those 5 months. Overall, this sequence caused 299 fatalities and 412 injuries, and left around 4800 people homeless. The earthquake affected significantly a total of 140 municipalities in the regions of Abruzzo, Lazio, Marche and Umbria. Most of these casualties were due to major damage and collapses of residential and architectural buildings in the municipalities of Amatrice (see Figure 87), Accumoli, and Arquata. This event represents one of the major natural disasters in Italy in the last 30 years.

Figure 87 - The town of Amatrice lies in ruins after the devastating earthquake on the 24th of August 2016.

The mainshock on August 24th was a shallow strong earthquake of Mw 6.0 and hypocentral depth of 8 km, with an epicenter in the village of Accumoli in Lazio. This event caused 299 fatalities, 390 injuries, and significant damages, primarily in the three aforementioned municipalities. One aftershock with Mw 5.3 occurred about 1 hour after the mainshock without causing any additional casualties. Until October 26th, the sequence was continued by numerous aftershocks less than Mw 5.0, and most of them occurred at a length of more than 40 km.

In October 26th, a Mw 5.9 earthquake occurred with epicenter at Visso in the Marche region, preceded by a Mw 5.4 event a few hours earlier. The epicenters of both events and the following weaker aftershocks were located approximately 25 km north-west of the epicenter of the mainshock from August 24th. Afterwards, in October 30th the strongest event of this sequence occurred at Norcia in the Umbria region, at an area located between the epicenters of the previous two mainshocks. This event had a magnitude equal to 6.5 (Mw), representing the strongest event in Italy since the 1980 Irpinia earthquake (Mw 6.8).

Fortunately, both events did not cause any casualties due to the fact that the population had already been evacuated to temporary shelters. In addition, these events affected the areas close to the Norcia municipality, where many buildings had been strengthened after the 1997 Umbria-Marche earthquake. Whilst the earthquake of August 24th had a very destructive impact on a restricted area, the impact of the following seismic events was distributed on a larger territory, extending northwards in the Marche region. Nevertheless, many small towns and villages which had survived the first event were heavily damaged during the October 30 earthquake.

Finally, on January 18th 2017, four seismic events with Mw$\geq$5 stroke the southern part of the areas affected by the previous earthquakes. These events coexisted with a heavy snowfall, which had started 2 days before, which fact created major difficulties in the emergency operations from the two independent perils for several days, and causing uncomfortable out of home accommodation for people with damaged residences. Even though no casualties occurred due to ground shaking, an avalanche at about 40 km to the east of the epicenters in Rigopiano caused the death of 34 people in a resort hotel. It is still uncertain if this avalanche was triggered by the seismic events. Nonetheless, several landslides were observed in this region due to the strong ground shaking.

The total monetary losses caused by the earthquake sequence is estimated around €23 billion. This amount includes the emergency costs and an estimation of the damages to infrastructure, public and private buildings, cultural assets, and the production system related with the agro-industrial sector and livestock. The breakdown of the damage shows that the private and residential buildings is the most affected sector, with a total of €12.9 billion in losses, of which €4.9 billion was due to the event in August and €8 billion was caused by the events between October and January. The second largest loss was due to damages in the cultural heritage. The damage to the infrastructure, including roads and networks of energy, water and gas, have been estimated in more than €2.7 billion. As for the public buildings, the total loss was estimated as €1.1 billion, and finally, the emergency response and relief expenses were calculated to be €3.24 billion, including the costs of urgent accommodation and housing solutions.

14.4.2. Protocols, tools and IT system used for the disaster data collection

The emergency response was coordinated, according to Law 225/1992, by the Department of Civil Protection (DPC), within the framework of the National Service of Civil Protection (SNPC). The SNPC is the authorized body for protecting the Italian society from all natural or man-made disasters, and its activities involve pre-disaster risk assessment and mitigation, post-disaster emergency response, relief, damage assessment, reconstruction and recovery.

Within the first hour after the first mainshock of the sequence, the National Institute of Geophysics and Volcanology (INGV) provided seismological information regarding the event. This information was integrated with data from the strong motion network of the DPC in order to derive a damage scenario, and acquire a preliminary picture of the potential consequences in the affected areas. In the next few hours the scenario was validated on the basis of the reports directly coming from the epicentral area to the DPC, along with the shakemaps provided by INGV. The final calibrated damage scenario provided useful information to the DPC, which assisted the planning of emergency response and rescue operations.

After the declaration of emergency state, the SPNC coordinated the actions of the local and national authorities and volunteer associations for the emergency response operations. While the search-and-rescue operations were under way, the Operational Committee met at the DPC headquarter to plan further actions. The Operational Committee is the decision making body responsible for multi-hazard disasters, towards a unified response and cooperation of all the stakeholders.

On August 28th, the Direction of Command and Control (DiComaC) was established in Rieti (Lazio region) as the national coordination system on site, in order to coordinate the components and operational structures of the DPC. The activities managed by the DiComaC involved the assistance to the impacted population, such as the design and management of temporary shelters and financial support, assessing the damage and usability of the buildings, and liaise with central and local decision making bodies.

Several days after the mainshock of 24th of August, 43 tent camps were set and in combination with other available public buildings, approximately 4800 people were accommodated. Subsequently, on 9th of September, a commissioner was appointed by the government to administrate all the activities related to the reconstruction of the area affected by the earthquake, while the DPC remained in charge of the emergency management coordination. These two authorities were in charge of different, but temporarily overlapping activities, which required collaboration and continuous interaction.

After the two mainshocks at the end of October, additional 1296 people were hosted in temporary shelters, while the population directly assisted by the DPC reached a peak of 31.763 people, and the forces operating along with volunteers reached a maximum of 6.916 people. Overall, the emergency response and relief activities were characterized by great efficiency due to the well-prepared and experienced system, but also due to the effective collaboration between the involved stakeholders from both the public and private sector.

During the emergency response, many technical activities took place to support the DPC management and decision making, and for this purpose, the DPC formed Competence Centers. The role of DPC Competence Centers (Centers for Technological and Scientific services, development and transfer), which were formed by various scientific and research institutions, was to provide technical services, information, and to consult in risk assessment and management. Various representatives of the Competence Centers were present in the DiComaC, in order to directly interact with DPC officers. The institutions participated along with their field of activities were:

- The INGV was responsible for the seismic monitoring and led the geological field surveys.
- The Instituto Superiore per la Protezione (ISPRA) led the field surveys concerning landslides, which could affect roads and buildings.
- The National Research Council (CNR) led the geological surveys related to microzonation.
- The National Agency for New Technologies (ENEA) was in charge of the debris management.
- The European Centre for Training and Research in Earthquake Engineering (EUCENTRE) supported the establishment of temporary shelters and contributed to the damage assessment.
- ReLUIS assisted in the damage assessment of buildings, in particular cultural heritage.

Nevertheless, during the 5 months of the seismic events sequence, many of these activities had to be restarted each time a new strong event occurred, specially the damage assessment of the built environment.

In the Italian context, the damage and usability assessment of buildings is performed using well-established guidelines since 1997. These guidelines were based on the experience of numerous surveys conducted in the past, such as 70,000, 250,000 and 35,000 building-by-building inspections after the 1976 Friuli, 1980 Irpinia and 1997 Marche earthquakes, respectively. The government enforced these guidelines at national level with a legal Act in 2011, which includes the AeDES (Agibilità e Danno nell'Emergenza Sismica) inspection form and the related manual (Baggio et al. 2000). Further updates were introduced in 2014 and 2015, and the experiences from the 2009 Abruzzo and 2012 Emilia earthquakes also allowed an improvement of this system, by establishing rules for the recruitment of experts, organization of training courses, and the creation of a new inspection form for large span prefabricated buildings (GL-AeDES[85]). Until the first mainshock in August 24th, approximately 6000 experts, professionals and public administrations employees had followed the training courses and were available to be recruited, on a voluntary basis, for inspections in the affected areas.

[85] http://www.protezionecivile.gov.it/resources/cms/documents/Scheda_GL_AeDES.pdf

The damage assessment and usability evaluation is a quick technical assessment based on the judgement of specially trained staff and damage data, using paper-based investigation forms. Its purpose is to assess whether a post-earthquake damaged building can still be used. Furthermore, it aims to estimate the temporary housing needs, the financial needs for reconstruction, and identify priorities for the repairing of essential public assets.

The AeDES form is composed by 9 sections described in 3 pages, while a supplementary page provides explanatory remarks on how to compile it (Baggio et al. 2007). These sections are:

1. Building identification.
2. Building description.
3. Typology.
4. Damage to structural elements and short term countermeasure carried out.
5. Damage to non-structural elements and short term countermeasure carried out.
6. External damage due to other constructions and short term countermeasure carried out.
7. Soil and foundations.
8. Usability judgment.
9. Other observations.

The building usability is the primary outcome from the damage assessment and according to the AeDES form it is classified into 6 categories:

A) Usable; the building sustains small damage, but negligible risk for human life, and can be used without measures.

B) Usable only after short term countermeasures; the building is damaged, but can be used when short term countermeasures are taken.

C) Partially usable; only a part of the building can be safely used.

D) Temporary unusable; the building has to be re-inspected and it remains unusable until the re-inspection.

E) Unusable; the building cannot be used due to high structural risk, non-structural risk or geotechnical risk for human life. However, not necessarily imminent risk of total collapse.

F) Unusable because of external risk; the building could be used, but it cannot due to high risk caused by external factors, such as heavy damage adjacent building or possible rock falls.

The inspection surveys were initiated a few days after the mainshock of August 24th. The priority was given to schools in order to immediately find the most suitable alternative solutions in case of heavy damage, or to carry out fast repair interventions in buildings where slight damage had occurred. The AeDES assessment was carried out by experts from different regions, including personnel from the National Fire Brigades, researchers from the DPC Competence Centers (ReLUIS and EUCENTRE), and by professional engineers and architects coordinated through the related national professional councils. All the inspectors had to fulfil the requirement of either having completed the AeDES training courses, or having a considerable experience in using the AeDES system in past earthquakes. Around 30,000 out of 80,000 (37.5%) inspections were carried out before the second mainshock of October 26th. During the period of maximum activity, the damage and usability assessment was conducted by 160 teams per day, with each team being formed by 2-3 experts. The outcomes of the inspections until October 26th were: 50% of the inspected buildings lied in category A (directly usable), 32% of the buildings were unusable due to external risk and/or heavy damages (category E and F), and 18% of the building were evaluated within categories B to D.

In order to deal with the emergency management of cultural heritage, a strong collaboration was established between the Ministry of Cultural Heritage, the operational structures of the civil protection system, the Competence Centers, and the DPC officers. More specifically, additional levels of detail were included in the inspection forms to account for specific damages and the movability of heritage content. For this purpose, individual inspection forms were created for specific typologies of structures, such as churches, palaces and towers. The inspections of cultural heritage buildings were carried out by teams formed by ReLUIS structural and Cultural Heritage Ministry experts, without the inclusion of volunteers. The outcome the assessment was similar to the standard AeDES forms for ordinary buildings (categories A to F).

Similarly to past earthquake experiences, the DPC officers coordinating these activities underwent a high pressure by the local authorities and impacted residents, who were in need of a fast evaluation of the safety of their buildings. On the other hand, assessing the usability of a building requires awareness and responsibility, and issues that have to be managed and carefully considered even in an emergency situation. After the October 26th and 30th shocks, the number of requests increased very rapidly, and more importantly most of the buildings already inspected had to be re-inspected. Based on these facts, the DPC decided that a different strategy had to be adopted, as the number of available teams, based mainly on volunteers, was not adequate to deal with such a large number of requests in a reasonable timeframe. For these reasons, a more rapid procedure for the usability assessment of residential buildings was created. This procedure was called FAST and included investigation forms for the rapid post-earthquake usability inspection of regular buildings. Nevertheless, public buildings and essential assets continued to be inspected following the AeDES procedure. The main features of the FAST procedure were:

- "Usable" or "Not Usable" were the only possible outcomes of the assessment.
- Long training courses were no longer required, which allowed training additional staff in a short period of time.
- The «Not Usable» outcome required a further AeDES inspection to assign a specific category between B to E. However, no internal inspections were needed to assign the "Not Usable" evaluation, as the damage was not quantified.
- The «Usable» outcome still required internal inspection, and it was equivalent to the AeDES category A.
- The efficiency of this approach was about 10 FAST inspections per day per investigation team, which doubled the corresponding capability of AeDES inspections.

Figure 88 illustrates the number of daily AeDES and FAST inspections from the beginning of the usability assessment until the end of February 2017. It is evident that the introduction of the FAST procedure considerably increased the number of teams per day, which in mid-December reached

300 inspections, 75% of which performed by FAST teams. Moreover, the increasing trend after each mainshock of the seismic sequence can also be observed, which lasted approximately 1.5 months. Finally, the number of usability assessments reduced significantly during the Christmas holidays and due to the exceptional snowfall in the second half of January.

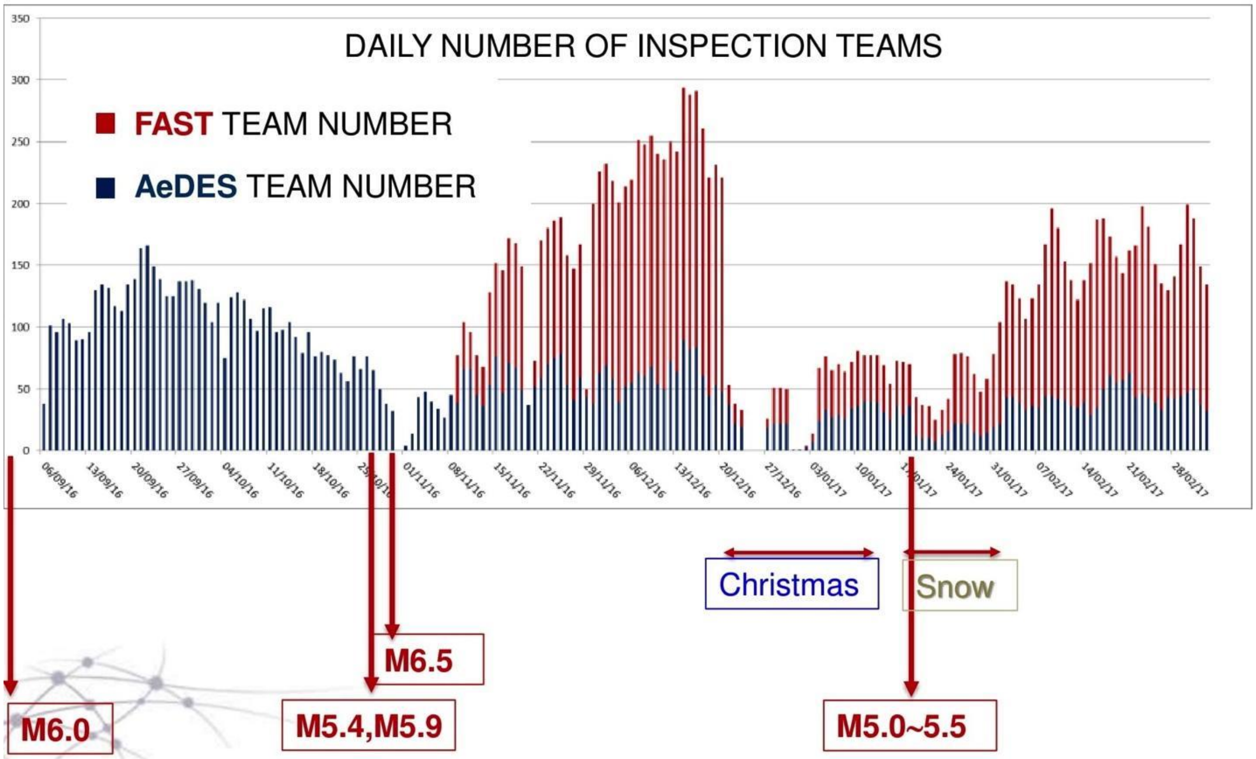

Figure 88 - Number of daily inspection teams from the beginning of the usability assessment until the end of February 2017. Reproduced from Dolce and Di Bucci 2017.

Even though the damage and usability assessment was successful considering the circumstances, and fulfilled its purpose towards the public, a vast number of inspection forms were unusable for the reconstruction process. This is due to the fact that the funding scheme adopted by the government Commissioner for the reconstruction and retrofitting reimbursement required evidence from a compiled AeDES form in order to issue a financial compensation, while the majority of the inspections were performed using the FAST forms. For this reason, when only the FAST form was available from the inspection of a residential building and the outcome was “Unusable”, a damage and usability assessment had to be completed through the compilation of the AeDES form by an expert appointed by the houseowner.

After the establishment of the government commissioner for reconstruction a few days after the first mainshock, the reconstruction process was essentially initiated. However, the responsibilities and activities for the emergency response coordination, damage and usability assessment, and the reconstruction process were kept separated. The reconstruction process had to adapt its strategy due to the multiple events during the seismic sequence, and for this reason, three reconstruction decree-laws were set into motion after each mainshock (August 24th, October 30th and January 18th).

14.4.3. Lessons learnt and recommendations

Overall, the emergency response, relief activities and the damage and usability assessment were successful. Some of the reasons for the efficiency of this system are due to the well-defined chain of command and flow of information, and the efficient collaboration amongst the various public and private stakeholders through the DPC coordination. Additionally, an important strength of the system was its link with the scientific community (through the DPC Competence Centers), which enabled up-to-date scientific and technical knowledge to inform decision-making.

Nonetheless, there are a few areas with room for improvement:

- Even though the DPC is the authorized body for the coordination of disaster management activities, it has to adapt to the 20 different regional systems in Italy. In the 2016 Central Italy earthquake sequence, 4 regions were affected, and administrative and coordination issues arose due to the different approach of each region. This reality required negotiations between the DPC and the local authorities, which caused the decentralization of the inspections management. Hence, this experience highlighted some deficiencies in this regulatory framework, where there is a mix of centralized and local autonomous authority.
- The coordination role in conjunction with technical and political guidance is fundamental to tackle the issues related with the lack of experience in post-disaster emergency situations. The DPC coordinator role, as a central decision making body, proved to be efficient in the unexpected complexities that had to be dealt with balancing and adapting the established guidelines and procedures.
- The number of building inspections to be carried out was much larger than what was required in other recent earthquakes (2009 and 2012), which stressed the existing system. This fact raised issues due to the urgency of completing damage and usability assessment for their importance in emergency and the reconstruction phases. There is a need to increase the number of experts capable of performing such damage assessments.
- Some of the difficulties in the damage assessment in the region were related with the geographical distribution of the damage covering various regions and some disruptions in the transportation infrastructure (damaged bridges, landslides, rockfalls, and building debris blocked several roads). These difficulties in combination with the occurrence of multiple shocks during the earthquake sequence delayed the completion of the inspections, and in some cases required a full restart of the activities. Such issues highlight the need to also have contingency plans for sequence of events (as opposed to single earthquakes), and to also evaluate the performance of the road network in case of disasters.
- The preparedness that is required for an efficient damage and usability assessment is of critical importance. For example, in 1997 when the guidelines of AeDES were implemented for the first time there were no trained surveyors. In 2009 and 2012 there was a limited number of AeDES trained surveyors prior to the seismic events. For this reason, training

courses had to be rapidly organized in the first days after the event to train additional volunteers. On the other hand, in 2016 the quality of the AeDES inspections had been improved due to the vast number of training sessions.

- The lack of data collection tools, centralized IT system and database for reporting and aggregating the data was a major setback. Even though the AeDES investigation forms are well-designed and include detailed technical information for further decision making, the fact that this information was just in papers limited significantly their usability. Private organizations were employed to upload the data from the forms to an oracle-based database management system. Nonetheless, a mobile application for the implementation of the AeDES forms and a GIS database for the reporting of damage in public infrastructure are under development.
- The clear definition of the scope of the damage data collection is very important and should be defined clearly before the inspections. For example, for the simply assessment of whether a building is usable or not, a simpler form was used in the Central Italy earthquakes, which improved considerably the performance of the damage and usability assessment process.
- The guidelines for emergency response and damage assessment should to be shared with all the stakeholders (public and private) before the occurrence of a disaster, this ensuring that everyone is aware of the data that will be collected. This approach will allow the identification of parameters that might be missing for specific uses, and enforce a sense of inclusiveness amongst all stakeholders. This is fundamental for the success of the activities, even if the coordinator is aware and experienced on the application of the procedure.
- It is not realistic to rely on volunteers for the conduction of the damage assessment and data collection for a long time after the occurrence of a disaster. A more comprehensive approach could be to build a core of trained operators who will lead the inspections in the aftermath of any future disaster.

15. Appendix E: Post-Disaster Data Collection and Management in the Republic of Armenia

15.1. Introduction

The main goal of this component of the project is the description of how the collection and management of disaster damage and loss data are performed in Armenia, and clarification of a few issues concerning the current condition of the system. To this end, several meetings and direct interviews with key players who have participated in disaster data collection, aggregation, assessment and reporting to any natural disaster event in Armenia were organized. The interviews were conducted using questionnaires developed by this project consortium, with recommendations from the GFDRR. Additional information was also collected that was not originally covered in the questionnaire. The team visited marzpetarans (regional government offices) in Ararat, Lori and Shirak marzes, communities of Getapnya, Ranchpar and Sipanik (Ararat marz), Lanjik (Shirak marz), Arevashogh and Spitak (Lori marz), Rescue Service Departments in Lori and Shirak marzes, and the central office of the Ministry of Emergency Situations. The interviews and discussions have been held with key players in disaster damage collection. Key players are considered those persons, who have been involved in post-event disaster assessment. The details of each interview can be found in Appendix A of this report, and the main findings were used to compile the recommendation of this section.

The interviews and discussions revealed that there were several disaster data assessment methodologies already adopted by the Ministry of Emergency Situations and Ministry of Agriculture, such as the “Multi-Cluster Initial Rapid Assessment” and “Post Disaster Needs Assessment in Agriculture Sector” toolkits. Furthermore, the publication entitled “Disaster Risk Finance Country Note: Armenia” supported by the World Bank group in 2017 was evaluated, which allowed a further investigation of the gaps and weaknesses of the current system.

The information presented in this chapter is critical for the development of protocols, field tools and aggregation systems for disaster damage and loss data collection in Armenia.

15.2. Legislation on Disaster Data Collection and Reporting in Armenia

The disaster damage and loss data collection, assessment, aggregation and reporting practice commenced after the Spitak earthquake (1988) and the establishment of the Emergency Situations Department and National Seismic Protection Service (1991). Further regulations were stipulated in the Governmental Decree No 753, dated August 14, 2001, which regulates the assessment of damages to state-owned property and 1582-N of 2011, which defines the workflow for damage and economic loss estimation caused by natural and man-made disasters to legal and physical entities.

According to degree No 753, in order to assess the damage to state-owned property from natural and man-made disasters, specific committees must be established depending on the nature, spatial coverage, and importance of the damaged assets. The committees may be established by decrees from the prime minister, regional authorities or state governance authorities. For damage assessment, the following information must be collected:

- List of buildings and structures damaged, including the type, location and short description.
- Assessment of technical condition of buildings and structures.
- List of activities to mitigate the damages to buildings and infrastructure.
- Assessment of damages to buildings and structures is estimated

Based on the preliminary assessment of damage in state-owned buildings, infrastructure, and historical monuments, experts from the associated sectors should prepare detailed project documentation and costs for rehabilitation activities, including demolishing, strengthening, renovation, space cleaning, debris removal, providing the population with temporary shelter, and construction of new buildings and infrastructure.

According to decree 1582-N, damage data from natural and man-made hazards are collected and reported using the following three-level system:

- The community loss assessment committee (LAC) consists of village mayors (head of LAC) and members of the local council, who collect and transfer damage and loss data to the regional (marz) administration.
- LAC at the regional level consists of regional governors (marzpet) or deputy marzpet (head of LAC) and respective experts from regional administration, who analyze and report to the Republican Commission.
- LAC at national level is headed by the Minister of Emergency Situations. Commission members include representatives from the Ministry of Territorial Administration, Ministry of Agriculture, Ministry of Nature Protection, Ministry of Health, Ministry of Energy Infrastructures and Natural Resources, Ministry of Culture, Ministry of Transport, Communications and Information Technologies, Ministry of Education and Science, Ministry of Economic Development and Investments, Ministry of Finance, Ministry of Emergency Situations, State Property Management Department, General Department of Civil Aviation, National Statistical Service, State Urban Development Committee, State Committee of the Real Estate Cadastre. The list of members of the Republican Commission is shown in Appendix B.

The Republican Commission can prioritize the allocation of resources during emergencies for financial compensation. For the evaluation of the three-level system, the most informed representatives from each level were interviewed. At the first level, mayors or deputy mayors of the local governments have been interviewed, which have experience with earthquakes, landslides and flood-related disasters.

15.3. Evaluation of the collected information

Visits to different regional administrations (marzpetarans) and communities showed that disaster damage collection practice varies across different marzes. In Shirak marz, the regional administration (marzpetaran) has prepared detailed forms for collection of disaster damage data. Losses from the agricultural sector are submitted to the agricultural department following the format described in Table 15, while losses to buildings and infrastructure are submitted to the department of urban development, following the format described in Table 16. Both Loss Assessment Acts (LAA) are then submitted to the rescue service department of the marz for aggregation and submission to the Ministry of Emergency Situation.

Table 15 - Farmers affected by more than 80-100% by natural disasters (hail, frostbite, mudflows) in 2017

Community	Name, Surname, Middlename	Area Affected (ha)	including (ha)																Land tax for damaged area (2017) (000's AMD)	Debt for Land Tax in 2017: (000's AMD)
			Vegetables		Grape		Crops		Fruit		Wheat		Barley		Corn		Other			
			Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)	Damage%	Area (ha)		
Total																				

Table 16 - Damage caused by strong wind in Lanjik village on March 28, 2018.

N	**First Name**	**Last Name**	**Family Name**	**Passport data**	**Type of damaged building material**				**Amount (AMD)**
					Roofing (asbestos tile, sqm)	**Glass (sqm)**	**Roofing (zinc tile, sqm)**	**Roofing (wood, m³)**	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Mari	Melikyan	Padvagani	AN0353013	75.0				150000.0

2	Svetlana	Mikaelyan	Movsesi	AM0619131	25.0				50000.0
3	Narine	Mnacakanyan	Hrachi	AM0803123			74.0	1.0	387000.0
4	Simon	Minasyan	Mkrtichi	AM0506320	40.0	5.0	18.0	0.5	229000.0
5	Mkrtich	Galoyan	Simoni	AM0534010			20.0		60000.0
6	Margarita	Khachatryan	Fedushi	4831764	20.0				40000.0
7	Irina	Mkhitaryan	Varujani	AN0545622	20.0	20.0			90000.0
8	Karine	Manukyan	Zhorzhiki	4368106	21.0				42000.0
9	Gevorg	Abajyan	Karapeti	AM0428190	30.0				60000.0
10	Javahir	Hovhannisyan	Muradi	AM0846402			50.0		150000.0
	Total				**231.0**	**25.0**	**162.0**	**1.5**	**1258010.0**

Monetary losses should be calculated based on the following prices:

- Roofing material (asbestos tile) – 1 sqm, 2000 AMD
- Roofing material (zinc tile) – 1 sqm, 3000 AMD
- Roofing material (wood) – 1 m^3 - 165000

In the Ararat marz, communities must submit damage data to the Marzpetaran electronically as a standard request note through a document management system. This is not specifically designed for damage or loss data submission. This system is used to submit other request notes to the marzpetaran. Hence, it cannot be considered as a specific tool for data collection (see Figure 89 for an illustration of the graphical user interface of this system). The Rescue Department in the Ararat marz does not take part in the assessment of damage and losses in the communities. They are just aggregating data received from the Marzpetaran (Agriculture and Urban Development departments) and then submitting them to the MES for further aggregation.

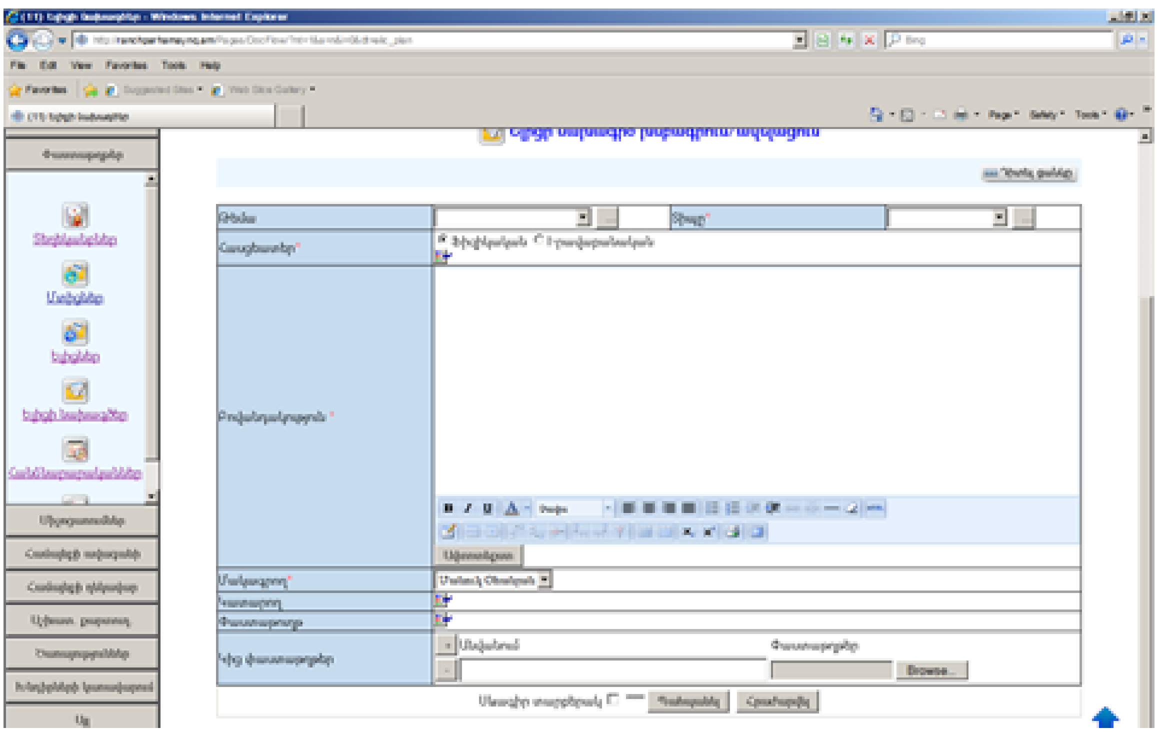

Figure 89 - Input form for sending request notes to Marzpetaran.

In the Lori marz, the damage data is collected by the LAC and then the final acts prepared by the community are endorsed by the community council and submitted to the Agriculture department and Urban development department. The format of the Loss Assessment Acts is not defined by the marzpetaran and each community creates its own individual format. For example, there were communities that prepared the LAAs with photos and detailed description of losses, while others included only the quantity of material. The Agricultural and Urban development departments of the marzpetaran summarize those damages into a table, add monetary losses (if those were not included in original LAA) and then send it to Rescue Department of the Marz along with scanned copies of LAAs. The Rescue Department of the Lori marz aggregates them into forms and sends them to the Department of Population Protection and Disaster Reduction of the Rescue service of the Ministry of Emergency Situation of Armenia.

Losses to infrastructure (water supply and sewerage, gas, electricity distribution) are assessed by the respective companies and the associated final acts are presented to the rescue service department of the marz. Losses to interstate and republican roads are assessed by the respective road maintenance companies in the regions. However, those losses are not presented to the rescue service department, and consequently not aggregated at the Ministry of Emergency Situations.

15.4. Damage Data Collection Workflow at the Ministry of Emergency Situations

In order to assess the situation of the damage and loss data collection protocols in the Ministry of Emergency Situations, we met with the Deputy head of Shirak marz Rescue Department Levon Hovsepyan, Head of Lori marz Rescue Department Karen Hovhannisyan, Head of Department for the Protection of Population and Disaster Reduction (PPDR) of the Rescue Service (RS) of the Ministry of Emergency Situations of the Republic of Armenia (Secretary of the Republican Commission) Arthour Mouradyan, Head of the Elimination of Disaster Consequences, Prediction and Programming Division of the Population Protection and Elimination of Disaster Consequences Management Department (PPEDCMD) of RS Armen Dashyan, Head of the Natural Hazards Division of the PPEDCMD of RS Hakob Hakobyan.

Rescue departments in marzes and city of Yerevan collect the LAAs, aggregate them into form No 65 (whose structure is presented in Table 17), and submit them to the PPDR of the Rescue Service of the Ministry of Emergency Situations of the Republic of Armenia. The PPDR department aggregates the information received from Rescue Departments of Marzes and presents the information to the Republican Committee for approval. At the same time, these data are provided to the Crisis Management Centre of MES, which processes them into graphs and also provides them with other disaster-related information to the Statistical Service of Armenia.

Upon approval of the funding to be transferred to physical and legal entities by the government of Armenia from the contingency fund, rescue service departments fill in form No 35 (see Table 18) and submit it to the MES again. Form No 35 includes additional information regarding the losses to be reimbursed from the Cabinet Contingency Fund.

Table 17 - Form N 65; Information Note: On Loss Assessment Acts compiled by Loss Assessment Commissions based on Government Decree No 1582-N dated November 10, 2011 "On Establishment of the Procedure for Assessing the Damage Caused to Physical and Legal Entities as a Result of Emergency Situations"

No	Marz (Yerevan city), community	The name of the disaster	Damage caused	Amount of damage (000's AMD)	Date of LAA adoption	Notes

Table 18 - Form N 35; On hazardous natural phenomena and natural disasters in the marz (Yerevan) and the work done to eliminate their consequences

N	Type of disaster	Date	Location	Damage Caused	Amount of damage (000's, AMD)	Necessary works	Allocated amount		Completed works	Notes
							Decree	Amount		

15.5. Damage Data Collection Practice at Ministry of Territorial Administration

On June 1, 2018 the Ministry of Territorial Administration (MTAD) of Armenia organized a meeting with relevant officials from the Ministry and Geocom (partner of this consortium). After this meeting a letter was sent to the MTAD for additional information. The MTAD was represented by:

- Narine Avetyan – Head of Territorial Investment Policy and Infrastructure Development Department.
- Arthour Soghomonyan – Head of Territorial Management Department.
- Karen Bakoyan – Head of Division of Coordination of Local Self-Governance Affairs of Department of Local Self – Government Policy.
- Ara Rostomyan – Head of Department of Administrative Control and Community Service Affairs.

A brief description of the project objectives and its deliverables for post-disaster assistance to the country were presented. Mr Bakoyan enquired if there are any limitations of collecting and registering disaster data depending on the disaster scale and type. He recommended that all disaster events and data related to disasters be registered, but that disasters should be classified according to intensity and scale.

Mr Soghomonyan mentioned that in practice the Ministry of Territorial Administration adheres to the Government decision No 1582-N. However, the Ministry does not collect any data related to disasters. The collected data is sent directly to MES from each Marzpetaran. He also mentioned that often communities send to them LAAs and they redirect them to MES. In case of serious disaster events (when the Government has immediately issued a decree), the Ministry of Territorial Administration directly cooperates with other Ministries as part of an Intergovernmental body. Mr Rostomyan noted that the assessment of disaster damage and losses should be methodologically justified. He also stressed that in order to have more accurate assessment of losses, pre-disaster data should be collected (particularly on buildings and infrastructure).

15.6. Existing Methodologies and Guidelines for Damage and Loss Assessment in Armenia

15.6.1. Multi-Cluster/Sector Initial Rapid Assessment (MIRA) Toolkit

MIRA is a joint needs assessment tool that can be used in emergencies, which includes the IASC System-Wide Level 3 Emergency Response. The IASC Transformative Agenda recognized the critical role of needs assessment as a basis for overall strategy development; agreed that needs assessment should be well coordinated, rapid and reviewed as necessary to reflect the changing dynamics, drivers and needs in each country and agreed that the results of needs assessments should inform the overall strategic planning and prioritization process.

Legal Framework for Introduction of Mira in Armenia

MIRA Toolkit was introduced in Armenia by decree No 888 of Minister of Emergency Situations dated May 4, 2017. The decree was adopted within the framework of the “National Strategy Programme on Disaster Risk Management” adopted on April 4, 2016 by Decree of Government of Armenia. The MIRA toolkit guideline was translated and adapted to Armenia according to paragraph 4.1 of the aforementioned governmental decree.

Section below outlines main activities and outputs of the Programme:

Development of methodological framework for disaster risk management

Activities: Adaptation of Multi-Cluster/Sector Initial Rapid Assessment Methodology

Expected Outcome: Quick Assessment of damage, losses and needs during disaster

Implementing Body: MES of RA

Co-implementing Bodies: Ministry of Health, Ministry of Nature Protection, Ministry of Agriculture, Ministry of Territorial Administration and Development, Regional Administrations, Local Governments (by consent), ARNAP (by consent), UNDP (by consent), WB (by consent).

Implementation period: 2017-2018

Financial Support: International Donor Organizations

Activities: Adaptation of International Post-disaster Multi-Cluster Needs Assessment Methodology

Expected Outcome: Improvement of Disaster Zone Rehabilitation Process:

Implementing Body: MES of RA

Co-implementing Bodies: Republican Executive Bodies, Regional Administrations (Marzpetarans), Local Governments (by consent), ARNAP (by consent), UNDP (by consent), WB (by consent)

Implementation period: 2017-2018

Financial Support: International Donor Organizations

The purpose of the MIRA Toolkit is to assist the rapid and initial assessment needs of the disaster-affected country, and to promote timely and targeted humanitarian assistance. MIRA is an inter-sector process that gives stakeholders an opportunity to have a general understanding of the current situation and its possible future development, and is a component of the Humanitarian Assessment System for Operational Assessment of needs in an Emergency. MIRA is an integral part of a larger frame of humanitarian assessments outlined in the IASC Operational Guidance on Coordinated Assessments in Humanitarian Crises which explains how to optimize the performance of existing assessment coordination structures and appropriate methodologies for the different stages of a crisis.

MIRA will be able to collect, coordinate and analyze primary and secondary data to provide stakeholders with detailed and operational information and support. The current capabilities of this framework are:

- Initial common understanding of the most pressing needs of affected populations and communities.
- Collection of information for further assessment and analysis of the needs in detail and in an operational way.
- Creation of accurate (as possible) database for response planning.
- Rapid assessment of needs based on best international experience, simplified and rapid interagency process.
- Coordination and provision of information on a multi-sector basis.
- Applicability in various situations and quick adaptability.

MIRA is implemented through a phased (Phase1 and Phase2) process of secondary and primary data collection, joint analysis and reporting. It takes place in the first two weeks following a disaster. Having a contextualized and adapted MIRA preparedness package in place before a crisis strikes will help ensure a successful MIRA exercise. The timeframe associated with the MIRA is conceptual in nature, as few crises proceed in a purely linear fashion (see Figure 90).

Figure 90 - MIRA Timeframe.

Phase 1 (0-3 days): Initial assessment

MIRA is ideally initiated by the government authority responsible for coordinating emergency assessment in the country, but can also be independently initiated by the HC and HCT. These bodies in consultation with the Government and in close coordination with the clusters, jointly determine the scope, establish a timeline and a coordination structure and identify resources for implementation.

The next step is a systematic inter-sector review of available pre-crisis and post-crisis secondary data by an assessment team. The resulting situation analysis is focused on the humanitarian dimensions of the crisis (i.e. humanitarian profile, estimated number of people in need, humanitarian access) and is the key document for informing initial strategic response planning and appeals, in particular the Flash Appeal.

Phase 2 (2 weeks): Joint data collection and analysis

On the basis of humanitarian needs identified during the review of secondary data, a field assessment is carried out to collect primary data through visits to affected areas and interviews with the affected communities. Secondary and primary data are analyzed in a joint process to generate a MIRA report that will inform the next cycle of response analysis and strategic planning.

Analytical structure of MIRA

The MIRA analytical framework classified and records information in two main areas: Crisis impact and Operational environment, each one with two domains, so that humanitarian aid organizations are provided with the necessary information to support both the affected areas and people which need humanitarian assistance, and also significantly reduce information inaccuracies affecting the final results. The format of the information coordination and classification is presented in Table 19.

Table 19 - Analytical structure of MIRA Toolkit.

<table>
<tr><th colspan="6">Crisis impact</th><th colspan="6">Operational environment</th></tr>
<tr><td colspan="3">1. Scope and scale of the crisis</td><td colspan="3">2. Conditions of the affected population</td><td colspan="3">3. Capacities and response</td><td colspan="3">4. Humanitarian access</td></tr>
<tr><td>Drivers of the crisis</td><td>Primary and secondary effects</td><td>Underlying factors</td><td>Humanitarian needs</td><td>Vulnerabilities and risks</td><td>Physical disruption of key infrastructures and losses</td><td>National and local capacities and response</td><td>International capacities and response</td><td>Affected population's coping mechanisms</td><td>Access of relief actors to affected population</td><td>Access of affected population to assistance</td><td>Security and physical constraints</td></tr>
<tr><td colspan="3">Humanitarian profile</td><td colspan="3">Severity of the crisis</td><td colspan="3">Gaps in response</td><td colspan="3">Operational constraints</td></tr>
<tr><td colspan="12">Likely evolution</td></tr>
<tr><td colspan="12">Priority humanitarian needs</td></tr>
</table>

For the effective coordination of MIRA, it is important to maintain the balance between the key actors and the groups in need of technical knowledge. The implementation of MIRA may impede the support of key players and/or involvement of many stakeholders, which can overload the coordinating mechanism and undermine the process. In case of emergency or community-level emergencies, the availability and resources available to MIRA are sufficient to conduct the necessary activities. In case of emergency situations of regional and national significance, there is a need for additional resources. Additional assistance procedures are being developed at the initial stage of MIRA implementation.

Methodology and tools

Data collection tools:

- A variety of data collection tools can be used in a MIRA. When selecting and designing tools, ensure they reflect information requirements and align with the analysis plan.
- Use a semi-structured questionnaire when little is known about a disaster, in order to encompass diversity and build a knowledge base.
- When more is known about the disaster, more structured questionnaires can be used.

Data collection techniques

Data collection should be undertaken using a mix of direct observations (DO), key informant interviews (KII) and community group discussions (CGD). The use of a combination of techniques for an assessment is critical to ensure good quality data and an age, gender and diversity-sensitive approach. Triangulation can build on the intentional combination of multiple data collection techniques, the use of a variety of data sources (various key informants, such as local leaders, teachers, health staff, etc.), ensuring different background and/or gender of the enumerators/assessors, and the use of multiple perspectives or lenses to interpret observations (i.e. protection, gender or age).

Data collection technology

The use of mobile technology (i.e. smartphones, tablets, field computers) for field data collection is an increasingly common approach. Mobile data collection can significantly reduce data entry error, the time and resources required to prepare the field data for analysis, and makes for more flexible and agile design of data collection tools. The decision to employ mobile data collection technology in the MIRA should be based on:

- The ICT environment in the area to be assessed (i.e. mobile phone/data coverage, access to electricity).
- The technical capacities of the MIRA stakeholders to adapt the technology rapidly if the system was not put in place during MIRA Phase 0: Preparedness Activities.

Joint Needs Analysis

The analysis process involves uncovering and describing patterns or trends in data and the existing relationships or associations between events and conditions observed at field level or reported by information sources. The analysis should consider available secondary and primary data. Data collection and analysis is an iterative process. New data are compared and contrasted to old, to note, confirm or contradict patterns and trends.

Reporting and Product Dissemination

The MIRA report is produced to inform strategic response planning and appeals. The purpose of the report is to help decision-makers – including the humanitarian country team, sector/cluster leads and members, the government and donors – to collectively appreciate and communicate on the nature and dynamics of the crisis and to further define strategic humanitarian priorities.

Documenting data and methods

The dissemination strategy should provide different levels of detail, formats and channels for different audiences in a series of reports, notes or briefings. In insecure environments, MIRA might contain sensitive information that cannot be shared publicly. Ensure context-specific methods are adopted for protecting and sharing data. Lack of information sharing can lead to inefficient and poorly-planned programming, the possible duplication of assessments and, subsequently, assessment fatigue among the affected population.

Recommendations for reporting

- Clearly cite limitations.
- Describe the methodology (including methods, assumptions made in developing scenarios and how conclusions were reached).
- Provide information on the data and the methods of collection and analysis.
- Be clear and transparent about the limitations of your analysis, the methods used, and your degree of confidence in the findings.
- Make the assessment questionnaires, tools, checklists, and other documentation publicly available, when possible, explaining how they were used during the assessment.
- Use assumptions but clearly define when these differ from facts or sufficiently verified information. Distinguish between facts/observations and judgement/interpretation.
- Key terms should be clearly defined to avoid misunderstanding and different interpretations. Use accepted terms and standards.
- Avoid jargon and technical language.
- Ensure the report captures how females and males and age groups have been affected.
- When using estimates for affected population figures, explain the methodology used to reach the final number or range.
- Be explicit, precise and double-check figures. Record source and other metadata.
- Include maps and use data visualization to ease understanding.
- Keep information as simple as possible while making sure no important information is omitted.
- Avoid repeating information.
- Articulate results. Translate conclusions into easily understandable language and focus on value added. Summarize the main findings briefly and clearly in an executive summary.
- Dissemination of findings is an iterative process. Products should be updated regularly. Make information available online where possible so all stakeholders can access it.
- Share findings with affected communities and national authorities to ensure accountability.
- When briefing on findings, ensure that the main differences and distinctive assistance and protection needs of the population are highlighted so as to feed into an evidence based and efficient response analysis.

- Clearly identify information gaps, or the known unknowns, and needs for further assessment phases.
- Give credit to participating stakeholders.

15.6.2. Post-Disaster Needs Assessment Methodology Developed for Agricultural Sector

The Ministry of Agriculture of Armenia with support from the European Union and the Food and Agriculture Organization has developed a methodology and guideline for post-disaster data collection, assessment and reporting of damages and losses in the agricultural sector. This guideline is an upgrade and modification of the existing post-disaster needs assessment (PDNA) methodology developed by the United Nations, World Bank and European Union in 2014. The Methodology was adopted by decree of Minister of Agriculture No 275-A, dated December 29, 2015.

The purpose of the guidance document is to provide a uniform methodology for the Government of Armenia for the assessment of damages and losses as well as post-disaster needs in the agriculture sector, including crops, livestock, fisheries and forestry. In particular, this upgrade considers and builds on the institutional setup, as well as on the territorial and administrative division of Armenia, utilizing the existing state structures for assessment of damages and losses put in place by the Ministry of Emergency Situation.

This methodology provides specific guidance and templates for post-disaster needs assessment to be used across all mentioned sectors. The methodology used allows comparison of the post-disaster assessment results to the pre-disaster national annual and multi-annual statistical averages published by the National Statistical Service of Armenia.

This methodology/guidance addresses the collection of information required for a more thorough post-disaster social and economic impact assessment, which should be a vital component when drafting the recovery and reconstruction plan. The scheme presented below shows the logical workflow of the PDNA methodology in the agricultural sector in Armenia.

1. Establishment of the PDNA Process
    a. Baseline Information and Agricultural Sector Overview.
    b. Consulting on Disaster and Consequences Assessment.
    c. Determination of Disaster Scale and Intensity (marz/national or community level).
    d. Assessment of damages and losses at asset level.
2. PDNA Implementation
    a. Pre-Disaster Assessment of information (see Note 1.).
    b. Damage and loss assessment:
        i. Evaluation of the economic value of full and partial destruction (damages).
        ii. Evaluation of the change in financial flows (losses).

c. Aggregation of Assessment Data:
   i. At community level.
   ii. At marz level.
d. Revision and compilation of the draft bulletin.

2. Definition of Recovery Strategy and Assessment of Recovery and Reconstruction Needs
   a. Develop vision and guiding principles.
   b. Assess reconstruction needs.
   c. Assess recovery needs.
   d. Develop recovery and reconstruction plan.
3. Preparation of a report on the losses and needs in Agricultural sector

Baseline information used to formulate the Agricultural Sector overview includes descriptions of:

- The people (farmers, fisher folk, and pastoralists) and their principal livelihood activities.
- Infrastructure and livelihood assets related to agriculture (including physical assets and productive equipment and inputs used to sustain agricultural livelihoods), as well as land.
- Production and delivery of agricultural goods and services.
- Governance and decision-making processes linked to and supporting the Agricultural Sector (including institutions, social organization and the policy environment).
- Pre-existing risks and vulnerabilities (including existing preparedness plans).

The methodology builds on the provisions of the Armenian Government Decree No. 1582 of November 10, 2011, further detailing and specifying the activities of the Ministry of Agriculture and providing uniform data collection, evaluation and assessment templates and procedures, leading towards development of resilience related policies.

The guide was adopted by the Ministry of Agriculture (decree No 275-A of Minister of Agriculture, dated December 29, 2015). Trainings to the staff of Agricultural departments of Marz administrations have been organized in April of 2017. However, during the interviews in marzpetarans, it was found that none of the staff was using the methodology adopted by Ministry of Agriculture.

In addition to the methodology and guideline, a web-based program was developed to assist communities and marzpetarans for providing disaster damage data. It is still in a development stage and the screenshots show that it is designed to introduce data at the asset level (see Figure 91) and aggregated level (see **Error! Reference source not found.**Figure 92).

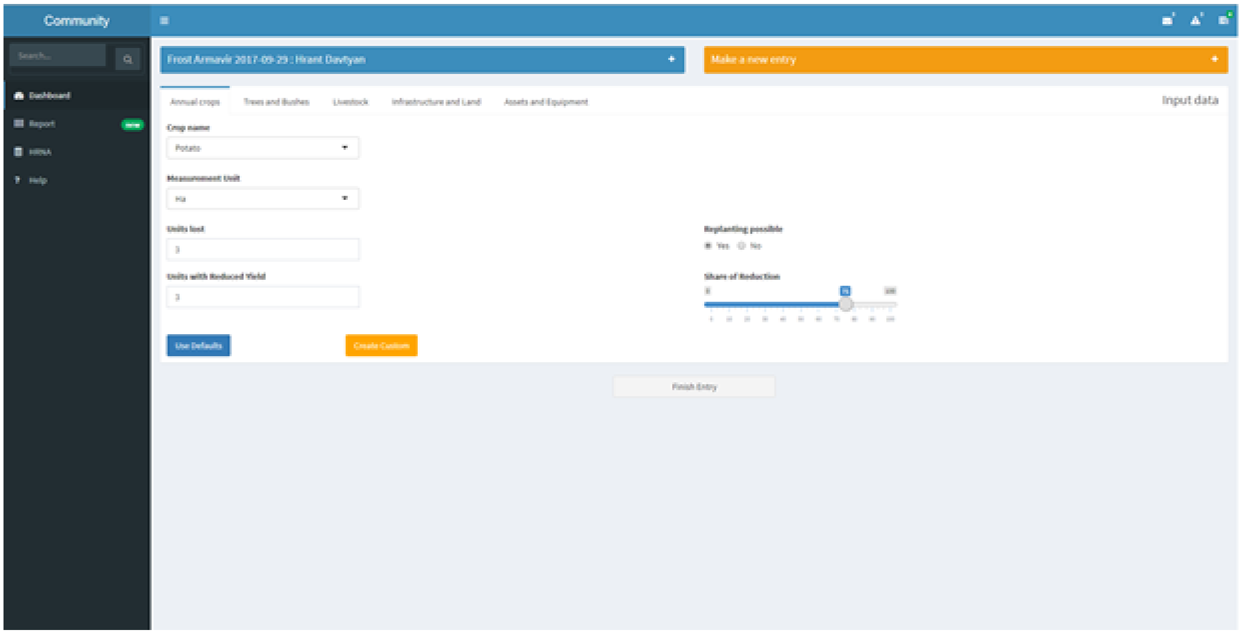

Figure 91 - Interface for registering disaster damage losses at community level.

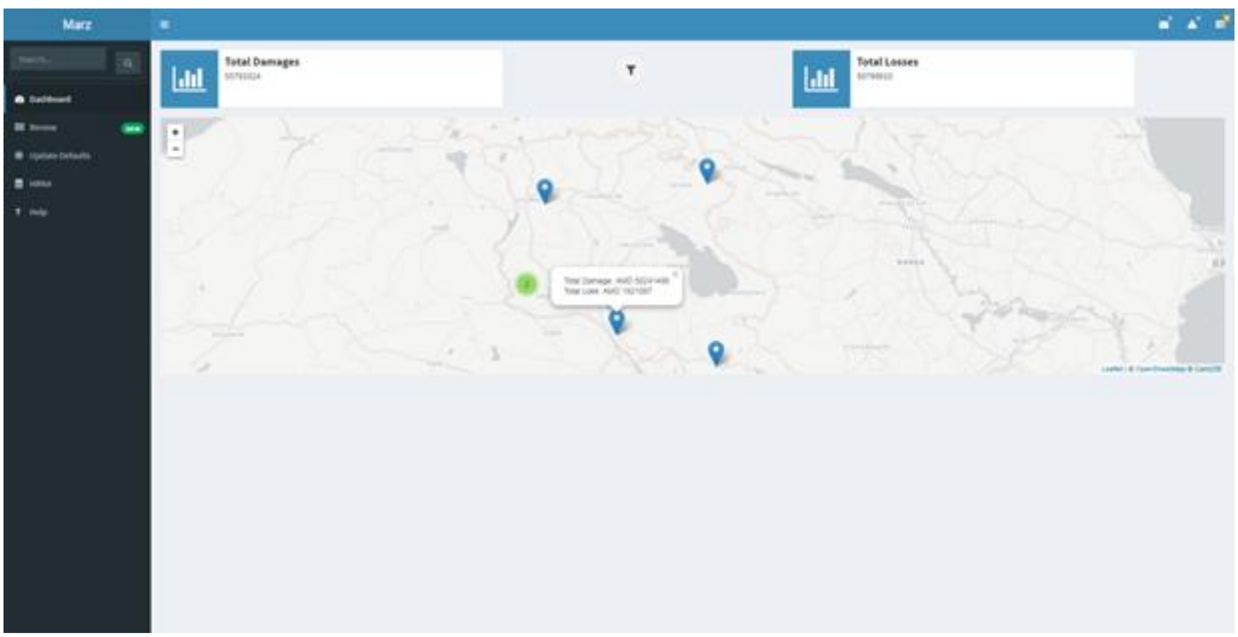

Figure 92 - Interface for viewing aggregated damages and losses at marz level.

15.6.3. Disaster Risk Finance Country Note: Armenia

A report entitled "Disaster Risk Finance Country Note: Armenia" was produced by World Bank in September, 2017, with external contributions and financial support from Japan and GFDRR. This report presents a preliminary assessment of the fiscal impacts of natural disasters in Armenia and the current state of the country's financial protection capacity. The main objective of this document is to analyse the existing legal and institutional framework for financial resilience against disasters in Armenia. At the same time, this report presents a detailed analysis of post-disaster data collection and management, current methodology, tools and practice in the country. The main findings are presented in detail in Chapter 9. Its findings and suggestions largely coincide with the results from this project. The main gaps and limitations of post-disaster data collection and management in Armenia are presented below, and some of them are compared with information received from the interviews of Armenian key players. One of the most important findings in this report is that "no official and a comprehensive dataset on disaster occurrence and damages and losses is available". Moreover, the authors of the report also mentioned that according to interviews held with government representatives, a tentative dataset covering the 1996-2010 period was prepared but had significant limitations:

- For the vast majority of cases, the damage and losses are only qualitatively presented, and there is no estimate of the monetary value of the impacts.
- Not all disaster occurrences are included in this dataset, as about 30% of the events were recorded only by specific line ministries and sectorial institutions.
- There is no guarantee of consistency across the damage and loss assessment methodologies employed.

The same opinion was expressed by key representatives from the MES. During the interviews, they noted along with the three levels (community, regional administration, and national) of chain of disaster data collection and reporting there is also a practice of direct sectorial damage assessment and reporting to Government by Ministries. For example, the Ministry of Transport, Communication and Information Technologies directly assesses and reports damages occurring on Interstate or State Roads. For this reason, the information is not centralized and there is no unified dataset on damages and losses. MES tried to establish the National Disaster Observatory of Armenia, but it did not include full and exact information on country damage and loss assessment.

This means that the only official dataset regarding disasters information is not reliable in its current state, and consequently not suitable to inform financial decision making by the government. While the challenges of disaster data availability may be considered as a matter of structural database management, they may also reflect the current institutional arrangements that govern disaster data collection routines and protocols in the country.

The current state of the framework for disaster data assessment and reporting in Armenia according to the aforementioned report is illustrated in Figure 93, along with possible weaknesses on the different stages of the process.

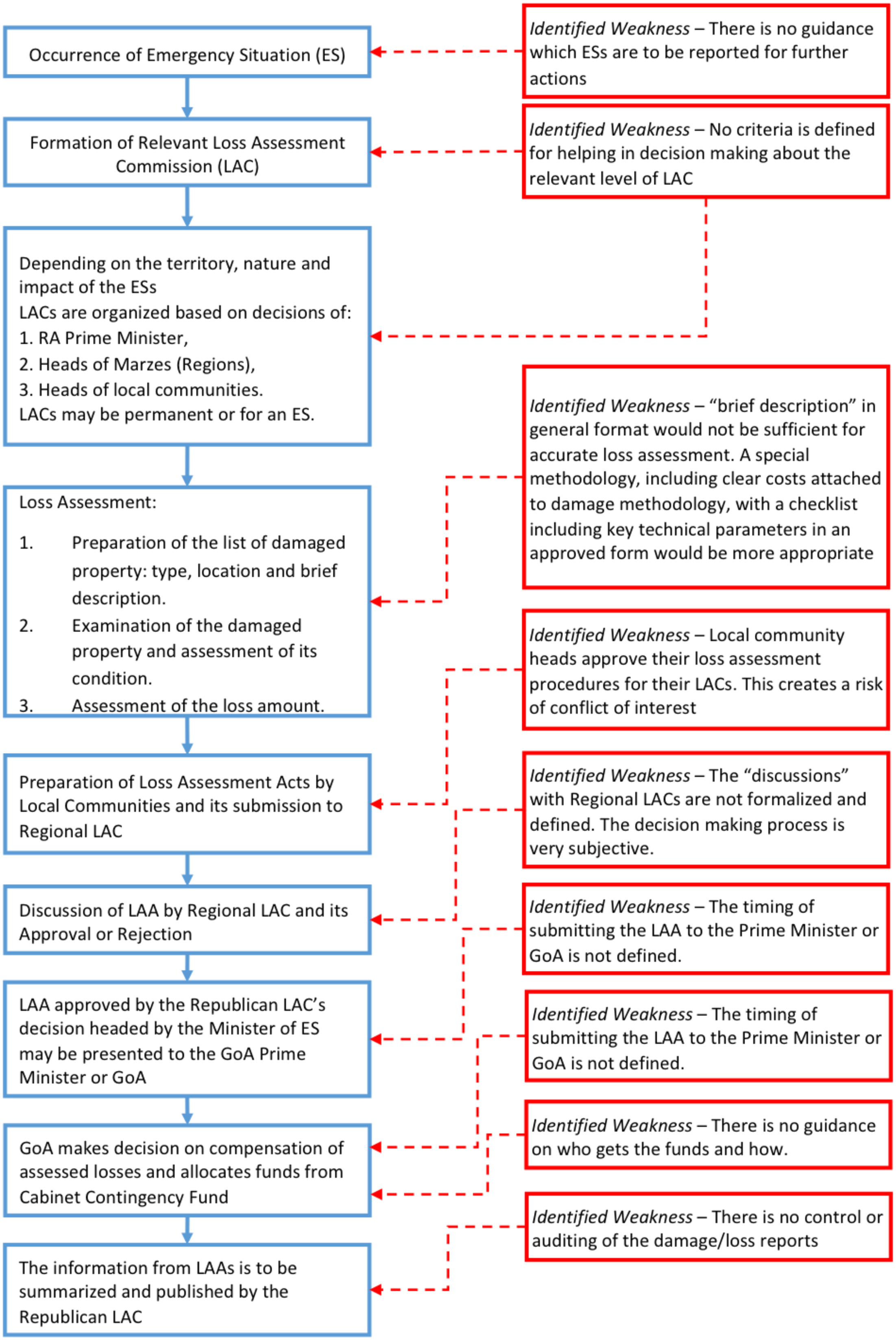

Figure 93 - Damage and Loss Assessment and Reporting Procedure.

The overall guidelines for the damage and loss assessment stipulate that:

1. The list of damaged property must include the type of property, location and a brief description.
2. The damaged property must be examined and its condition evaluated.
3. The amount of the loss to the property is to be assessed.

The damage and loss assessment should consider the following:

1. Agricultural damage and losses.
2. Damage and losses to the population's property.
3. Damages to infrastructure.
4. Possible medical-sanitary losses.

For the purpose of covering all the relevant sectors, the commissions are supposed to include experts in emergency situations, healthcare, agriculture, transport and communication, and civil construction. These experts examine, record, and assess the situation and identify possible threats in each sector. Beyond these general instructions, however, there are no officially approved damage and loss assessment methodologies to which the commissions are required to adhere when producing their estimates. This leaves room for inconsistency across events, regions, types of hazards and sectors. In this context, part of the current agenda of the MES is to prepare and approve damage and loss assessment acts in order to:

- Establish a common approach to be used by all institutions involved in disaster impact assessments.
- Strengthen the management of the information collected at different levels.

Efforts to improve the damage and loss assessment protocols are relevant to disaster risk financing because the local and regional authorities base their funding requests for disaster response on these assessments, and because greater efficiency in allocating disaster response resources requires reliable information on the impacts of disasters among different areas and sectors. Thus, from the perspective of the institutions responsible for public financial management, it is important that ongoing discussions about disaster damage assessments and any resulting reforms take into account the importance of disaster damage data as inputs to an effective financial protection strategy against natural hazards.

The revision of the disaster damage and loss data collection and management in Armenia revealed a number of inefficiencies and gaps, that go from the current protocol used for data management to the lack of a proper IT system capable of collecting reliable data in the field, and storing them in a centralized system. The recently release publication entitled “Disaster Risk Finance Country Note: Armenia” reported the following findings:

- Armenia currently relies on an extensive system for post-disaster damage and loss reporting, aggregating disaster impact upward from the community to the national level. This reporting directly determines the allocation of financial resources for disaster response from the Cabinet Contingency Fund.

- There are a number of inefficiencies in the current system that, if addressed, could fundamentally transform disaster financing in Armenia.
- The government could review the current process for bottlenecks and upgrade the current paper based system with a modern IT infrastructure. An IT based system could automate the aggregation of damage reporting, inform resource allocation, and provide the government with detailed, disaggregated information on damage and losses from disasters.
- An approved official Methodology for damage assessment would also help to allocate the funds for post-disaster expenditures across regions.

Communities preparing the LAAs mentioned that there is no timeframe specified for collecting and submitting the LAAs to marzpetarans. This is specifically important for those settlements that are included in communities having more than one village. There is only one LAC for the community and it may take a considerable amount of time for the committee to visit the village and assess the losses. The administrative representatives of communities in the villages recommended that a specific timeframe be defined to assess the losses and present them to marzpetarans.

Representatives of Marz Rescue Service Department recommended that the future tool for collecting the damage data in the field have a specific validation function that experts in different sectors can use to validate and correct data collected by communities. This is stipulated by the fact that often the communities do not have qualified experts to assess the damages and often experts from marzpetaran visit the locations and make corrections to LAAs prepared initially by communities. The representative of Shirak Marz Rescue Service Department also mentioned that it would be relevant to have a spatial representation of the event and photos of the damaged property. The final conclusion that we had from meetings with Armenian Rescue Service Departments in marzes is that they all want to have a universal tool for damage and loss assessment and registration.

Key experts from PPDR of MES outlined the importance of a single methodology for carrying out the damage data collection at lower levels, since they have difficulty in aggregating and presenting the collected data to the government in one format. MES has raised this issue to different ministries (especially for quantifying the damages in monetary terms), but this issue was not resolved up to now. MES has also developed and recommended a template for use by communities based on Decree 1582-N. This template was submitted to different ministries and also marzpetarans for discussion and amendments (see Table 20). MES also stressed the importance of having a single web-based platform for registration and sharing of damage and loss data collected by communities, verified by regional authorities, regional ARS departments and MES. The existence of a single web based platform would allow tracking the flow of damage data collection from the community to the government and improve the transparency and efficiency of the resource allocation. Other relevant ministries involved in assessing and mitigating the losses would also benefit from open web-based platform, by having access to damage data information on a permanent basis.

Ministry of Emergency Situations operates and maintains a number of Servers that provide internal document workflow and provide connection of the Ministry with the Government and other Agencies. There are also a number of dedicated servers (e.g. a server provided by JICA for registering seismic activity and a server for registering landslide movement) that operate independently for receiving, storing and transmitting data to Crisis Management Centre and respective regional rescue service departments. All servers are located in a basement and access to these servers is highly restricted. Remote connection to servers is prohibited.

Given the current situation, it is highly recommended that the proposed solution be easy to install and configure, so that the IT administrator has no problems installing and maintaining it. Moreover, it would be better if the software comes pre-installed on the server. Geocom has developed 2 programs for MES and in both cases Geocom has pre-installed the software, tested in its office and then provided the servers along with the pre-installed software to MES.

Table 20 - Template Recommended by MES for Communities for Assessing Losses According to Decree 1582 - N

Name of the emergency situation	Date	Number of registered emergency situations	Economic Losses (000s AMD)	Number of people affected by the emergency			Buildings, structures	Technique	Crops (tons)	Land area (orchards/ ha)	Domestic animals	Forage
				Died	Affected, Injured	Temporarily displaced (Evacuated)						
				Total	Total							
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.

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17. Appendix F: Results from the interviews in Armenia

Required questions to all key-players

1. Name
2. Organization
3. Participation in Past Events
4. What was your role in the disaster data collection and/or reporting?
5. Which hazard(s) was (were) covered in the disaster data collection?
6. What was the resolution and level of aggregation used for the disaster data collection?
7. What type of data was collected?
8. What was the purpose (end use) of the disaster data and who were the main users?
9. Did you have experience in advising decision makers for the purpose of allocating resources?

Disaster Data Collection Methodology

10. Which protocol(s) was (were) followed for the disaster data collection?
11. Did the protocol have a clear method of estimating the monetary losses given the reported damage on buildings and infrastructure?
12. Which authority/organization(s) coordinated the data collection procedure? How many and which independent organizations, stakeholders and authorities participated? Was the collaboration effective?
13. Was the collected information disseminated among the involved entities? Who has access to the data and who monitors or controls this access?
14. Did assessment teams of specialists from various fields conduct the data collection? If yes, which fields? Any recommendations for future assessment team composition?
15. Did the methodology have a predefined framework and time-frame? Were the guidelines transparent and efficient?
16. Using a scale of 0= Unsuccessful and Inefficient to 10= State of the art, please rate the overall methodology's/protocol's performance.
17. What were the main advantages of the protocol?
18. What were the main limitations of the protocol, and what would you improve?

Field Data Collection Tools

19. Which IT tools have you used for disaster loss data collection? If 'none', were paper data collection forms used?
20. Which type of input data was (were) was supported by the tool(s)?
21. Which baseline data were required by the tool(s)?
22. Which level of expertise is needed for using the tool(s)?
23. Were mapping tools available for supporting the in-field assessment?
24. Which level of data accessibility is supported by the tool(s)?
25. Were statistical and mapping tools for post-processing included into the tool(s)?
26. What was the technology used to develop the tool(s)?

27. Using a scale of 0= Unsuccessful and Inefficient to 10= State of the art, please rate the overall tool(s) performance.
28. What were the main advantages of the tool(s)?
29. What were the limitations of the tool(s), and what would you improve?

Data Reporting and Aggregation System

30. How were the resulting damage data aggregated and reported? What tool(s) were used?
31. At what level of aggregation did you need to report the results?
32. In what format were the resulting data reported?
33. If you used data reporting tools, could you see the original damage data in its full granularity?
34. In which format(s) do data need to be extracted from the reporting system?
35. What was the technology used to develop the system?
36. Using a scale of 0= Unsuccessful and Inefficient to 10= State of the art, please rate the overall reporting and aggregation system's performance.
37. What were the main advantages of the system?
38. What were the limitations of the system and what would you improve?

A. Davit Minasyan

1. Davit Minasyan
2. Administrative head of Lanjik village.
3. Yes
4. Data Collection and submission of damage data to Marzpetaran.
5. Strong winds, hail.
6. Asset.
7. Damaged and destroyed buildings, damaged equipment and infrastructure, damaged crop area
8. Marzpetaran (regional authority).
9. No.

Disaster Data Collection Methodology

10. Forms adopted by Marzpetaran.
11. Yes.
12. The procedure was coordinated by Marzpetaran.
13. Aggregated data is submitted to the Marzpetaran.
14. Disaster data is collected by LAC of communities.
15. No.
16. 7
17. /
18. /

Field Data Collection Tools

19. Paper data collection forms were used.
20. Information
21. None
22. Low.
23. No.
24. /

25. /
26. /
27. 7
28. Forms are available for quickly filling in the missing data.
29. No time frame specified for completing and sending the damage data.

Data Reporting and Aggregation System

30. LAC of Community submitted data in corresponding forms and provided to Marzpetaran.
31. Asset level
32. Tables.
33. No data reporting tools were used.
34. Print, Download, Web-links, Other.
35. /
36. 8
37. /
38. /

B. Hrant Gevorgyan

1. *Hrant Gevorgyan*
2. *Ararat Marz, Head of Sipanik Community*
3. *Yes.*
4. *Data collection*
5. *Strong winds, hail.*
6. *Asset.*
7. *Homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure*.
8. *Marzpetaran and MES*
9. *No*

Disaster Data Collection Methodology

10. *No protocols have been used*.
11. *No*.
12. *Marzpetarans and Rescue Service Departments of MES*.
13. /
14. *Data was collected by specialists from various fields (urban development, agriculture)*
15. *No*.
16. 7.
17. /
18. /

Field Data Collection Tools

19. *Data was collected on paper; no specific data collection forms were used.*
20. *Photographs.*
21. /
22. *Moderate*
23. *No.*
24. /

25. /
26. /
27. *4.*
28. /
29. /

Data Reporting and Aggregation System

1. *Collected data is submitted to Marzpetaran by «Community Management Information System» software.*
2. *Municipality (admin 3).*
3. *Tables, Images*
4. *No data reporting tools were used*
5. *Print, Download, Other*.
6. /
7. *8.*
8. /
9. /

C. Davityan Zvard

1. *Davityan Zvard*
2. *Ararat Marz, Secretary of the Staff in Ranchpar community*
3. *Yes*
4. *Data collection*
5. *Strong winds, frostbite*.
6. *Asset.*
7. *Damaged and destroyed buildings, damaged equipment and infrastructure*.
8. *Marzpetaran.*
9. *No.*

Disaster Data Collection Methodology

10. *No protocols have been used.*
11. *No*.
12. *Marzpetaran*
13. *Aggregated data is submitted to the government.*
14. *Data was collected by LAC of community.*
15. *Yes*.
16. *5*.
17. /
18. /

Field Data Collection Tools

19. *Paper forms were used. No specific data collection forms were used.*
20. Maps, Photographs, Information, Damage data, Other.
21. /
22. High, Moderate, Low, None.
23. /
24. /
25. /

26. /
27. *5*.
28. /
29. /

Data Reporting and Aggregation System

30. *Collected data was submitted to Marzpetaran by "Community Management Information System" software.*
31. *Municipality (admin 3).*
32. *Tables, Images*.
33. *Yes.*
34. *Print, Download*.
35. /
36. *7.*
37. *It is possible to send collected data quickly.*
38. *Sometimes the program is not responding.*

D. Armen Janazyan

1. *Armen Janazyan*
2. *Lori Marzpetaran Head of Urban Development Department*
3. *No*
4. *Data Aggregation and submission of damage data to ARS and Ministry of Territorial Administration.*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows*.
6. *Asset*
7. *Homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure.*
8. *The Government of Armenia.*
9. *No*

Disaster Data Collection Methodology

10. *No protocols used.*
11. No.
12. *The procedure was coordinated by Marzpetaran*.
13. *Aggregated data is submitted to the government and GOA may disseminate the information among the ministries. .*
14. *Disaster data is collected by LAC of communities. Marzpetaran specialists checked and aggregated data.*
15. /
16. 6
17. /
18. /

Field Data Collection Tools

19. No specific paper data collection forms were used.
20. Maps, Photographs, Information, Damage data, Other – Road signage was mentioned.
21. /

22. /.
23. No
24. /
25. /
26. /
27. 6
28. /
29. /

Data Reporting and Aggregation System

30. *Collected data was aggregated by MTCIT and provided to Government.*
31. Asset level, Municipality (admin 3).
32. Tables.
33. No data reporting tools were used
34. Print, Download, Web-links, Other.
35.
36.
37.
38.
39.

E. Karen Hovhannisyan

1. *Karen Hovhannisyan*
2. *Ministry of Emergency Situations of Republic of Armenia Head of Lori Department of ARS*
3. *No*
4. *Data Aggregation and submission of damage data to the MES*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows.*
6. *Asset, Municipality*
7. *Fatalities, injuries, homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure.*
8. *The Government of Armenia, Crisis Management Centre of MES.*
9. *No*

Disaster Data Collection Methodology

10. *Form 35 and Form 65, adopted by Minister of MES and submitted by Rescue Services of Marzes*
11. *No.*
12. *The procedure was coordinated by MES and Regional Administration. Water, Gas, Electricity supply companies calculate the losses themselves and present data to MES.*
13. *Aggregated data is submitted to the government.*
14. *Disaster data is collected by communities. Specialists from Regional Administration can check and edit data.*
15. *No.*
16. *7.*
17. *The forms provide the ability to quickly provide data to MES.*

18. *No possibility to present more detailed information and correct assessment of losses.*

Field Data Collection Tools

19. /
20. /
21. /
22. /
23. /
24. /
25. /
26. /
27. /
28. /
29. /

Data Reporting and Aggregation System

30. *Data received from communities, is aggregated by specialists in Marzpetaran and submitted to ARS departments in Marzes. ARS departments then provide it to MES.*
31. *Municipality (admin 3). LAAs are attached*.
32. *Tables.*
33. *No data reporting tools were used*
34. *Print*
35. /
36. 6
37. /
38. /

F. Levon Hovsepyan

1. *Levon Hovsepyan*
2. *Ministry of Emergency Situations of Republic of Armenia Lori Department of ARS Head of Population Protection Department*
3. *Yes*
4. *Data Aggregation and submission of damage data to MES*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows.*
6. *Asset, Municipality*
7. *Fatalities, injuries, homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure.*
8. *The Government of Armenia, Crisis Management Centre of MES.*
9. *No*

Disaster Data Collection Methodology

10. *Form 35 and Form 65, adopted by Minister of MES*
11. *No.*
12. *The procedure was coordinated by Regional Rescue Department of MES and Marzpetaran.*

13. *Aggregated data is submitted to MES.*
14. *Disaster data is collected by specialists from various fields (emergency situations, urban development, ecology, agriculture, social security).*
15. *No.*
16. *7.*
17. *The loss can be easily calculated by the cost scale presented in the form.*
18. *It is impossible to display accurate information about losses.*

Field Data Collection Tools

19. *Only paper forms.*
20. Maps, Photographs, Information, Damage data, Other.
21. *None*
22. *Low*
23. *No.*
24. /
25. /
26. /
27. /
28. /
29. /

Data Reporting and Aggregation System

30. *Data received from communities is aggregated by ARS departments and then provided to MES.*
31. *Municipality (admin 3).*
32. *Tables.*
33. *No data reporting tools were used*
34. *Print.*
35.
36.
37. *Allows viewing the events in generalized form.*
38. *Currently, there is no software system in place, but it would be desirable to create a tool that will be able to collect data in the field, attach pictures, and have a mapping possibility.*

G. Arthour Mouradyan

1. *Arthour Mouradyan*
2. *Ministry of Emergency Situations of Republic of Armenia, Head of Department for the Protection of Population and Disaster Reduction of the Rescue Service of the Ministry of Emergency Situations of the Republic of Armenia (Secretary of the Republican Commission)*
3. *No*
4. *Data Aggregation and submission of damage data to the Government of RA*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows, rockfalls.*
6. *Asset, municipality*
7. *Fatalities, injuries, homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure.*

8. *The Government of Armenia, Crisis Management Centre of MES.*
9. *No*

Disaster Data Collection Methodology

10. *Form 65, adopted by Minister of MES and submitted by Rescue Services of Marzes. Besides form 65, MES has developed cluster methodology for disaster data collection based on MIRA methodology, which was adopted by ministerial decree No 888 on August 4, 2017. However, this methodology is not used.*
11. *No.*
12. *Marzpetarans and Rescue Service Departments of MES*
13. *Aggregated data is submitted to the government and GoA may disseminate it among the relevant ministries*
14. *Initial data is collected by LAC of communities. Respective departments in Marzpetaran check the information and, if needed, may visit and validate the damages and apply corrections.*
15. *No.*
16. *6.*
17. *It provides quick assessment of the situation*
18. *No detailed assessment of damages. No clear methodology for assessment of losses.*

Field Data Collection Tools

19. /
20. Maps, Photographs, Information, Damage data, Other.
21. /
22. High, Moderate, Low, None.
23. /
24. /
25. /
26. /
27. /
28. /
29. /

Data Reporting and Aggregation System

30. *Data is aggregated from MS Word documents (form 35) provided by ARS department of Marzes*
31. *Municipality (admin 3). LAAs are attached*.
32. *Tables, Graphs.*
33. *No data reporting tools were used*
34. *Print.*
35. /
36. 4.
37. *None*
38. *Ministries should provide their methodology for Governmental decree 1582-N. However, up to now they haven't developed this methodology.*

H. Armen Dashyan

1. *Armen Dashyan*
2. *Ministry of Emergency Situations of Republic of Armenia, Deputy Head of Department for the Protection of Population and Disaster Reduction of the Rescue Service of the Ministry of Emergency Situations of the Republic of Armenia*
3. *No*
4. *Data Aggregation and submission of damage data to the Government of RA*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows, rockfalls*.
6. *Asset, municipality*
7. *Fatalities, injuries, homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure*.
8. 8. *The Government of Armenia, Crisis Management Centre of MES.*
9. 9. *No*

Disaster Data Collection Methodology

10. *Form 65 and Form 35, adopted by Minister of MES and submitted by Rescue Services of Marzes*
11. 2.
12. Which authority/organization(s) coordinated the data collection procedure? *How many and which independent organizations, stakeholders and authorities participated? Was the collaboration effective? Marzpetarans and Rescue Service Departments of MES*
13. *Aggregated data is submitted to the government and GoA, Crisis Management Centre of MES. Crisis management centre provides these data to Statistical Service of Armenia. Government may disseminate it among the relevant ministries for commencing mitigation activities*
14. *Initial data is collected by LAC of communities. Respective departments in Marzpetaran check the information and, if needed, may visit and validate the damages and apply correctio*ns. In many cases, independent experts have been involved for assessment of damages (for example the landslide in Toumanyan community).
15. 6.
16. /
17. *The form provides a quick overview of monetary losses incurred in the community*
18. *Having a web-based tool for collecting and assessing the LAAs would be preferable. The tool should have a clear methodology for assessing the monetary losses.*

Field Data Collection Tools

19. /
20. /
21. /
22. /
23. /
24. /

25. /
26. /
27. /
28. /
29. /

Data Reporting and Aggregation System

30. *Data is aggregated from MS Word documents (form 35) provided by ARS departments of Marzes. After some time ARS departments send form 65 for assessing what was done to mitigate the effects of natural disasters*
31. *Municipality (admin 3). LAAs are attached.*
32. *Tables, Graphs.*
33. *No data reporting tools were used.*
34. *Print.*
35. /
36. *4*.
37. /
38. /

I. Hakob Hakobyan

1. ***Hakob Hakobyan***
2. *Ministry of Emergency Situations of Republic of Armenia, Head of Natural Disasters Department of the Rescue Service of the Ministry of Emergency Situations of the Republic of Armenia*
3. *No*
4. *Data Aggregation and submission of damage data to the Government of RA*
5. *Earthquake, flood, landslide, wildfire, strong winds, hail, frostbite, mudflows*.
6. *Asset, municipality*
7. *fatalities, injuries, homeless or relocated people, damaged and destroyed buildings, damaged equipment and infrastructure.*
8. *The Government of Armenia, Crisis Management Centre of MES.*
9. *No*

Disaster Data Collection Methodology

10. *Form 65, adopted by Minister of MES and submitted by Rescue Services of Marzes*
11. *No*.
12. *Marzpetarans and Rescue Service Departments of MES.*
13. *Aggregated data is submitted to the government and GoA may disseminate it among the relevant ministries.*
14. *Initial data is collected by LAC of communities. Respective departments in Marzpetaran check the information and, if needed, may visit and validate the damages and apply corrections.*
15. *No.*
16. *6.*

17. *It provides quick assessment of the situation.*
18. *No detailed assessment of damages. No clear methodology for assessment of losses.*

Field Data Collection Tools

19. /
20. /
21. /
22. /
23. /
24. /
25. /
26. /
27. /
28. /
29. /

Data Reporting and Aggregation System

30. *Data is aggregated from MS Word documents (form 35) provided by ARS department of Marzes*
31. *Municipality (admin 3). LAAs are attached*.
32. *Tables, Graphs.*
33. *No data reporting tools were used*
34. Print, Download, Web-links, Other.
35. /
36. /
37. /
38. /

18. Appendix G: Members of the Armenian Republican Commission

Members of the Republican Commission for assessment of the damages of physical and legal entities as a result of emergency situations.

H. Rostomyan	Minister for Emergency Situations (Chairman of the Commission)
A. Petrosyan	First Deputy Minister of Labor and Social Affairs of the RA
K. Isakhanyan	Deputy Minister of Territorial Administration and Development of the RA
A. Harutyunyan	Deputy Minister of Agriculture of the RA
Kh. Hakobyan	Deputy Minister of Nature Protection of the RA
T. Sahakyan	Deputy Minister of Healthcare of the RA
H. Harutyunyan	Deputy Minister of Energy Infrastructures and Natural Resources of the RA
A. Pogosyan	Deputy Minister of Culture of the RA
B. Demirkhanyan	Deputy Minister of Transport, Communication and Information Technologies of the RA
D. Sahakyan	Deputy Minister of Education and Science of the RA
A. Adilkhanyan	Head of the Legal Department of the Legal Department of the RA Ministry of Finance
E. Tarasyan	Deputy Minister of Economic Development and Investments
M. Ghazaryan	Director of the Rescue Service Ministry of Emergency Situations of the RA
V. Gasparyan	Deputy Head of the State Property Management Department under the Government of the Republic of Armenia
A. Poghosyan	Deputy Head of Civil Aviation at the Government of the Republic of Armenia
L. Mirzoyan	Deputy Chairman of the National Statistical Service of the Republic of Armenia (by consent)
A. Nazaretyan	Head of the Department of Construction and Scientific and Technical Regulation of the State Committee for Urban Development at the RA Government
L.Manukyan	Head of the Department of Geodesy and Cartography of the State Committee of Real Estate Cadastre adjunct to the Government of the Republic of Armenia
A. Muradyan	Head of the Department for the Protection of Population and Disaster Reduction of

	the Rescue Service of the Ministry of Emergency Situations of the Republic of Armenia (Commission Secretary)

19. Appendix H: Site Data Collection Tool Functional Requirements Document

JBA consulting

Post-Disaster Data Collection - Data Aggregation and Reporting System

Functional Requirements Document

August 2018

www.jbaconsulting.com

THE WORLD BANK

The World Bank
1818 H Street, NW
WASHINGTON DC
20433
USA

JBA Project Manager

John Bevington
8a Castle Street
WALLINGFORD
Oxfordshire
UNITED KINGDOM
OX10 8DL

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2.0 / 17th August 2018	Modifications based on partner comments	GEM Foundation
2.1 / 20th August 2018	Report format change	Project partners and World Bank
3 / 16th November 2018	Final version	World Bank Group

Contract

This report describes work commissioned by the Global Earthquake Model (GEM) Foundation on behalf of the World Bank Group, by a letter dated 9th March 2018. GEM's representative for the contract was Dr Vitor Silva. Derek Farrier and Dr John Bevington of JBA Consulting carried out this work.

Prepared by .... Derek Farrier BSc MSc MCP MBCS CITP

Technical Director

.... John Bevington BSc MSc PhD DAS

Technical Director

Reviewed by .... Andrew Gubbin BSc MSc PGDip CEng MICE FCIWEM C.WEM MBCS

Director

Purpose

This document has been prepared as a Draft Report for the GEM Foundation. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

JBA Consulting has no liability regarding the use of this report except to the GEM Foundation.

JBA consulting

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We are grateful for the feedback received to date from Benedikt Signer and Mathijs van Ledden from the World Bank and would like to acknowledge the contributions to this report received from project partners: the GEM Foundation, the CIMA Foundation and GEO-COM.

Carbon footprint

A printed copy of the main text in this document will result in a carbon footprint of 173g if 100% post-consumer recycled paper is used and 220g if primary-source paper is used. These figures assume the report is printed in black and white on A4 paper and in duplex.

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Executive summary

Countries prone to the effects of natural hazards have a responsibility to carry out rapid post-disaster damage assessment and loss estimation to understand the spatial scale of the event and its impacts on populations, assets and the economy. Ideally, data should be captured at the asset level, with supplementary display, analysis, aggregation and reporting tools provided to allow government agencies to allocate funds for response and recovery efforts. However, the process for undertaking post-disaster damage assessment differs widely between countries in terms of designated responsibility, protocols and technologies available for use. Rarely has it been seen that decision makers have a transparent audit trail linking aggregated loss estimations to the individual assets that have been inspected.

This report provides a conceptual design of an in-field post-disaster damage data and loss capture tool. The tool, designed to run on hand-held tablet hardware, is based on open-source software, databases and secondary data. The design describes a tool that is expansible in nature, allowing a variety of stakeholders to use the tool to collect data on damage to a variety of Exposed Elements, e.g. population, buildings, transportation, lifelines, critical facilities, agricultural assets. The tool supports data collection for a number of use cases, including basic and detailed damage assessment, building safety inspections and asset-level tracking of recovery and reconstruction.

The tools fit into the conceptual framework and protocol outlined in the main report. The conceptual design for a linked data aggregation and reporting system is also provided in a separate document (see Appendix B of the main report).

This report was commissioned by the World Bank as part of project 1250664 - Improving Post-Disaster Damage Data Collection to Inform Decision Making.

Contents

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Abbreviations

API .... Application Programming Interface
AWS .... Amazon Web Services
BCA .... Benefit-cost Analysis
CSV .... Comma Separated Values
DATA .... Disaster Loss Data
EMS .... European Macroseismic Scale
FONDEN .... Mexico natural disaster fund
FRD .... Functional requirements document
GED .... Global Exposure Database
GEM .... Global Earthquake Model
GDPR .... General Data Protection Regulation
GPS .... Global Positioning System
HTTPS .... Hyper Text Transfer Protocol with Secure Sockets Layer
IDCT .... Inventory Data Capture Tools
JSON .... JavaScript Object Notation
KML .... Keyhole Markup Language
LAN .... Local Area Network
M_w .... Earthquake moment magnitude scale
MAGE .... Mobile Awareness GEOINT Environment
MoSCoW .... Must have, Should have, Could have, Won't have
NDOIS .... National Disaster Observatory Information System
NGO .... Non-governmental organisation
OCR .... Optical Character Recognition
OGR .... Open source library of vector manipulation tools
OS .... Operating System
OSM .... OpenStreetMap
PDF .... Portable Document Format
QR .... Quick Response
RASOR .... Rapid Analysis and Spatialisation of Risk
UNISDR .... United Nations International Strategy for Disaster Reduction
URL .... Uniform Resource Locator
USD .... United States Dollars
USGS .... United States Geological Survey
UTC .... Universal Coordinated Time
WAN .... Wide Area Network
WGS .... World Geodetic System
WHE .... World Housing Encyclopaedia

1 Introduction

1.1 Purpose

The purpose of this document is to advise on the functions required to achieve a post-disaster data collection mobile application that will collect data for use within a centralised data aggregation and reporting system.

1.2 Intended audience

This document is intended to advise the World Bank on the requirements needed to achieve an expansible post-disaster system for aggregating post-disaster data and derived reporting of this data. These requirements could then be used to procure the application via a future development project.

1.3 Product scope

The scope of this document is to provide a conceptual design for a data aggregation and reporting system which will analyse and report on data collected in the field at the asset-level by a site data collection tool (described in Appendix A). The overall solution should be customisable for use independently by multiple countries according to their specific needs. A degree of standardisation is provided to allow the aggregation of data across multi-country events.

The main users of this solution are expected to be a national or regional disaster management authority working alongside the local Ministry of Finance / designated authority responsible for distributing relief and recovery funding in their sector. There are a range of other potential users who may benefit from using the solution, including government agencies, multi-lateral agencies and donors, non-governmental organisations (NGOs) or private organisations.

A key objective of this design is to provide a practical, easy to use, low cost and extensible application for rapidly analysing, aggregating and reporting on post-disaster damage and loss data.

The proposed software solution should be able to analyse data on damage caused by a number of perils, including:

- flood,
- earthquake,
- landslide,
- tropical cyclone.

The design should be flexible to allow future addition of perils such as:

- droughts,
- extreme temperatures,
- tsunami,
- volcanic activity.

In the context of this project, the solution should be able to analyse damage and loss inventories for the following physical assets:

- residential buildings,
- public buildings,
- commercial and industrial buildings,
- critical facilities (schools, hospitals, power plants),

- infrastructure (road, rail),
- agricultural crops.

The functional requirements considered here will need to be considered in light of the cost of running a system, hardware costs, training and IT capabilities of users.

A conceptual design for the linked post-disaster site data collection tool is presented in Appendix A of the main report - Post-disaster Data Collection – Site Data Collection Functional Requirement Document (FRD) and should be read in conjunction with this document.

2 Overall description

2.1 Product perspective

The conceptual design of an aggregation and reporting system based on a data collection takes into account the proposed conceptual framework presented in the Phase I report (Figure 2-1). The solution is designed to collect data within Phases 1, 2 and 3 of the conceptual framework.

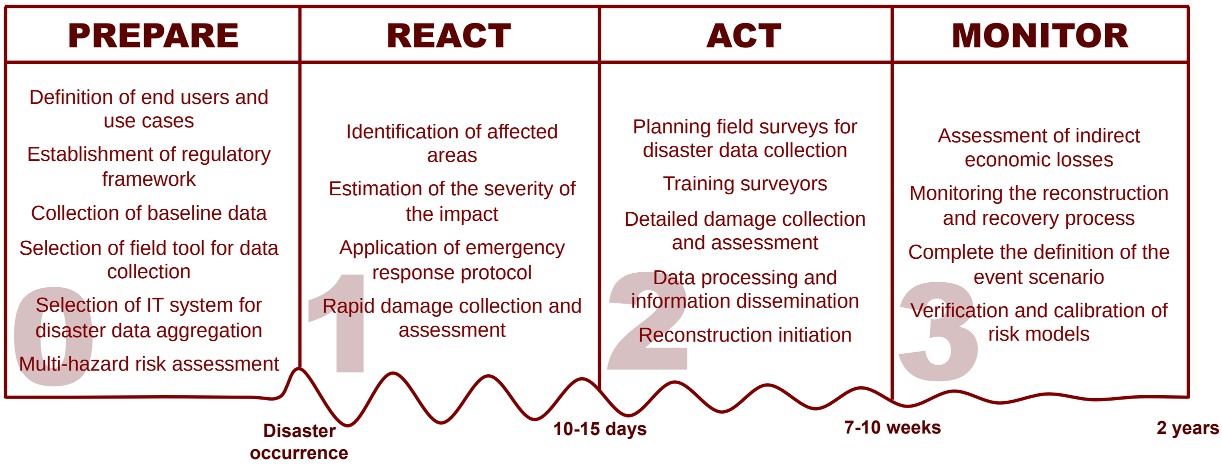

Figure 2-1. Conceptual framework developed in Phase I of the project

There are a variety of methods for aggregating post-disaster data and reporting on the damage and loss outcomes as listed and discussed within the project Phase I report. With respect to reporting of data, each country has its own methodology and reporting requirements within their governmental and administration hierarchy.

The functional requirements defined here aim to leverage the learning on best practice, structure and products outlined in Phase I, extracting the strengths of the technology products presented and provide a coherent design from these strengths taking in current technologies.

The product needs to provide a transparent and low-cost solution for adoption by users in low to middle-income countries and will hence uses open source components by choice.

In developing these requirements, we have drawn on best practice and design of a number of systems reviewed in Phase I:

- **AJDA**: Evidence based multi-hazard damage and loss data aggregation, spatially defined events, data review and country specific legislation
- **NDOIS:** Country legislated reporting formats
- **FloodCat:** Modern interface and architecture, geospatial representation and event data management
- **DesInventar**: Sendai framework repository
- **RASOR**: Multi-hazard taxonomy and Sendai framework output
- **Global Exposure Database (GED):** Taxonomy, visual taxonomy support (GED4GEM, GED4ALL)
- **MAGE:** Open source dual-platform customisable web aggregation tool using a NoSQL

As with the site data collection tool, it should be noted that none of the above systems are considered to be suitable for direct adoption as a single application without modification due to limitations within each system. However, although the data model, form templating, taxonomy and reporting used with MAGE will require modification, the technology stack used within the product and open source Apache licensing mean that MAGE could provide a suitable and substantial starting point for any future data collection application development work.

As a conceptual design, elements of the above products have been used, such as the evidence-based data collection, review and legislative reporting of AJDA, the technology of MAGE, the multi-hazard taxonomy of RASOR and subsequent linkage to the Sendai Framework and DesInventar, and the visual taxonomy of GED.

The general philosophy of the conceptual design is to attempt to simplify to the end-user a complex series of data collection objectives to achieve an efficient aggregation of collected data and focused reporting. This will shift the system complexities to the system developer to provide an expansible and dynamic method of data aggregation, limiting user options presenting only information required for/of a user in a specific scenario.

Data collected within the system described will be aggregated from data collected on site by a site data collection tool(s) defined separately in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

2.2 Product functions

The major functions of the aggregation and reporting system are:

- Clear easy to use and customisable/expansible data collection forms
- Provide visual support to relevant pick lists generated from pre-defined taxonomies
- Geo-reference all collected data and media
- Map interface to display collected data and user location against street level background mapping or user-input imagery
- Allow for user loading of simple spatial datasets to be overlaid on the map interface
- User login
- Portable Document Format (PDF) reports for individual or aggregated Exposed Element records
- Export of data to Microsoft Excel (through Comma Separated Value, CSV, format) and spatial data formats such as Esri Shapefiles or Keyhole Markup Language (KML)
- Evidence-based damage and loss estimation
- Aggregation of data to inform decision-makers
- Flexible aggregation reporting to meet legislative and administrative requirements.

2.3 User classes and characteristics

The aggregation and reporting system will need to be secured with a user identity. Initially, the required users/roles will be:

- System Users
    - Viewer: Read-only users
    - Editor: Site data collection team

- Advance Editor: Responsible organization data review team.
- System Administration
  - Emergency Coordinator / Data Manager: Responsible organization data manager
  - System Manager: Responsible organization IT support
  - System Administrator: System implementation, support and maintenance team.

All users will be created, edited and deleted using the aggregation and reporting system.

2.4 Operating environment

The aggregation and reporting system should be mountable on a web server running Windows Server or a Linux based operating system but must, as a minimum, run on Linux to provide a lower cost hosting. Server hardware used to serve the web application will need to be defined at the implementation stage within a country based on the likely usage within an individual country. If the system is to be hosted in the cloud server scaling can be applied to react to usage, demand and resilience. However, if a fixed server is to be used, consideration will be needed to the likely future usage of the system and server oversized to allow for future system growth.

2.5 Design and implementation constraints

The conceptual design follows a general philosophy of using open source components and products wherever possible. This is to reduce the running costs of a system for the end users and ensure no recurring commercial licence fees that would restrict adoption of the tool.

The solution must also comply with the provisions of local Data Protection Acts and any other relevant legislation on privacy, data protection or public collection of data. These will vary by country.

As a conceptual design no further constraints to development are to be defined.

2.6 User documentation

Documentation will need to be produced alongside any developed system:

- Technical document - will need to summarise the coding process, provide details of the functionality provided and any configuration options. This should provide an explanation of how to add new devices, users, templates, taxonomies or data into the system.
- User manual - will need to provide a clear and illustrated guide to use of the software targeting novice users which could be subsequently used within future training.

2.7 Assumptions and dependencies

The following generalised assumptions have been made

- Operating language, code description and documentation will be in English. These can be translated at a future stage.
- Taxonomy for basic classification of buildings will use the GEM Building Taxonomy v2.0 (Brzev et al. 2013).
- Extended taxonomy to be based on GED4ALL – the Global Exposure Database for Multi-Hazard Risk Analysis, RASOR, Hazus, ICC and IUCN with implied linkage to the Sendai framework (Silva et al. 2018).

- The solution is limited to aggregation of in-situ collected data, rather than remote sensing or other broadscale analysis, although viewing of output data generated by broadscale analysis should be supported by the system.
- No direct data streaming of data is to be considered, but near real-time data transfer could be achieved.
- We assume that the conceptual design of the data aggregation and reporting system will fulfil each of the use cases and user stories described in section 2.8 of the site data collection tool FRD (Appendix A).

In a similar manner to language a default system of units will be used to provide a consistent global data collection:

- Date and Time: Universal Time Coordinated (UTC)
- Location: World Geodetic System 1984 (WGS84)
- Units of measure: SI
- Currency: US Dollars.

Provision will be made for localised conversion for ease of user entry, but the primary data storage units will be assumed to be as listed.

The conceptual design focuses on the key requirement to collect damage data that can be edited, used, aggregated in the data aggregation system. There will be many add-on features that could be developed in the future. We will highlight these, but focus on a model for a simple, workable but extensible design.

3 Conceptual data design

The conceptual data design is defined for the overall system in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A), which should be referenced with this document.

4 System architecture

A system architecture that defines the structure, and behaviour of a system as a logical overview and representation of the system components and inter-relationship.

4.1 Hardware interfaces

The hardware interfaces are defined for the overall system in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A), which should be referenced with this document.

4.2 Software interfaces

The software interfaces are defined for the overall system in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A), which should be referenced with this document.

4.3 User interfaces

4.3.1 Wireframe workflow

Figure 4-6 illustrates the conceptual workflow for the aggregation and reporting system and connectivity for the proceeding wireframes.

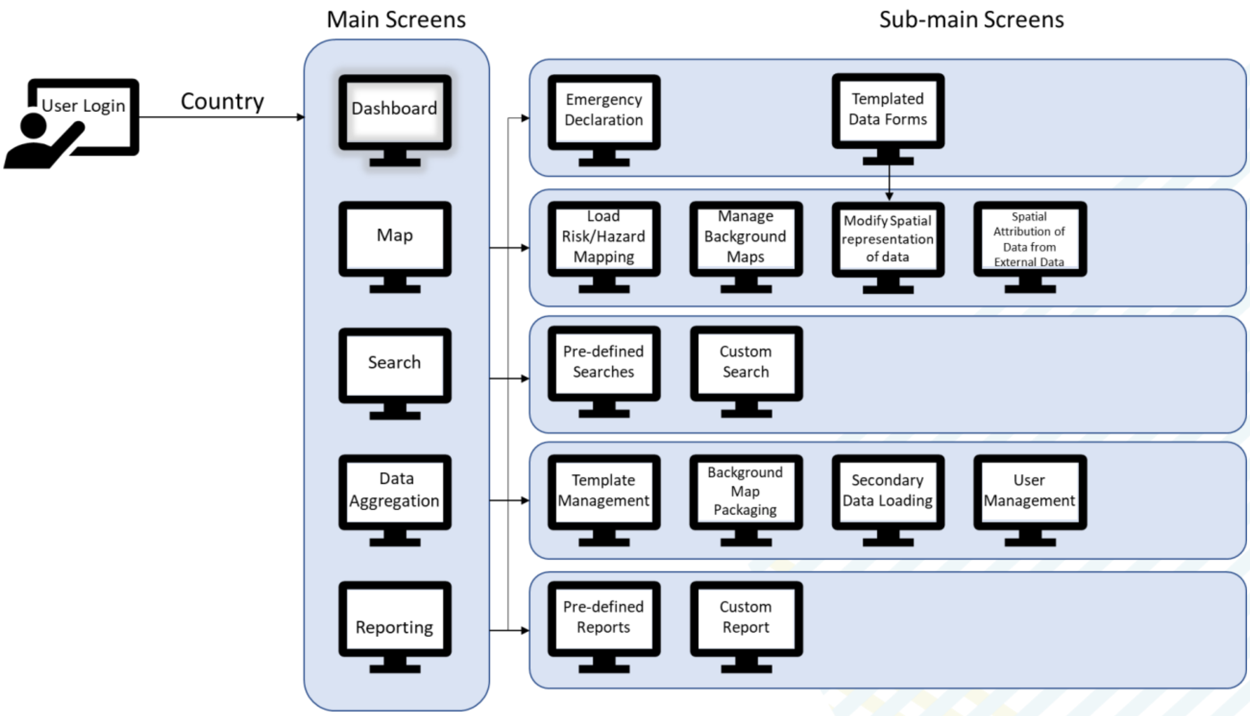

Figure 4-1: Conceptual mobile application workflow

4.3.2 Main Screen Wireframes

Dashboard wireframe

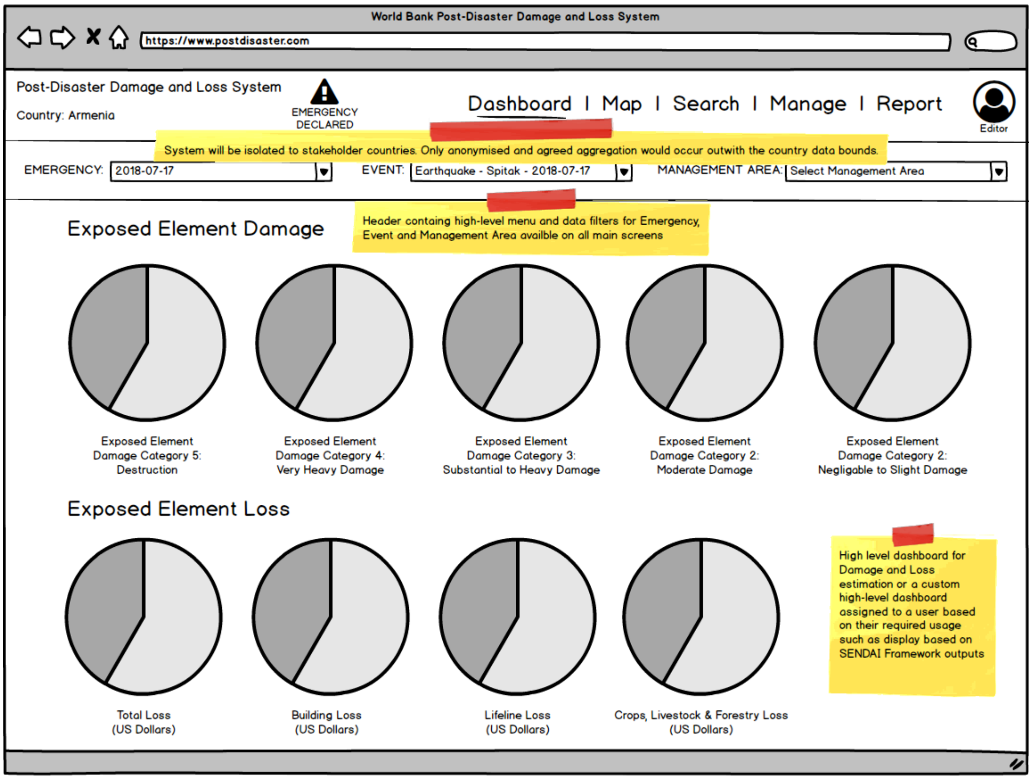

Figure 4-2: Dashboard Wireframe

Map Wireframe

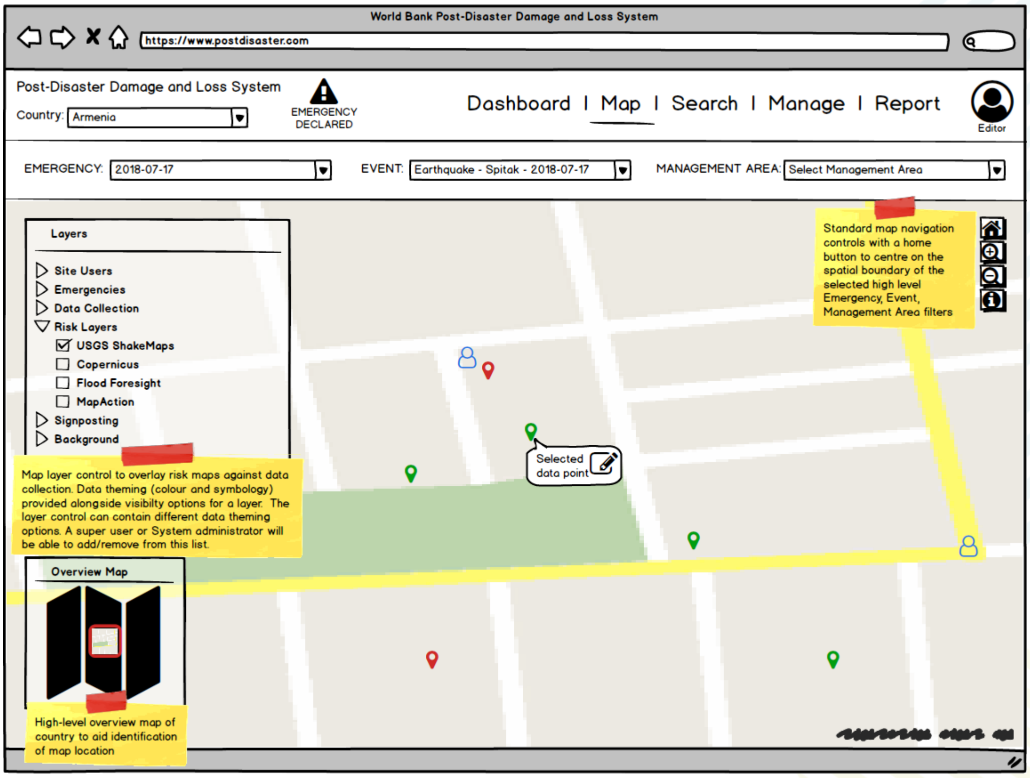

Figure 4-3: Map Wireframe

Search Wireframe

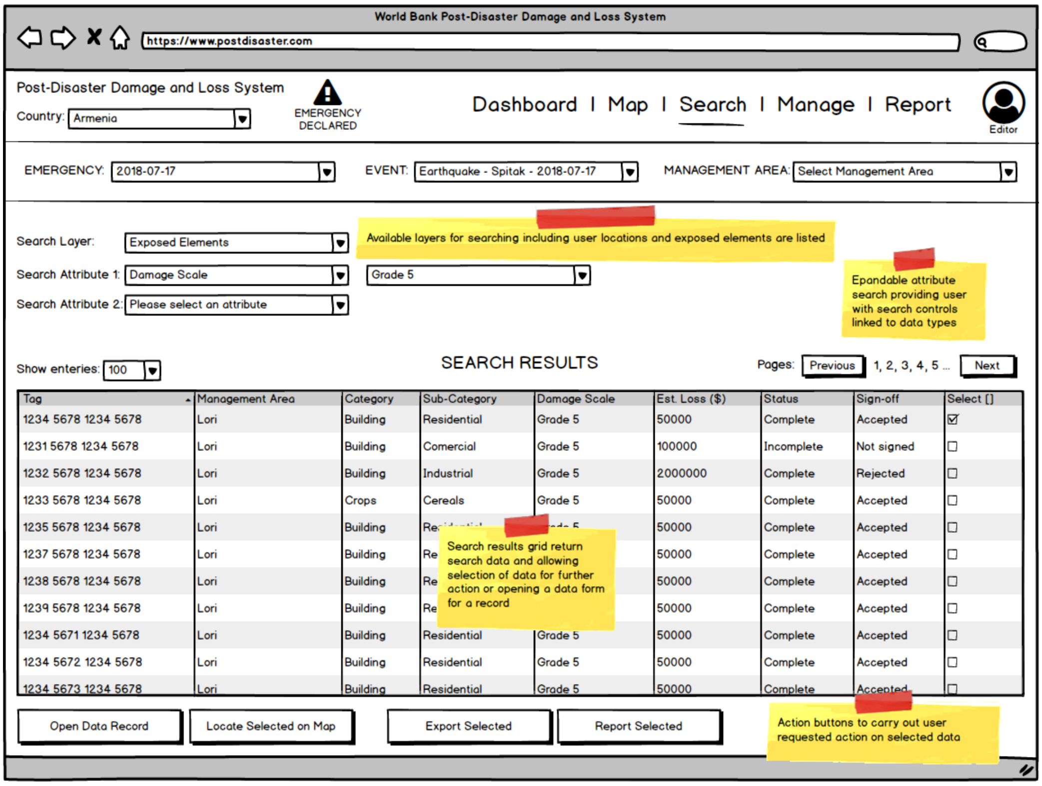

Figure 4-4: Search Wireframe

Manage Wireframe

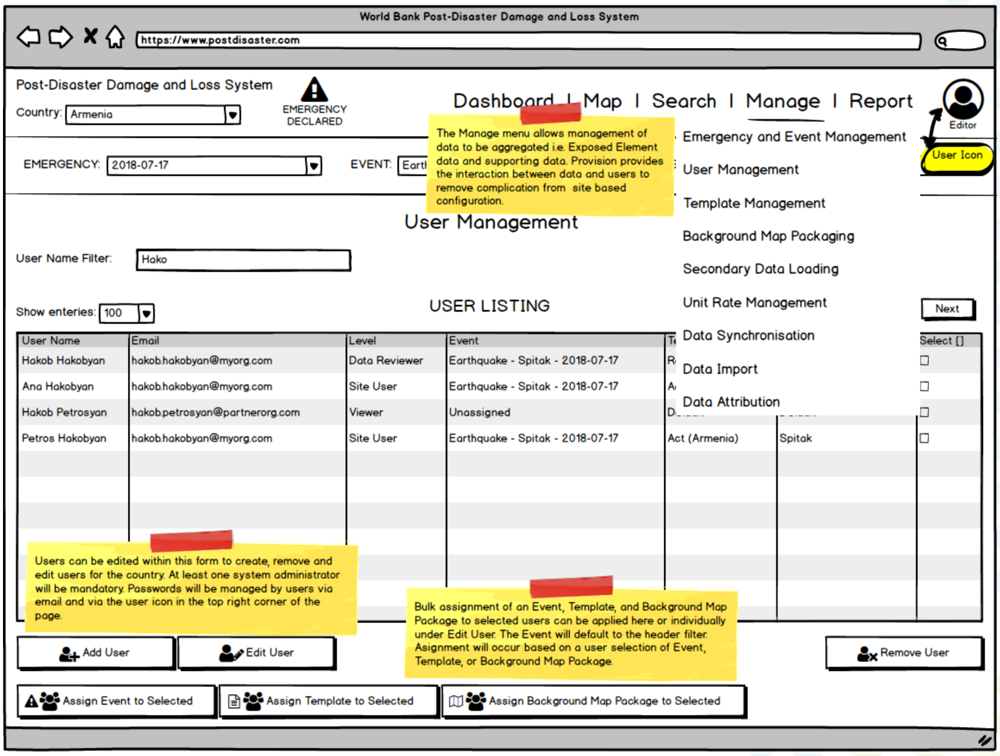

Figure 4-5: Manage Wireframe

Report Wireframe

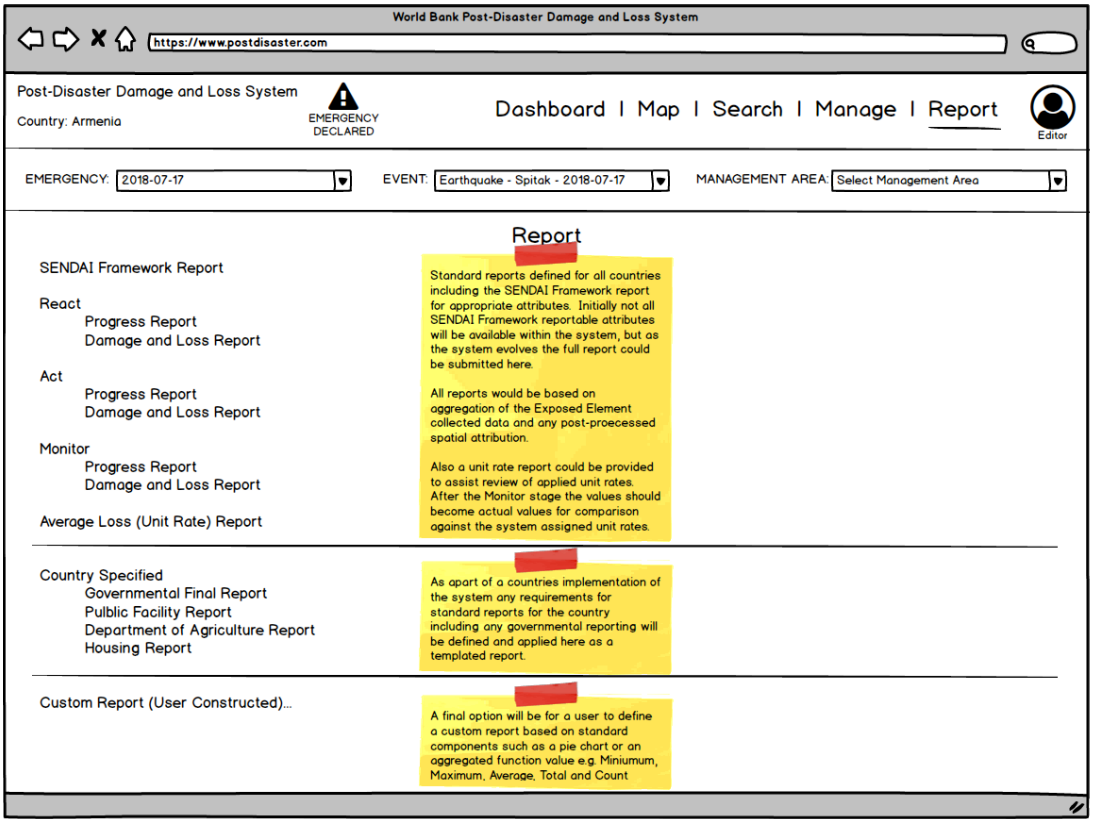

Figure 4-6: Report Wireframe

Data form Wireframe

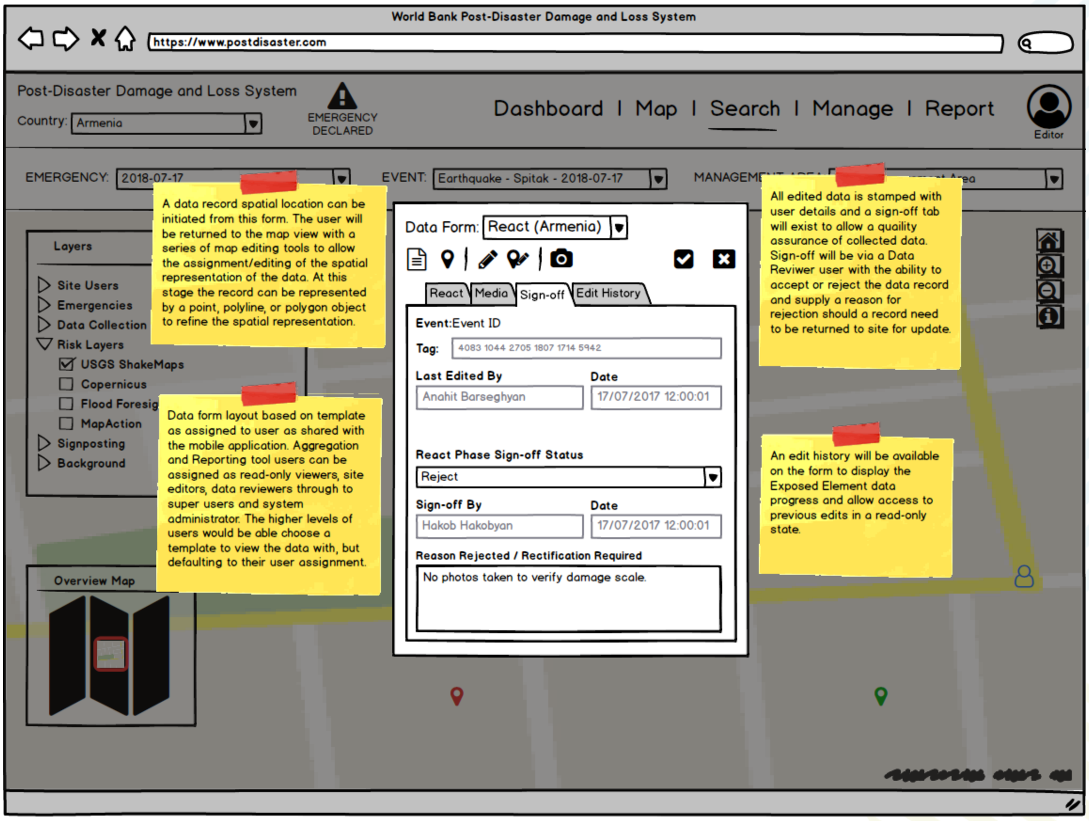

Figure 4-7: Data form wireframe

5 External interface requirements

5.1 User interfaces

The data aggregation and reporting system is to be designed as a web application. The application is envisaged to be available on the internet behind a user security layer but could also be installed across an intranet or indeed locally as a virtual machine. Users are to be verified as a part of an emergency team but could extend to government departments and partner organisations, but potentially sections of the web application could be opened up for public access for crowdsourcing data in the future. As such the application will need to be clear, but able to provide a sophisticated suite of tools for managing the system to more advanced users. Therefore, users will be provided levels of access only showing the required components and user configuration of the web application to user interface for the specified user.

The user interface design for the web application will continue the theme of the site data collection tool with an expansible and templated approach to data presentation.

The envisaged application will have the following user interfaces available from the main web page header menu as outlined in Table 5-1:

Table 5-1. Summary of web application screens

Screens	One-off verification(s) of the device and user
Login screen(s)	User assigned summary of key aggregated data attributes
Map screen	Map screen to visualise, spatially overlay data, edit spatial representations and access to data form(s)
Search screen	Data attribute filtering/search screen and access to data form(s)
Scan tag screen	Manage interaction between users, templates and data
Data collection screen	Provision of data aggregation reports for both system-defined, and user-defined reports

The data form should be designed to fit varying screen resolutions within a cross-browser format, but specific design for smartphone screen resolutions are not required. As per the site data collection tool, data entry questions should be clearly defined and logically grouped rather than a continuous list of scrolling questions and will use the same templating mechanism employed in the mobile application.

5.2 Hardware interfaces

As a browser-based web application there are no specific hardware requirements for the users' 'client' hardware other than use of a modern standards compatible web browser is a prerequisite.

The aggregation and reporting system will need to run using a server or machine capable of serving web pages. The system is designed to be platform agnostic, but with the intention of using an open source web server platform based on a Linux operating system and Apache web server to reduce running costs. This would also allow the use of container technology such as Docker. There would be separate servers for the web application and the database hosting unless the hardware is fully hosted within an individual country, and potentially a further separation for a mapping server.

The location, ownership and responsibility of a server is discussed in Section 4 of the Site Data Collection FRD as a part of a country's implementation strategy and is repeated for convenience in Figure 4-3 below:

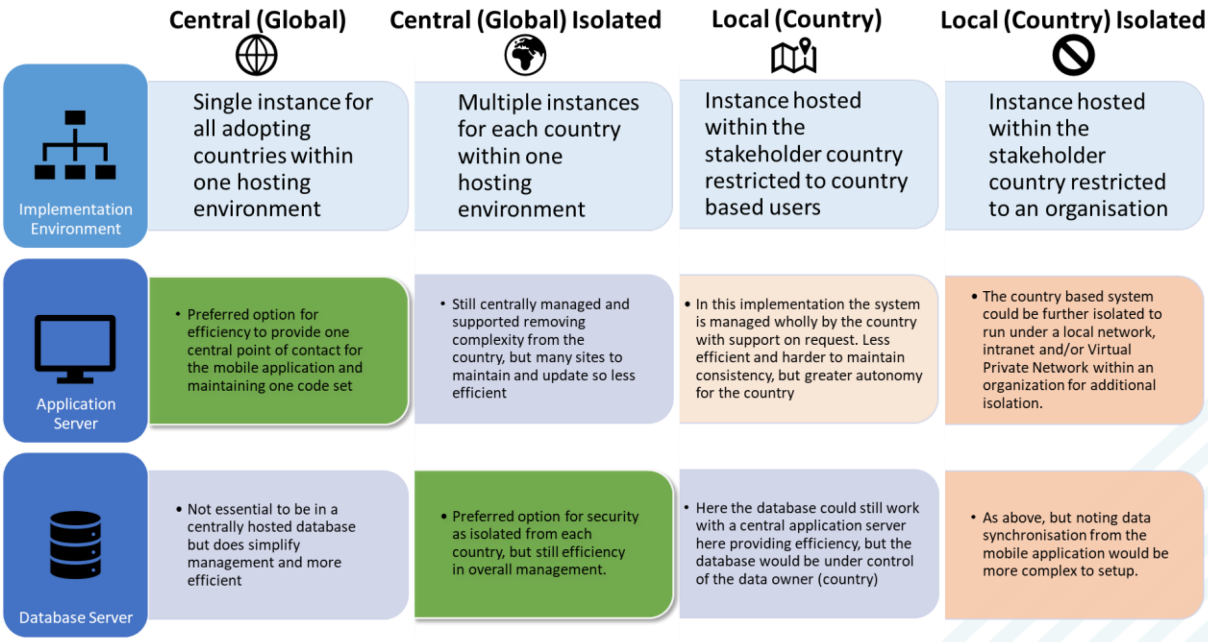

Figure 5-1: Implementation strategy options matrix

The options matrix highlights the web server hardware that could be implemented in a number of ways with differing configurations. The following primary options can be used:

- Central (Global)
    - Cloud Hosting - e.g. Amazon Web Services (AWS), Azure
    - Providing scalable servers
    - Instant upscaling in high demand or with increased stakeholders
    - Can be hosted in different continents or 'regions' i.e. US, Europe, Asia etc.
    - Partner hosting
    - On-premises servers
    - Fixed server
    - Harder to scale.
- Local (Country)
    - Country hosting

- As per country requirements and available resources
- Assumed to be on-premises server(s).
- Local hosting
- Within a country-based organisation
- Assumed to be on-premises server(s).
- Laptop
- Providing a mobile server for backup and transfer of data within a site team.

The recommended hardware for efficiency of usage, support and maintenance would be to use multiple instances of cloud hosted servers but is dependent on the requirements of an individual country.

5.3 Software interfaces

The software interface is defined for the overall system in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A), which should be referenced with this document.

5.4 Communications interfaces

The communications interfaces are defined for the overall system in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A), which should be referenced with this document.

6 System features

The overall objectives of the system are:

- Collect site-level data on damage to assets of interest (Exposed Elements) sufficiently to generate a rapid and transparent post-disaster loss estimate.
- Provide aggregated Exposed Element disaster statistics compatible with the Sendai framework and other governmental reporting requirements.

The main system functions to achieve these high-level objectives are described in the following section, as an overall conceptual design for the site data collection tool. The aggregation and reporting system is proposed to be in the form of a web application to view, store, edit, review and report on data collected on site. The site data collection application will communicate and transact with the aggregation and reporting system containing the functions described here. The site data collection tool functions, described separately, should be read in conjunction with this section.

The system features follow the user interface menu system which groups functional requirements.

Functions linked to menu:

- *Login*
- *Menu Header*
- *Dashboard*
- *Map*
- *Search*
- *Manage*
- *Aggregation and Reporting*
- *Sampling* Module.

6.1 User log in

6.1.1 Description and Priority

An operational system should not be openly accessible to the general public and therefore requires a user security layer to be applied to restrict access to the system to authorised users. The system will be accessed via a standard login page with a user providing an email-based user name and password.

6.1.2 Stimulus/Response sequences

The entry point for the system by a user will be a user login page. On a successful login any disclaimer information should be displayed and accepted by a user on first use.

6.1.3 Functional requirements

Login

The login page should implement a modern authentication protocol appropriate for the chosen development environment. The user should supply an email address as a user name, although a friendly name should be used in the system to identify a user and their associated organisation for stamping data. A password will also be entered into the web page using a password control to protect the password entry.

Password management should be via the supplied email address and allow a user to change their own password. Further policy could be considered for password expiry.

Permissions and disclaimers

On first entry to the system a user should be informed of any personal information to be stored and presented with any required disclaimers, with a confirmation that these can be stored. If the user chooses to store confirmation the permissions and disclaimers page will not be presented to the user again, other than in the event of a change in storage of personal information or disclaimer wording. For site users this will require an extra permission to store and view a user's site location which will be optional to the user and not mandated to access the system.

6.2 Page header

6.2.1 Description and priority

Most web applications require a means of navigating around the pages contained within a website in non-sequential manner. The aggregation and reporting system will allow a user to choose elements of the web site they wish to view based on a grouping of functional use, and this will be enabled by a page header. The page header will also contain an application title, high-level data filter, messaging and user settings.

6.2.2 Stimulus/Response sequences

A user will be able to select which area of the website and the Emergency related data they wish to view (see Section 3.1 of the site data collection tool FRD for a definition of Emergency and Event).

6.2.3 Functional requirements

Menu

The web application will present a header area consistent across the system containing a menu system. The menu system will allow access to:

- Dashboard
- Map
- Search
- Manage
- Report.

These header menu items are discussed as further sections of the system features.

Data filter

The data filter will be a key feature of the web page header. Data presented on the web pages and any default settings will be based on the following data filters:

- Country
- Emergency
- Event

- Management Area.

The country will be defined for a user, except for a scenario where multiple countries are hosted together where by a system administrator could change the country. The assigned country could be used to define the database connection for the system to use, thus a single user interface could connect to multiple database instances. Whichever methodology is used, the website will never display more than one country at a time. The exact functionality will be dependent on the implementation strategy chosen and so here the functionality should enable each of the implementation strategies, outlined in Section 4.1, to be used.

The Emergency would default to the latest Emergency occurrence but would allow a user to filter all viewed data by Emergency, Event, and management area (i.e. administrative areas, operations areas) within a country. The selected filters should be stored against a user between sessions.

User settings

A user icon will be displayed on the header bar, which would allow access to a user's settings for:

- Support Request
- Help
- Changing Password
- Logging Out.

The user icon would also present to the user details of the account for user name and type of account assigned.

Messaging

An icon should be displayed to highlight if there are any emergency declarations in place for a country and any further high-level information on any current Emergencies, limited to 100 characters.

6.3 Dashboard

6.3.1 Description and priority

The dashboard screen provides the 'landing' screen for a user upon successful login with the intention of displaying the user an immediate view of the high-level aggregated statistics.

6.3.2 Stimulus/Response sequences

High-level view of aggregated data displayed on selection of the 'Dashboard' menu.

6.3.3 Functional requirements

Dashboarding

The intention of the dashboard is to present the user with an immediate high-level view of the exposed element aggregated data linked to the page header data filters. The default dashboard might be charts showing the split of exposed element types for each damage scale category and financial loss for each exposed element type showing the split by exposed element sub-type, but the aim will be to present the key attributes to a user.

In many ways the dashboards will be very similar to the reporting except the dashboard is intended to be a decluttered user interface with clear visualisations of the aggregated data.

User assigned dashboard

The information that is regarded as 'key' information may vary by the user, for instance, a site data collection manager may regard survey progress as key, where as a governmental department may regard the SENDAI framework as key. Therefore, the dashboard viewed by a user could be assigned for a user from a pre-defined selection of dashboards. The selection could also be available under the user settings and altered by an individual user.

6.4 Map

6.4.1 Description and priority

The spatial representation is a key element of the collected data. Collected data should be overlaid with other sources of spatial data such as administrative boundaries, risk data and background maps. The visualisation and spatial overlay of location data is achieved using a map user interface and a back-end service to serve generated map images to a web map user interface.

6.4.2 Stimulus/Response sequences

A user will be presented with an interactive map with which they can dynamically modify and navigate based on user actions. Several components are required to allow the user to manipulate the map viewed but primarily navigation controls and a layer control are required.

6.4.3 Functional requirements

Mapping

The presented map should use as much screen real estate as possible to provide a clear map view. Overlaying the map will need to be map navigation controls to allow:

- 'Zooming' the map in and out, such as zooming in to see a town or zooming out to see a region
- 'Panning' the map, moving the viewed location of the map
- 'Selecting' information, such as clicking on a building to identify the attributes of Exposed Elements
- 'Home' icon to allow a user to re-orientate themselves to a view of the assigned country.

The Exposed Element site data viewed on the map will be restricted to the page header data filters, i.e. restricted to a specific Event or management area.

Data from OpenStreetMap will be used to provide a background context to the map and the user - referred to as 'Background Mapping'.

In order to generate map images for use on a webpage a web map server is required. An open source server should be used to achieve this, and the following products are widely used to achieve this:

- MapServer
- GeoServer.

A client-side JavaScript library such as OpenLayers will also be required to provide the client interaction with the map server. The chosen mapping server should be compatible with the chosen Exposed Element database format so that only one consistent source of data is maintained without any spatial and attribute data separation.

The system should allow for the addition of externally hosted data such as for risk layers which is commonly supplied via a Web Mapping Service (WMS) or Web Feature Service (WFS) but also imported data via a data transfer format commonly in an Esri Shapefile (.shp) format.

A dynamic layer will exist to specified users to show the location of site users where mobile connectivity permits. Locations will update on each map refresh.

Layer control

The purpose of the layer control is to manage how and which data should be overlaid in the composite map. A map layer can be considered to be equivalent to a 'table' in conventional database terms and represents a grouping of data with similar attributes. A layer of data can be represented in two ways:

- Vector: data drawn from a point location or grouped points or nodes forming a polyline or a polygon that can be selected by a user
- Raster: data drawn as an image intended to be background context.

All supplied layers of data are overlaid in a specific order, with visibility determined by a user to manipulate what the user can view on the map - i.e. a user could choose to overlay Exposed Elements over an administrative boundary etc.

The layer control should group layers of data into functionally similar groupings such as:

- Site users
- Data collection
- Emergency and event boundaries
- Administrative boundaries
- Risk Layers
- Background maps.

The layer control should allow the user to decide which layers they wish to view and the transparency of overlay between layers.

Data theming can be applied to a layer as a 'colour by numbers' to aid visualisation of data. One or many themes can be applied to a layer, for which a legend should be provided to a user and a user should be able to choose should more than one theme be defined. For example, the exposed element data could be styled based on:

- Survey Phase
- Complete and Incomplete
- Damage Grade
- Estimated Loss
- Exposed Element Type.

This could either by a combination of the above to produce a style or individual as five separate themes.

Where possible, a layer should be applied to the Map Server as a part of the system implementation and optimised, but layers could also be added through the management user interface by a system administrator.

Signposting

A further grouping of the layer control should allow the addition of signposting hyperlinks to external web content of relevance to the data collection exercise but would not provide any integrated map layers.

Overview map

An overview map should be provided to be enable user orientation when zoomed in to high level of granularity on the map. The overview map should show the country boundary and major place names along with an icon or rectangle to indicate the location of the currently viewed map. An optional feature would allow users to navigate the viewed map to the location clicked on the overview map.

Spatial editing

An advanced feature of a web mapping system is the ability to edit spatial features. This will be needed within the aggregation and reporting system to allow Exposed Element spatial data to be created and edited, including the alteration of a point object to a polyline, polygon object. It is expected only a simple spatial representation will be required for point, polyline, and polygon objects and editing of complex geometries should not be required. For users with editing rights additional map tools will be available on the map screen to enable the creation and editing of spatial data.

Data attribution based on provision of a polygon dataset will also be provided under the Manage section of the web application to allow addition/update of attributes based on a supply of a predefined polygon (area/region) spatial data.

6.5 Search

6.5.1 Description and priority

The 'Search' functional area of the web application will provide a general search facility primarily for the Exposed Element data and a place gazetteer. The user will be able to choose the attributes to search on and the attributes to return in the results.

6.5.2 Stimulus/Response sequences

In order to identify data a user may wish to search/filter data based on the attributes of an entity, to narrow down the data the user wishes to see, analyse or report on.

6.5.3 Functional requirements

Search layers

The search facility should take the form of a flexible and expansible attribute search for an individual layer. The default search layer should be the exposed element data, but all layers with attribute data should be listed, including a place name gazetteer.

A user will be able to select an attribute to search on and the desired filter for the attribute. The filter will be provided in a format consistent with the data type and should a lookup list be defined for the attribute this should be used and presented to the user for filtering. Attributes can be added one at a time to generate a search filter. Some assumptions will need to be made to simplify the user interface in terms of the AND/OR linkage between multiple attributes.

An additional search control will allow a data search to include any data marked as deleted. Any physical deletion of records would need to occur directly on the back-end database and not within the web application user interface.

A search results data grid will be used to return results. The viewed data will be limited to a user defined number of entries on the web page to manage responsiveness and standard data grid paging, similar to a Google search results list, applied to allow viewing of a large number of results.

Default result attributes for a layer should be provided in the system configuration, otherwise the first five columns will be used. A listing of all attributes will be made available to a user to allow alteration of the result column listings.

Search actions

- Once a filtered result listing has been generated and returned an additional end column should be applied to enable 'selection' of individual records to allow the following actions to occur:
- Open a data record form/card: single selection
- Locate Selected on Map: zoom map to the single or multiple selection
- Export Selected: export to spreadsheet/shapefile multiple selection
- Report Selected: export to PDF multiple selection
- Add Record: to users with editing rights will launch a new data form requesting spatial definition to be supplied on the 'Map'
- Remove Record(s): to users with advanced editing rights will allow the marking of single or multiple selected exposed element data as deleted
- Retrieve Record(s): to users with advanced editing rights will allow the demarking of single or multiple selected exposed element data as not deleted.

Potentially further actions could be supplied to enable bulk sign-off of records, but further consideration would be required to assess efficiency against quality, as to whether bulk attribution should be allowed.

Care should be taken in the exporting of data to anonymise data should the information be used outside of the responsible organisation.

6.6 Expansible database

6.6.1 Description and priority

To compliment the site data collection and allow review of data, the same expansible data form templating applied to site should be applied to the web application based on user assignment.

6.6.2 Stimulus/Response sequences

To view, edit and review data a user should be able to open a data form for a specified data record. Accessibility and editing rights will be based on user role.

6.6.3 Functional requirements

Data template

A data form will be made available to a user from the Map and Search functional areas of the web application based on user selection. The data form will be based on the expansible templating described in the Post-disaster Data Collection – Site Data Collection FRD, Appendix A, where the template functions are described in more detail. The web application will match the site form, including the ability to upload and attach media data.

Three further features will be available on the web application compared to the site application:

- Report to PDF: provide an individual report for a record
- Spatial editing: allowing editing and redefinition of a record's spatial attribution, see section 6.4.3
- Select template: for advanced users, the user will be able to choose which of the associated templates to view, i.e. React, Act, Monitor etc.

The web application data form could be used for entering paper-based data should this be required on site, or creating data in the Prepare phase, but it is envisaged the primary usage will be in the review and approval of site data after each conceptual framework phase of data collection.

Data history

The web application will also display the data edits made over time, and hence the record can be viewed through its data cycles. For example, an exposed element might have the following edit history:

- 11/05/2025: React: Incomplete: A. N. Other
- 12/08/2020: Monitor: Complete: A. Reviewer
- 24/09/2018: Act: Complete: A. N. Expert
- 22/09/2018: Act: Incomplete: A. N. Expert
- 17/07/2018: React: Complete: A. N. Official
- 14/05/2016: Prepare: Complete: A. Data.

Each record in the history listing could be opened in a read-only state for viewing.

6.7 Manage

6.7.1 Description and priority

To maintain simplicity in other areas of the system, there will be an increased system management requirement by a system administrator. A series of administration forms will be made available to enable management of the system.

6.7.2 Stimulus/Response sequences

A user will be able to manipulate functionality and data within the web and site data collection application tools, including the interaction between the users and data templates as a key feature of the system concept.

6.7.3 Functional requirements

Emergency / Event management

A user interface will be required to manage Emergencies and associated Events. A user will be able to declare an emergency within the system in line with the conceptual framework initiation of the React phase. A minimum of one Event will also be assigned to an Emergency and a spatial polygon / event area definition will need to be outlined. This would be carried out by a system administration level user, and likely to be the Emergency Coordinator (Data Manager) with the responsibility for data management.

The Emergency and Event records can be edited once created, and additional events added to an Emergency at any point during an Emergency. The phase and type of an Event can be edited on the data record along with the defining spatial polygon or Event area used to identify Exposed Element data for inclusion (if pre-existing and applicable).

The Emergency and Event management user interface is not intended to be a reporting tool, with a limited user access, and will be focused on management of data and the conceptual framework phases.

Deletion of Emergencies and Events will only be possible through the system administrator user via direct manipulation of the back-end database. If an Emergency or Event is accidentally added the record should either be renamed and re-used via the editing tools or marked as void. The system will need to ignore any data records marked as 'Void'. This will avoid potential loss of data and allow re-instatement of records should it be required.

User management

This form will allow the creation, editing and removal of a user account. The following user attributes will be assigned through this page:

- User credentials
- User role (or level)
- Assigned Event
- Assigned Data Form Template
- Assigned Background Map Package.

Passwords will not be set within the user management and will rely on issuing via email a system generated password, which will be managed by individual users.

Bulk assignment will be accessible by selecting users. The following can be bulk assigned:

- Event
- Data Form Template
- Background Map Package.

On assignment, users of the site data collection tool will be requested to update their devices at the earliest opportunity. Event (data) and background map package changes will not automatically change due to variations in mobile network speeds for download and instead allow the user opportunity to gain a reliable data connection for update. However, the user will receive continual infrequent notifications until changes are applied. A data template can be changed with immediate effect.

It should be noted that although data form templates are set for a single user, different templates can be issued across multiple users at any given time, allowing for overlap of data collection within conceptual framework phases.

In general, there will be a trade-off between the size of data packaging and frequency of requirement to change data package, and it is envisaged larger packages would be used by default to avoid changing background map packages, for example an assignment flow might be:

- Background Map Package: (Large storage size-Gigabytes) Downloaded in Prepare phase for a regional area
- Event Data: (Medium storage size-Megabytes) Once after emergency declaration in the React Phase, unless a surveyor needs to assist a different event
- Data Form Template: (Small storage size-Kilobytes) Multiple times with each phase change.

Template management

The template management in its simplest form will allow the download and upload of templates in the raw format (i.e. XLSForm or similar). Four predefined templates should be fixed in the system relating to each of the conceptual framework phases:

- Prepare: Data development
- React: Minimalistic for rapid data collection
- Act: Detailed data collection
- Monitor: Focused on recovery status and final outcomes.

These forms will provide the core data model, which should not be altered, but can be added to for specific circumstances and requirements. Alterations would be loaded under a different template name.

A more advanced template management could be provided to allow a user to alter forms within the web application user interface removing the need to handle the raw template format. Within this user interface a user would be able to drag and drop controls onto a wireframe form and define required data entry control attributes. This would be a reasonably sophisticated function to develop and is not required to implement the system but would provide a more intuitive administration of the system.

Background map packaging

A user interface is required to manage available background map packages to the system. Background packages, where possible, would be created during implementation of the system and / or within the Prepare phase. A package would be prepared for any required background map data, such as OpenStreetMap (OSM) data, based on appropriate boundaries such as Level 1 administrative areas. Production of the background map package would occur externally to the web application and uploaded into the web application.

A system administrator would be able to add and remove background map packages. Background map packages would require infrequent periodic refresh to reflect dynamic change.

Secondary data loading

The ability to upload and download secondary data by a system administrator into and out of the web application will be provided by a further management user interface.

Data synchronisation

A summary report on user data transaction will be provided to allow monitoring of data progression and view of any errors issued. This might include per user:

- Last location submission date and time

- Last data transaction date and time
- Records Created and Edited in previous x days
- Errors.

Data import

The data import form will allow the import of Exposed Element data to a specific format to assist in the creation of exposed element data.

Data attribution

The attribution of Exposed Element data based on a spatial data query with a supplied boundary / polygon dataset will be accessible within this user interface. The user interface would allow the upload of a spatial dataset containing a polygon and any attributes to be assigned and a spatial intersection query used to attribute all contained Exposed Element data. A background server process will carry out the attribution with progress reported back to the user interface. Attribution could be persisted once a boundary dataset is uploaded and applied at data synchronisation assigning to newly created records to ensure data consistency.

An example of data attribution would be the application of hazard intensities from third parties such as USGS ShakeMaps[1] or administrative unit information across the levels of administration granularity:

- Level 0 - National-level administrative boundary
- Level 1 - Administrative boundaries of the first sub-national level
- Level 2 - Administrative boundaries of the second sub-national level
- Level 3 - Administrative boundaries of the third sub-national level.

6.8 Aggregation and reporting

6.8.1 Description and priority

The aggregation and reporting of the collected exposed element is the required outcome from the system and provides an evidence-based damage status report and estimation of loss to inform decision makers. These reports will use the page header to define the data filters for the report.

6.8.2 Stimulus/Response sequences

In order to summarise and report collected data, to efficiently inform stakeholders, aggregation of collected data is required. A user should be able to instantly view high-level aggregation of data to both pre-defined outputs and user-defined outputs.

6.8.3 Functional requirements

Pre-defined reports

Key reporting parameters should be developed as pre-defined reports within the system. Such reports might include:

- Sendai Framework
- Building safety tagging
- Progress reporting

[1] https://earthquake.usgs.gov/data/shakemap/

- Damage and Loss reporting
- Unit Rate reporting.

Country specified reports

Within an implementation for a country it is envisaged some reports may need to be to a fixed format defined by the governmental and administrative organisations within a country. These requirements should be set out and templates developed ideally during the Prepare phase, coordinated by the Data Manager. These reports may contain data form the expanded attributes for a country and set out the taxonomies/schema(s) to be used for data collection and reporting.

Custom reports (User-constructed)

The custom report would continue the expansible philosophy of the system and allow a user to define the attributes for aggregation and visualisation. The following data aggregation functions could be applied to an attribute:

- Sum / Total
- Count
- Minimum
- Maximum
- Average.

The full expansible database will be available to choose attributes for aggregation, which for example could include:

- hazard intensity - i.e. USGS ShakeMaps maps for earthquake, flood depth maps
- administrative unit
- structural type
- occupancy type.

A combination of the attributes could be used to develop a table and/or chart, e.g. occupancy per administrative district (L2).

Created reports could be saved for an individual user or for a system administrator applied to all users.

Export

Reports and aggregation data layers generated in the system should be available for export for analysis in other business software/systems and dissemination. Outputs should be available in a variety of formats, including,

- Reports – PDF
- Tabular data – Comma Separated Values (CSV)
- Spatial data – Shapefile, KML.

7 Other non-functional requirements

7.1 Performance requirements

No further performance requirements beyond those described in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

7.2 Safety requirements

No specific safety requirements are defined for the web application.

7.3 Security requirements

No further security requirements beyond those described in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

7.4 Software quality attributes

No further software quality requirements beyond those described in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

7.5 Business rules

No further business rules beyond those described in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

8 Other requirements

A number of requirements are described in the Post-disaster Data Collection – Site Data Collection Tool FRD (Appendix A).

Links to centralised damage data catalogues

Damage and loss data collected and aggregated following disaster events is of great value for both research or commercial purposes to the international disaster risk and engineering communities. For example, vulnerability and loss functions and catastrophe model calibration can be greatly improved through the use of historic damage or loss data. When developing a globally-applicable system for collecting and aggregating post-disaster data, consideration should be given to providing links to centralised open catalogues of damage information.

The users of the system should at all times have total control of the data collected, input and analysed in the system. Should they consent to data sharing, they should be provided with an optional feature to link those data they wish to share (likely to be limited to data in an aggregated form) with public repositories.

Consideration should be given to the repositories that could host the resulting open data. Options include:

- The GEM Global Consequences Database2
- EERI Learning from Earthquakes virtual clearinghouses3
- The Humanitarian Data Exchange (HDX)4.

[2] https://storage.globalquakemodel.org/what/physical-integrated-risk/consequences-database/
[3] https://www.eeri.org/lfe/clearinghouse/
[4] https://data.humdata.org/

9 MoSCoW analysis

The following table provides a prioritisation of the identified system features using the Must have, Should have, Could have, Won’t have (MoSCoW) nomenclature. An estimate of effort using a High Medium, Low scale is also provided based on a new code development.

Report Section	Feature (hyperlinked to text)	MoSCoW	Effort
6.1 User log in			
	Login	Must	Medium
	Permissions and disclaimers	Must	Low
6.2 Page header			
	Menu	Must	Low
	Data filter	Could	Medium
	User settings	Should	Medium
	Messaging	Must	Low
6.3 Dashboard			
	Dashboarding	Must	Medium
	User assigned dashboard	Could	Medium
6.4 Map			
	Mapping	Must	High
	Layer control	Must	Medium
	Signposting	Must	Low
	Overview map	Should	Low
	Spatial editing	Must	High
6.5 Search			
	Search layers	Must	Medium
	Search actions	Must	Medium
6.6 Expansible database			
	Data template	Must	High
	Data history	Should	Medium
6.7 Manage			
	Emergency / Event management	Must	Low
	User management	Must	Medium
	Template management	Should	Low
	Template designer	Won't	High
	Background map packaging	Should	Medium
	Secondary data loading	Could	Medium
	Data synchronisation	Could	Low
	Data import	Could	Medium
	Data attribution	Should	Medium
6.8 Aggregation and reporting			

	Pre-defined reports	Must	Medium
	Country specified reports	Should	Medium
	Custom reports (User-constructed)	Could	High
	Export	Must	Low

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Offices at

Coleshill
Doncaster
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Isle of Man
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Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
South Barn
Broughton Hall
SKIPTON
North Yorkshire
BD23 3AE
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn Associates Limited

Registered in England 3246693

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Post-Disaster Data Collection – Site Data Collection Tool

Functional Requirements Document

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www.jbaconsulting.com

THE WORLD BANK

The World Bank
1818 H Street, NW
WASHINGTON DC
20433
USA

JBA Project Manager

John Bevington
8a Castle Street
WALLINGFORD
Oxfordshire
UNITED KINGDOM
OX10 8DL

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Prepared by .... Derek Farrier BSc MSc MCP MBCS CITP

Technical Director

.... John Bevington BSc MSc PhD DAS

Technical Director

Reviewed by .... Andrew Gubbin BSc MSc PGDip CEng MICE FCIWEM C.WEM MBCS

Director

Purpose

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Executive summary

Countries prone to the effects of natural hazards have a responsibility to carry out rapid post-disaster damage assessment and loss estimation to understand the spatial scale of the event and its impacts on populations, assets and the economy. Ideally, data should be captured at the asset level, with supplementary display, analysis, aggregation and reporting tools provided to allow government agencies to allocate funds for response and recovery efforts. However, the process for undertaking post-disaster damage assessment differs widely between countries in terms of designated responsibility, protocols and technologies available for use. Rarely has it been seen that decision makers have a transparent audit trail linking aggregated loss estimations to the individual assets that have been inspected.

This report provides a conceptual design of an in-field post-disaster damage data and loss capture tool. The tool, designed to run on hand-held tablet hardware, is based on open-source software, databases and secondary data. The design describes a tool that is expansible in nature, allowing a variety of stakeholders to use the tool to collect data on damage to a variety of Exposed Elements, e.g. population, buildings, transportation, lifelines, critical facilities, agricultural assets. The tool supports data collection for a number of use cases, including basic and detailed damage assessment, building safety inspections and asset-level tracking of recovery and reconstruction.

The tools fit into the conceptual framework and protocol outlined in the main report. The conceptual design for a linked data aggregation and reporting system is also provided in a separate document (see Appendix B of the main report).

This report was commissioned by the World Bank as part of project 1250664 - Improving Post-Disaster Damage Data Collection to Inform Decision Making.

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Abbreviations

API .... Application Programming Interface

BCA................................ Benefit-cost Analysis

DATA.............................. Disaster Loss Data

EMS .... European Macroseismic Scale

FONDEN .... Mexico natural disaster fund

GED .... Global Exposure Database

GEM .... Global Earthquake Model

GDPR............................. General Data Protection Regulation

GPS................................ Global Positioning System

HTTPS .... Hyper Text Transfer Protocol with Secure Sockets Layer

IDCT............................... Inventory Data Capture Tools

JSON.............................. JavaScript Object Notation

LAN .... Local Area Network

M_w.................................. Earthquake moment magnitude scale

MAGE............................. Mobile Awareness GEOINT Environment

MoSCoW......................... Must have, Should have, Could have, Won't have

NDOIS............................ National Disaster Observatory Information System

NGO .... Non-governmental organisation

OCR .... Optical Character Recognition

OGR ....Open source library of vector manipulation tools
OS ....Operating System
OSM ....OpenStreetMap
QR ....Quick Response
RASOR ....Rapid Analysis and Spatialisation of Risk
UNISDR ....United Nations International Strategy for Disaster Reduction
URL ....Uniform Resource Locator
USD.................................United States Dollars
USGS ....United States Geological Survey
UTC.................................Universal Coordinated Time
WAN................................Wide Area Network
WGS................................World Geodetic System
WHE................................World Housing Encyclopaedia

1 Introduction

1.1 Purpose

The purpose of this document is to advise on the functions required to achieve a post-disaster data collection mobile application that will collect data for use within a centralised data aggregation and reporting system.

1.2 Intended audience

This document is intended to advise the World Bank on the requirements needed to achieve an expansible post-disaster data collection application for use on handheld mobile devices. These requirements could then be used to procure the application via a future development project.

1.3 Product scope

The scope of this document is to provide a conceptual design for a software solution for collecting damage data in the field at the asset-level in an efficient, transparent and standardised fashion, with data fit for storage and analysis within an ancillary data aggregation and reporting system. The overall solution should be customisable for use independently by multiple countries according to their specific needs. A degree of standardisation is provided to allow the aggregation of data across multi-country events.

The main users of this solution are expected to be trained field data capture teams, commissioned, organised and managed by a national or regional disaster management authority working alongside the local Ministry of Finance / designated authority responsible for distributing relief and recovery funding. There are a range of other potential users who may benefit from using the solution, including government agencies, multi-lateral agencies and donors, non-governmental organisations (NGOs) or private organisations. The resulting data will be analysed within an ancillary data aggregation and reporting system to inform post-disaster resource allocation.

The key objective of this design is to provide a practical, easy to use, low cost and extensible application for rapidly collecting data within a challenging working environment, with or without internet connectivity.

The proposed software solution should be able to capture data on damage caused by a number of perils, including:

- flood,
- earthquake,
- landslide,
- tropical cyclone.

The design should be flexible to allow future addition of perils such as:

- droughts,
- extreme temperatures,
- tsunami,
- volcanic activity.

In the context of this project, the solution should be able to collect damage inventories for the following physical assets:

- residential buildings,

- public buildings,
- commercial and industrial buildings,
- critical facilities (schools, hospitals, power plants),
- infrastructure (road, rail),
- agricultural crops.

The functional requirements considered here will need to be considered in light of the cost of running a system, hardware costs, training and IT capabilities of users.

A conceptual design for a linked system for subsequent aggregation and reporting of the data collected by the described solution is presented in Appendix B - Post-disaster Data Collection – Aggregation and Reporting System Function Requirement Document (FRD) and should be read in conjunction with this document.

2 Overall description

2.1 Product perspective

The conceptual design of a site data collection tool takes into account the proposed conceptual framework presented in the Phase I report (Figure 2-1). The solution is designed to collect data within Phases 1, 2 and 3 of the conceptual framework.

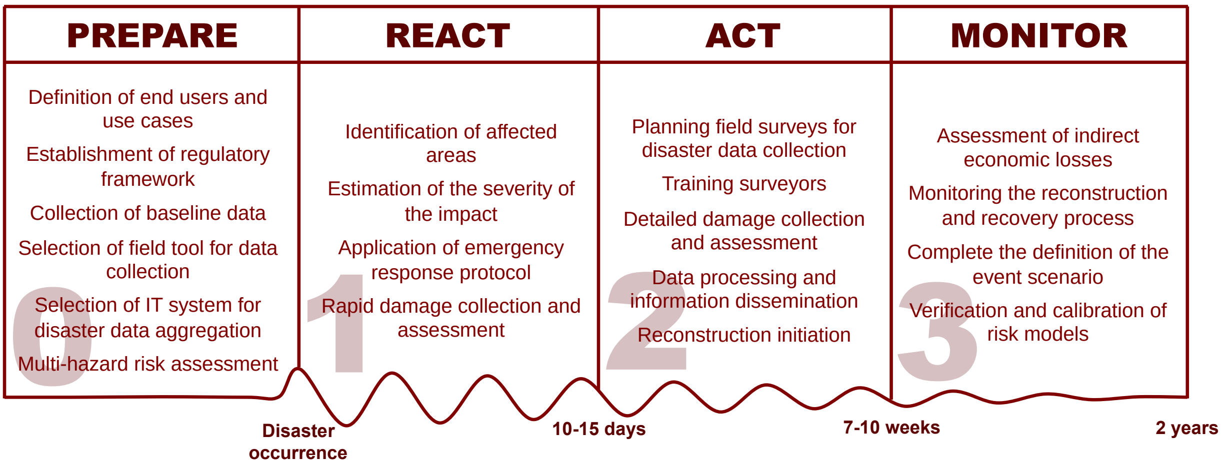

Figure 2-1. Conceptual framework developed in Phase I of the project

There are a variety of methods for post-disaster data collection as listed and discussed within the project Phase I report. With respect to on-site damage data collection, each country will have their own methodology and systems to collect data. This can vary from summary estimates, paper-based surveys to structured data collection.

The functional requirements defined here aim to leverage the learning on best practice, structure and products outlined in Phase I, extracting the strengths of the products presented and provide a coherent design from these strengths taking in current technologies.

The product needs to provide a transparent and low-cost solution for adoption by users in low to middle-income countries and will hence seek to use open source components by choice.

In developing these requirements, we have drawn on best practice and design of a number of systems reviewed in Phase I:

- **DARMSys**: Cross-platform customisable data collection tool
- **FONDEN**: Geo-referenced photographs and data verification
- **RASOR:** Multi-hazard taxonomy and Sendai framework output
- **GEM Inventory Data Capture Tools (IDCT)** Android App: Taxonomy, map interface, visual taxonomy support and open source data collection tool
- **MAGE**: Open source dual-platform customisable data collection tool using a NoSQL Database.

It should be noted that none of the above systems are considered to be suitable for direct adoption as a single application without modification due to limitations within each system. However, although the data model, form templating, taxonomy and reporting used with MAGE will require modification, the technology stack used within the product and open source Apache licensing mean the product could provide a suitable starting point for any future data collection application development work.

As a conceptual design, elements of the above products have been used, such as the simplicity of the user interface, and contextual help of the GEM Android App, the technology of MAGE, the multi-hazard taxonomy of RASOR and subsequent linkage to the Sendai Framework and the extensibility and scalability of DARMSys – Survey 123.

The general philosophy of the conceptual design is to attempt to simplify to the end-user a complex series of data collection objectives to achieve an efficient data collection. This will shift the system complexities to the system developer to provide an expansible and dynamic method of data collection, limiting user options presenting only information required for/of a user in a specific scenario.

Data collected within the system described will be aggregated and used to report the data to relevant parties within a web application – described in Appendix B.

2.2 Product functions

The major functions of the site data collection tool are:

- Clear easy to use and customisable/expansible data collection forms
- Provide visual support to relevant pick lists generated from pre-defined taxonomies
- Geo-reference all collected data and media
- Allow physical identification of Exposed Elements via a scan code such as a QR code
- Map interface to display collected data and user location against street level background mapping or user-input imagery
- Allow for user loading of simple spatial datasets to be overlaid on the map interface
- Collect data in a mobile connected and disconnected environment
- Minimise battery usage
- Collect data in variable weather conditions
- Data to be synchronised with a central location as a multi-user environment
- User login.

2.3 User classes and characteristics

The site data collection tool will need to be secured with a user identity. Initially, the required users will be:

- Editor
- *Ad-hoc* unverified user, with 'Add' only rights and view rights to local data on device only (one-way data synchronisation)
- Read-only viewer.

Consideration should be given to a further user level to enable a site-based review / approval of data. As data collection is intended to be rapid and likely to be undertaken in a challenging, post-disaster context, a site review user would be considered a secondary requirement and so has not been included in these requirements.

The application is not intended to be used without a user account. User accounts will also be associated to a specific 'Emergency' and 'Event(s)' (see Section 3.1) to limit data that can be viewed by a user, reducing data transfer to site. However, as indicated above, consideration should be given to an ad-hoc user logging in based on a time-based token without system verification to allow data to be added without download of data. The resulting data would be aggregated into a secondary dataset for merging within the aggregation and reporting application by verification of the data and assignment to an event. The ad-hoc user would be limited to the React phase of the protocol where there may not be time and/or communication to verify as a user.

Further users will be required within the aggregation and reporting system to which the site users will be a subset. As such**, all users of the site data collection tool will be setup using the aggregation and reporting system**. The site data collection tool will require a connection to the aggregation application to initialise usage on a device.

2.4 Operating environment

The site data collection tool is **designed to be operated from mobile devices such as smartphones and tablets.** The two major mobile operating systems (OS) are:

- Android (77% market share)
- iOS (19% market share)

Android has by far the greater market share globally and generally provides a lower cost device. Of greater importance for site-based usage, Android is open source and can be installed on a variety of hardware, including ruggedized devices. Rugged devices are specifically designed to withstand a higher range of operating temperatures, ingress and protection. As such, **we recommend Android as a target OS for development.**

The system is designed to be **widely distributed** to field data capture teams in multiple countries. Apple iOS devices still retain a sizeable market share and popularity and generally are seen to be more reliable and secure devices. Hardware using iOS is restricted to Apple manufactured devices and currently, there is no available hardware that is ruggedized for site work. However, Apple devices can have some increased protection provided by rugged cases. As such, **iOS should also be a target OS for development.**

The target versions should be:

- Android 4.1+ (Jelly Bean +) with a 99.7% share of Android market (May 2018)
- iOS 9+ with a 99.3% share of the iOS market (May 2018).

Should this cause an unacceptable restriction to functionality, alteration to these target versions could be considered.

2.5 Design and implementation constraints

The conceptual design follows a general philosophy of using open source components and products wherever possible. This is to reduce the running costs of a system for the end users and limit any recurring commercial licence fees that would restrict adoption of the tool.

The solution must also comply with the provisions of local Data Protection Acts and any other relevant legislation on privacy, data protection or public collection of data. These will vary by country.

As a conceptual design, no further constraints to development are to be defined.

2.6 User documentation

Documentation will need to be produced alongside any developed system:

- Technical document - will need to summarise the coding process, provide details of the functionality provided and any configuration options. This should provide an explanation of how to add new devices, users, templates, taxonomies or data into the system.
- User manual - will need to provide a clear and illustrated guide to use of the software targeting novice users which could be subsequently used within future training.

2.7 Assumptions and dependencies

The following generalised assumptions have been made

- Operating language, code description and documentation will be in English. These can be translated at a future stage.
- Taxonomy for basic classification of buildings will use the GEM Building Taxonomy v2.0 (Brzev et al. 2013).
- Extended taxonomy to be based on GED4ALL – the Global Exposure Database for Multi-Hazard Risk Analysis, RASOR, Hazus, ICC and IUCN with implied linkage to the Sendai framework.
- Provision of contextual help information and images to users within the app is an effective feature of the GEM Android App. Information will be derived from a number of sources:
  - Structural information: Glossary for GEM Building Taxonomy v2.0. , World Housing Encyclopaedia1
  - Damage categories - earthquake: EMS-98 and IMS-14 extensions (masonry, RC, steel, timber)

It should be noted that no visual glossaries have yet been developed for the GED4ALL or RASOR taxonomies or for damage classifications for flood, windstorm or landslide. It is recommended that in a future project, a glossary should be developed in order to provide user support when collecting data on exposure relevant to multiple peril types.

- The solution is not designed to collect detailed technical information on the cause(s) of damage that may require specialist technical interpretation by seismologists, engineers, hydrologists or geotechnical experts (e.g. to determine lateral spread vs. earthflow/creep in landslide assessment). It is expected that specialist teams (e.g. from the Earthquake Engineering Research Institute (EERI), Earthquake Engineering Field Investigation Team (EEFIT), or Geotechnical Extreme Events Reconnaissance (GEER) Association) are the most suitable teams to make these observations.
- The solution is limited to on-site data collection and aggregation of this data, rather than remote sensing or other broadscale analysis, although viewing of

1 http://www.world-housing.net/

output data generated by broadscale analysis should be supported by the system.

- Social media data gathering will not be included in the direct functionality. However, output datasets may be viewed in the tool.
- No direct data streaming of data is to be considered, but near real-time data transfer could be achieved.
- We assume that the conceptual design of the site data collection tool will allow for data collection to fulfil each of the use cases and user stories described in section 2.8.

In a similar manner to language a default system of units will be used to provide a consistent global data collection:

- Date and Time: Universal Time Coordinated (UTC)
- Location: World Geodetic System 1984 (WGS84)
- Units of measure: SI
- Currency: US Dollars.

Provision will be made for localised conversion for ease of user entry, but the primary data storage units will be assumed to be as listed.

The conceptual design focuses on the key requirement to collect damage data that can be edited, used, aggregated in the data aggregation system. There will be many add-on features that could be developed in the future. We will highlight these, but focus on a model for a simple, workable but extensible design.

2.8 User stories

A number of user stories were defined in Phase I to help test the design of the tools for specific use cases. In practise, the tools may be used for a wider set of use cases and they will be extensible in nature. The data requirements from each of these use cases is described, with **those features supported by the site data collection tool shown in bold:**

2.8.1 Emergency management and immediate relief measures

These are considered as follows:

- Data requirements: Aggregated statistics regarding the direct effects of the disaster, including the total number of damaged and collapsed buildings, affected population, fatalities, injuries, and homeless people. Hazard footprint and list of affected areas.
- End users: Emergency management authorities, governmental agencies, humanitarian NGOs, and local authorities responsible for emergency operations.

2.8.2 Evaluation of safety and usability of buildings

These are considered as follows:

- Data requirements: Asset level damage classification according to a broad system and immediate occupancy evaluation, including short-term safety countermeasures recommendations, with particular importance on public buildings, residential building stock and essential services.
- End users: Civil protection authorities, local governments, affected communities and individuals, post-emergency relief decision makers.

2.8.3 Funding mobilization

These are considered as follows:

- Data requirements: **Detailed georeferenced damage and loss data of each affected asset including photographic evidence that covers structural and non-structural components**, adequate to estimate the funding needs based on a loss estimation formula.
- End users: Governmental organizations (responsible for the funding allocation – e.g. FONDEN in Mexico), ministry of finance, (re)insurance companies, and policyholders involved in natural catastrophe insurance schemes.

2.8.4 Reconstruction planning

These are considered as follows:

- Data requirements: **Georeferenced damage data of each affected building, infrastructure, and environmental asset, including a classification of the reported damage** to inform decision-makers for either reconstruction or repair, and prioritize such activities.
- End users: National reconstruction authorities, ministry of finance, ministries of public works, urban planners, international NGOs funding the reconstruction and recovery, and private entities involved in the reconstruction process.

2.8.5 Development of disaster risk reduction measures

Disaster loss accounting

- Data requirements: **Transparent and accurate data regarding the overall effects of a disaster, covering the physical damage and human casualties** (direct and indirect losses).
- End users: National and international organizations (e.g. UNISDR) involved in disaster risk reduction and mitigation, scientific and humanitarian institutions involved in disaster resilience studies.

Disaster forensics

- Data requirements: Detailed data that incorporate hazard-specific intensity measures, information about the exposure indicators and physical vulnerability, **occurred damage and extent of damage to structural and non-structural components.**
- End users: Building code committees, physical vulnerability experts, natural catastrophe exposure modelers, disaster prevention and management decision makers.

Disaster risk modeling

- Data requirements: Physical event footprint and spatial distribution of hazard intensities, quantified damage and losses in physical units and monetary losses.
- End users: Natural catastrophe and disaster risk modelers, (re)insurance companies, scientific institutions and organizations involved in risk reduction and mitigation, research institutions and academia.

2.8.6 Exploration of benefit-cost analysis (BCA)

These are considered as follows:

- Data requirements: **Detailed damage data in physical units**, accurate repair and reconstruction costs.
- End users: Structural engineers, ministries of public works, urban planners, and disaster risk reduction organizations.

2.8.7 Long-term investment planning

These are considered as follows:

- Data requirements: **Transparent and accurate data regarding the overall effects of a disaster, covering all the physical damage and human casualties, direct and indirect losses.**
- End users: Governmental agencies, ministries of public works, ministry of finances, and private sector involved in long-term investment.

In addition to these use cases, generalisability of the tools is essential to fit the following scenarios:

2.8.8 Low- or lower-middle-income economies - e.g. Armenia, Nepal, Philippines

Tools should be usable in situations where cellular connectivity may be intermittent (pre-event or post-event), and IT access is also limited.

The tools should not be limited by recurrent license fees and be openly accessible (downloadable, customisable, usable) to users.

Tools should be usable for damage assessment and quantification with aggregation reporting that is customisable to meet local legislation

Considerations:

- Access to hardware: Availability of appropriate hardware for data collection may be an issue in this use case, as the data capture tool will be designed to work with handheld hardware, such as smartphones or tablets.
- Access to hosting: web-based hosting of the data aggregation tool may allow for access to the data aggregation tool through a web browser interface. This would negate the need to support older versions of Windows OS.
- Language of the conceptual design will be English.

Customisation of the tools for Armenia (Section 5 of the project Final Report) will be the main test-case here.

2.8.9 High-income economies - e.g. Italy, New Zealand

Tools should be usable in situations where cellular connectivity may be intermittent (pre-event or post-event).

It is assumed that IT access is not limited.

The tools should not be limited by recurrent license fees and be openly accessible to users.

Tools should be usable for damage assessment and quantification with aggregation reporting that is customisable to meet local legislation.

Considerations:

- Language of the conceptual design will be English.

2.8.10 Long-term event (i.e. earthquake sequence or cascading event) - e.g. 2016 Central Italy earthquakes

Tools should be able to collect and aggregate information for a sequence of damaging events, such as the 2016 central Italy earthquakes.

Data collected should be simple, allowing rapid damage collection and aggregation at multiple points in time throughout the duration of the event sequence.

2.8.11 User stories implementation

To summarise, the site data collection tool and the data aggregation and reporting tool will be utilised in all phases of the conceptual framework, as described in Figure 2-2.

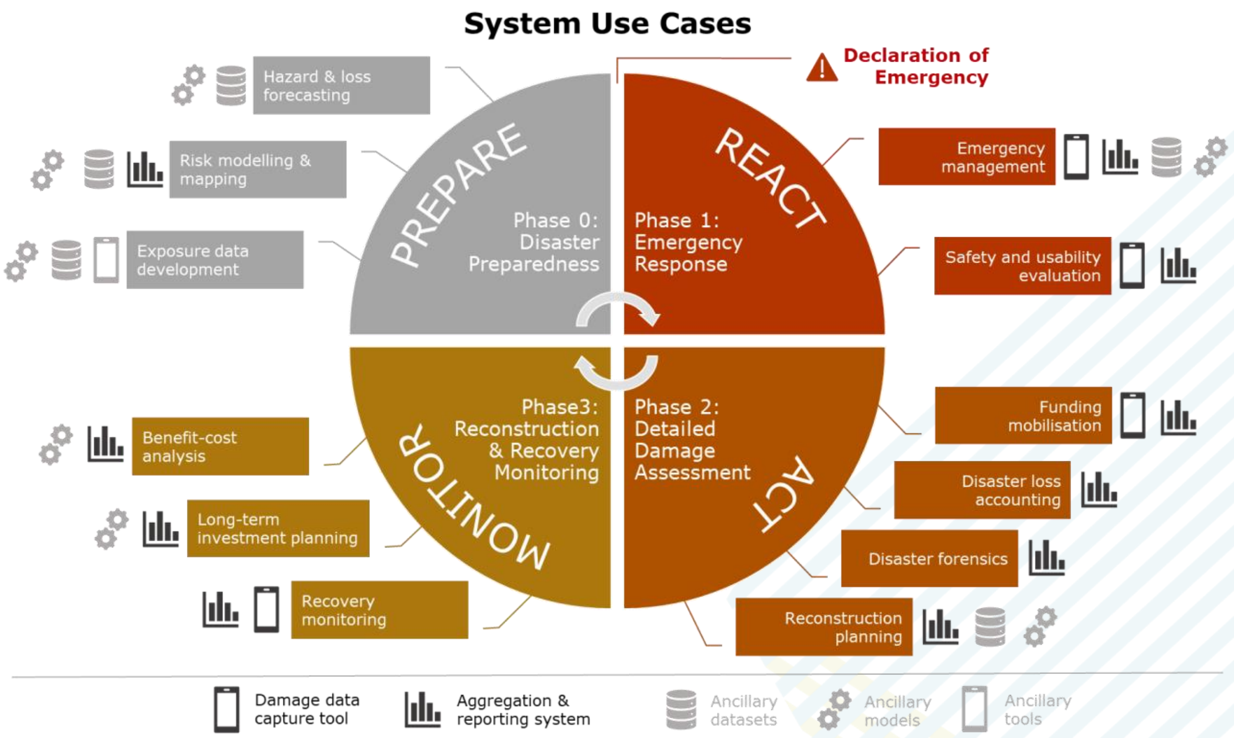

Figure 2-2. The use of the site data collection tool and data aggregation and reporting system to meet the use cases in each phase of the conceptual framework

3 Conceptual data design

3.1 Definition of the core entity relationship

An entity relationship describes interrelated items of interest within an area of knowledge, resulting in a data model. At a conceptual level the data model establishes the overall scope of what is to be included within the model set.

Figure 3-1 represents the 'Core' conceptual entity relationship diagram for the post-disaster data collection.

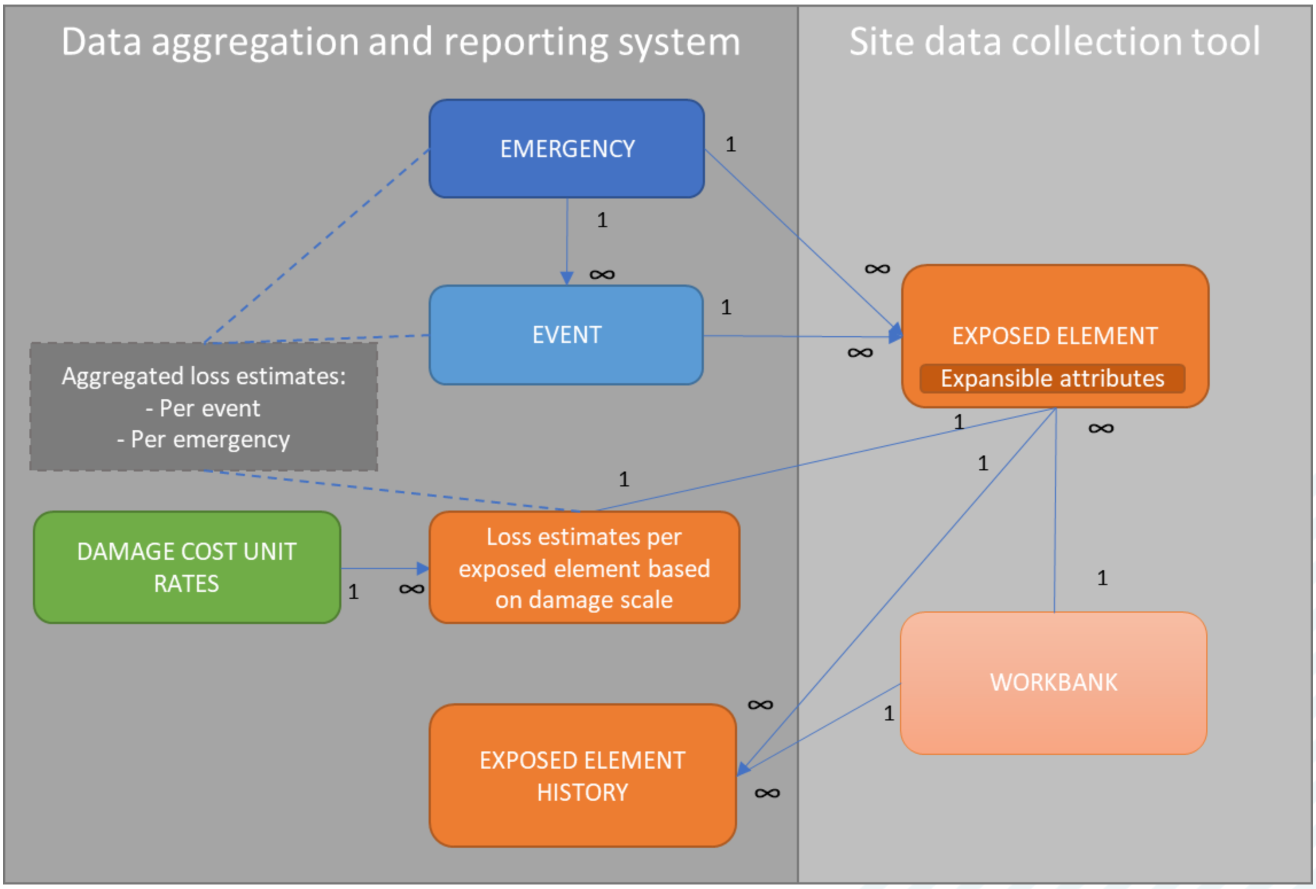

Figure 3-1: Conceptual 'Core' entity relationship diagram

The post-disaster data model should be designed to include the concept of 'Emergency' and 'Event' entities. These parameters will be used to define the context within which data on Exposed Element entities (buildings, roads, rail, critical facilities, agricultural crops, etc.) are collected.

The conceptual data model will consider a 'Core' data model required to collect post-disaster damage loss only. However, the system features seek to make the system extensible from this core data model as required by the responsible party at the time of implementation based on any additional or localised data collection requirements.

3.1.1 Emergency entity

An Emergency is defined when a state of emergency is declared by the responsible public authority in the affected country. It is intended that although the physical cause of an emergency may affect multiple countries, that an emergency will always relate to the declaration of a state of emergency which is linked to a singular government and country. The emergency entity forms the high level 'parent' entity to which all data will be related to.

3.1.2 Event entity

Within an Emergency, an Event will be defined for a single cause of damage, such as earthquake, flood or landslide events and links to the Disaster Loss Data (DATA) family classification proposed under the Integrated Research on Disaster Risk (IRDR) programme (UNISDR, 2018) 'Main Event' as represented in Figure 3-2.

The Event entity forms the main aggregation entity to summaries the site collected data in a format compatible, for relevant sections, with the Sendai Framework and the DesInventar Sendai Disaster Information Management System described in the Phase I report.

Figure 3-2: Integrated Research on Disaster Risk (IRDR) Disaster Loss Data (DATA) family classification (UNISDR, 2018)

As noted in Section 1.3, the product scope will restrict the full listing of DATA Events but can be expanded to cover all the DATA Events in the future.

Structuring the data in this form will meet the requirement to capture damage data following clustered events such as the New Zealand or Central Italy earthquake sequences, or from cascading events, such as earthquake-induced landslides. In addition, it also allows for data to be captured by multiple affected authorities, each with independent requirements to quantify losses, allocate funds for relief and recovery and manage/control their own damage and loss data.

3.1.3 Exposed element entity

The Exposed Element entity forms the mechanism for the data collection and the 'core' mandatory data to be collected on site. An Exposed Element is the generic term for the following categories of elements that may be affected by a disaster as defined within GED4ALL (Silva et al., 2018):

- Buildings
- Lifelines
- Crops, Livestock and Forestry
- Socio-economic.

The latter category is not considered a part of the 'core' data model as they do not represent a physical damage loss, but the data model could be extended to include these.

Each of the Exposed Elements will have a generic set of data to be collected. Variance will exist based on the Exposed Element category and the event or hazard type which will form a matrix of required data templates around the data model. The suggested matrix is illustrated in Figure 3-3.

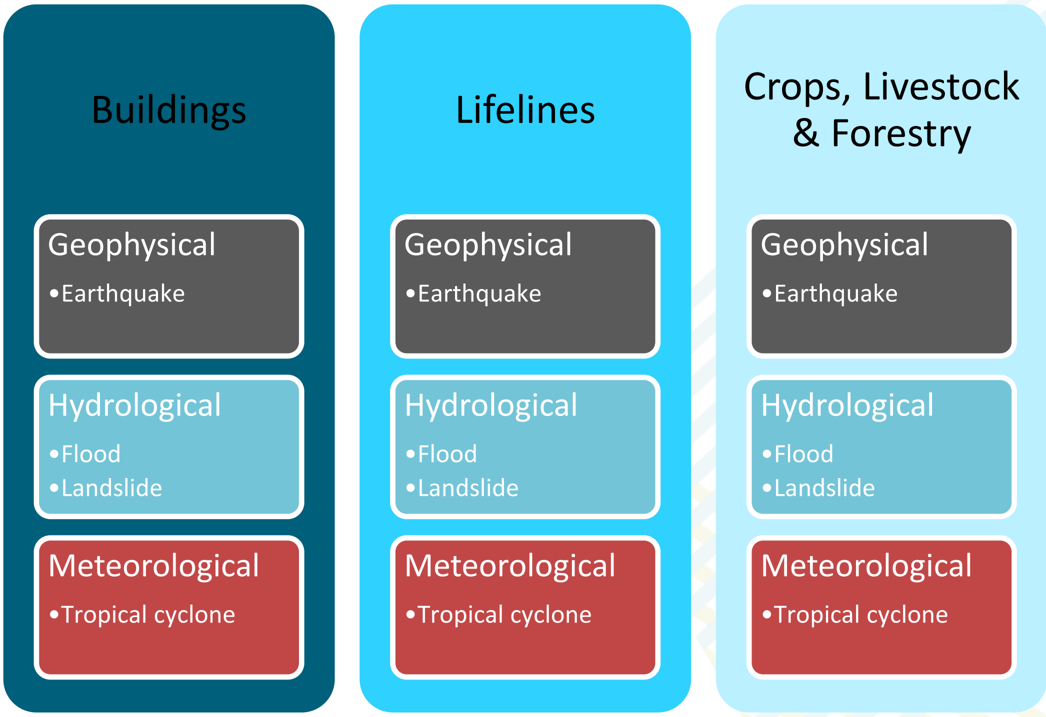

Figure 3-3: Exposed Element / Event Data Matrix

A generic damage categorisation could be applied to the Exposed Element based on the EMS-98 Grade 1 to 5 definitions but extrapolated from the building Exposed Element type to all Exposed Element types. Although EMS-98 provides a generic definition of damage grades, elaborated definitions are provided for a clearer definition of damage based on construction type. Elaborated definitions will need to vary based on the matrix presented in Figure 3-3 and functionality to enable the expansibility and data grouping of forms provided in the system functions Section 6.5.

3.1.4 Damage cost unit rates entity

A table of unit rates for damage costs related to the Exposed Element type could be provided to enable a rapid loss estimate, with a lower confidence of accuracy. Unit rates would be applied in the aggregation and reporting application based on the Exposed Element attributes.

As a minimum, the average unit rate would be provided based on the Exposed Element category and the damage scale with suggested units based on:

- **Point:** Buildings (occupancy)
- **Linear**: Lifelines (per length of linear section)
- **Area:** Crops, Livestock, Forestry (per tonne of produce or per hectare of land).

The unit rates would need to be expansible for a more detailed unit rate which would be based on the extended attributes of each individual Exposed Element category, using more accurate unit rates.

It is intended any modelling of unit rates would occur outside the system and the unit rate entity will be used to apply derived unit rates to Exposed Elements to produce a dynamic estimation.

A methodology such as outlined in the Hazus Multi-Hazard Loss Estimation Methodology[2] could be employed in a simplified form to enable a rapid estimation in the React phase, which allows for scaling of unit rates based on a simplified order of magnitude i.e. a building unit rate can be supplied based on average occupancy and linearly scaled at the Exposed Element level by the recorded building occupancy. Similar methodologies exist in the construction industry and quantitative surveying estimations. There is an important trade-off to be balanced within the React phase between accuracy of estimation and speed of data collection and estimate production.

The ability to override a unit rate should be provided to always allow an individual Exposed Element damage loss to be applied. The estimation override would be optional in the React phase but should form the basis for the estimation in the Act phase of the conceptual framework.

At the end of an Event, the established recovery costs collected in the Monitor phase should be used to review and refine unit rates for future estimation. Unit rates should also be periodically reviewed to adjust for any inflation/deflation affects. Versioning (version codes or dates) of unit rates will allow for future modification and transparency when analysing loss estimates.

3.1.5 Exposed element history entity

To enable monitoring of Exposed Elements over time, a secondary table containing all edits to an Exposed Element record will be stored on the server. Each historic record will be created on edit upload from site or via web-form entry. The Exposed Element historic entity should contain both the current

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2 FEMA (2013): Hazus - MH 2.1, Multi-hazard Loss Estimation Methodology Technical Manual, https://www.fema.gov/media-library-data/20130726-1820-25045-1179/hzmhs2_1_eq_um.pdf

Exposed Element record and the full history of edited records across Events. The Exposed Element entity will remain as the vehicle for editing data and site data delivery, and as such no direct editing of the Exposed Element history entity will occur. A record of Emergency and Event phase change will also be kept for reference.

The proposed scan tag reference would be the ID linking all Exposed Element data over time irrespective of Emergency or Event.

The Exposed Element history will enable data that have been generated in other projects/initiatives to be brought into the system. These exposure data can be brought in from official repositories developed by national mapping agencies, OpenStreetMap, cadastral datasets or those generated in previous projects. Users therefore would have the ability to cross-reference these data, updating the historic record with information on damage, temporary repairs or full restoration throughout the phases of the disaster.

3.1.6 Workbank entity

The workbank is an optional entity in the data model and represents the ability to predefine a listing of site locations to be visited. The workbank does not directly relate to an Event and is essentially a static list of spatial locations acting as a 'To-Do' list for data collection. The workbank might be derived from:

- A pre-considered set of locations based on supporting data such as address information or land usage
- Exposed elements of specific interest
- Statistically representative sampled locations.

The workbank would be used to guide and advice a site user in data collection. The entity has a loose relationship with Exposed Elements in that the relationship may be purely based on spatial proximity or a more formal one-to-one relationship with an Exposed Element, becoming a one-to-many relationship over time should multiple events occur. Where a more formal one-to-one relationship exists the workbank reference should be applied to the Exposed Element enabling tracking of data collection progress.

3.2 Logical entity attributes

To provide more detail and understanding to the conceptual data model, potential attributes to the main entities are suggested in the following sub-sections. The listed attributes do not represent a definitive list of attributes but rather important attributes to describe the conceptual data model.

3.2.1 Emergency entity attributes

The following table describes the logical attributes for the Emergency entity and provides summary information on the overarching Emergency along with an aggregated estimated damage loss for all Events associated with the Emergency.

Table 3-1: Emergency entity attributes

Attribute	Description	Type	Mandatory	Capture
ID	Primary Key - Unique identification value	Unique value	Yes	Generated
Void	Deletion marker should a record be accidently added allowing re-instatement should it be required without loss of data.	Boolean	No	Manual
OGR Geometry	OGR Spatial Object - Polygon - Emergency region	OGR	Yes	Map entered
Centroid Latitude	Latitude location for region under emergency declaration (bounded by country)	Float	Yes	Auto
Centroid Longitude	Longitude location for region under emergency declaration (bounded by country)	Float	Yes	Auto
Cause	Qualitative description of root cause of Emergency	Text	No	Manual
Magnitude	Qualitative / quantitative description of magnitude of Emergency	Text	No	Manual
Phase	Conceptual Framework phase the Emergency is in assumed to be the minimum of the constituent Events	Lookup List	Yes	Auto
Emergency Declaration Date	Date and time Emergency started	Date	Yes	Auto (create)/ Manual (edit)
Emergency Recovery Date	Date and time Emergency recovery is complete, and all Events return to Prepare phase.	Date	No	Auto (create)/ Manual (edit)
Emergency Duration	Store as time span float i.e. days, time, but ask in optional units of Days, hours, seconds	Float	No	Manual
Responsible Authority	Name of authority declaring state of emergency	Text	No	Manual
Loss Value (local)	Sum of losses directly caused by the disaster in	Decimal	No	Calculated

	local currency. Aggregated from Events.			
Loss Value (US)	The equivalent in dollars (US$) of the value of losses in local currency; according to the exchange rate on the date of the disaster. This figure is useful for comparative evaluations between databases. Aggregated from Events.	Decimal	No	Calculated

3.2.2 Event entity attributes

Table 3-2 describes the logical attributes for the Event entity and aims to provide aggregated data based on the Sendai framework as well as an estimated damage loss for an Event. Aggregated data should be automatically updated based on associated Exposed Element data.

Table 3-2: Event entity attributes

Field/Attribute	Description	Type	Mandatory	Capture
ID	Primary Key - Unique identification value	Unique value	Yes	Generated
Emergency ID	Foreign Key reference to Emergency. Supplied as site data collection project as one project per one Emergency.	ID	Yes	Auto
Void	Deletion marker should a record be accidently added allowing re-instatement should it be required without loss of data.	Boolean	No	Manual
DATA Family	DesInventar DATA	Lookup List	Yes	Manual
DATA Event	DesInventar DATA	Lookup List	Yes	Manual
Responsible Authority	Authority immediately responsible for the disaster recovery	Text	No	Manual
OGR Geometry	OGR Spatial Object - Polygon	OGR	Yes	Map entered
Centroid Latitude	Latitude location for Event	Float	Yes	Auto
Centroid Longitude	Longitude location for Event	Float	Yes	Auto

Field/Attribute	Description	Type	Mandatory	Capture
Phase	Conceptual Framework phase.	Lookup List	Yes	Manual
Cause	Qualitative description of root cause of Event	Text	No	Manual
Magnitude	Qualitative / quantitative description of magnitude	Text	No	Manual
Start Date	Date and time of Event start	Date	Yes	Auto (create)/ Manual (edit)
End Date	Date and time Event is deemed to be complete, occurring with a change in phase back to Prepare.	Date	No	Auto (create)/ Manual (edit)
Duration	Store as time span float i.e. days, time, but ask in optional units of Days, hours, seconds	Float	Yes	Auto
Relocated	The number of persons who have been moved permanently from their homes to new sites. If the information refers to families; calculate the number of people according to available indicators.	integer	No	Calculated
Evacuees	The number of persons temporarily evacuated from their homes; work places; schools; hospitals; etc. If the information refers to families; calculate the number of people according to available indicators. Aggregated from Exposed Elements.	integer	No	Calculated
Victims	The number of persons whose goods and/or individual or collective services have suffered serious damage; directly associated with the Event. For example; partial or total destruction of their homes and goods; loss of crops and/or crops stored in warehouses; etc. If the information refers to families; calculate the number of people according to available indicators.	Integer	No	Calculated

Field/Attribute	Description	Type	Mandatory	Capture
	Aggregated from Exposed Elements.			
Homes affected	The number of homes with minor damage; not structural or architectural; which may continue being lived in; although they may require some repair or cleaning. Aggregated from Exposed Elements.	Integer	No	Calculated
Homes destroyed	The number of homes levelled; buried; collapsed or damaged to the extent that they are no longer habitable. Aggregated from Exposed Elements.	Integer	No	Calculated
Routes affected	The length of transport networks destroyed and/or rendered unusable; in metres. Aggregated from Exposed Elements.	Integer	No	Calculated
Crops and Woods	The amount of cultivated or pastoral land or woods destroyed or affected. If the information exists in another measurement; it should be converted to hectares. Aggregated from Exposed Elements.	Float	No	Calculated
Livestock	The number of animals lost (bovine; pig; ovine; poultry) regardless of the type of Event (flood; drought; epidemic; etc). Aggregated from Exposed Elements.	Integer	No	Calculated
Educational centres	The amount of play schools; kindergartens; schools; colleges; universities; training centres etc; destroyed or directly or indirectly affected by the disaster. Include those that have been used as temporary shelters. Aggregated from Exposed Elements.	Integer	No	Calculated

Field/Attribute	Description	Type	Mandatory	Capture
Health centres	The number of health centres; clinics; local and regional hospitals destroyed and directly or indirectly affected by the disaster. Aggregated from Exposed Elements.	Integer	No	Calculated
Loss Value (local)	Sum of losses directly caused by the disaster in local currency. Aggregated from Exposed Elements.	Decimal	No	Calculated
Loss Value (US)	The equivalent in dollars (US$) of the value of losses in local currency; according to the exchange rate on the date of the disaster. This figure is useful for comparative evaluations between databases. Aggregated from Exposed Elements.	Decimal	No	Calculated
Other Losses	A description of other losses not included in the fields of the basic record. For example: religious buildings and monuments; architectural or cultural heritage buildings; theatres and public installations; public administration buildings relating to banks; commerce and tourism; vehicles or buses lost; bridges.	text	No	Manual
Sectors Affected	Qualitative fields in the database. It has two options: Affected or Not Affected. It relates to damages to the Sectors affected: - Transport - Communications - Aid organisations - Agriculture and Livestock - Drinking Water (Aqueducts) - Sewerage - Education - Energy - Industry - Health - Other	Multi tick	No	Calculated

3.2.3 Exposed element entity attributes

Table 3-3 describes the logical attributes for the Exposed Element entity and focuses on the generic attributes shared by all Exposed Elements. Expansion of these attributes will seek to follow the Rasor (2017) data structure for Exposed Elements which incorporated data structure from GEM, Hazus, and ICC.

Table 3-3: Exposed element generic entity attributes

Field	Description	Type	Mandatory	Capture
ID	Primary Key - Unique identification value.	Unique value	Yes	Generated
Emergency ID	Foreign Key reference to Emergency. Supplied as site data collection project as one project per one Emergency. Should be provided from server but connectivity may not allow addition of a new Event in which case this will be optional and applied on connection or assigning following upload to server.	ID	No	Auto
Event ID	Foreign Key reference to Emergency. Optionally added on site. Should be provided from server but connectivity may not allow addition of a new Event in which case this will be optional and applied on connection or assigning following upload to server.	ID	No	Auto
Void	Deletion marker should a record be accidently added allowing re-instatement should it be required without loss of data.	Boolean	No	Manual
Scan Tag Reference	Proposed to be in the form of human readable tag either embedded in a QR Code or as a written numeric code. Code based on location and date/time of creation. Tag remains for Exposed Element across Events and linked to physical object.	Unique value	Yes	Generated
Workbank Reference	Optional Foreign Key reference to the Workbank dataset. Formally linked using this attribute to monitor progress and can be automatically applied using closest spatial proximity or pre-selection to create the Exposed Element.	ID	No	Auto
Phase	Phase of data collection linked to protocol, Prepare, React, Act, Monitor. Links directly to form template the user has been assigned.	Lookup List	Yes	Auto
Country	Region parent grouping. Confined and defined by Emergency parent.	Lookup List	Yes	Auto

Field	Description	Type	Mandatory	Capture
Management Area	List of regions/municipalities etc linked to Country. (Spatially derived/list) maybe different to primary Event grouping.	Lookup List	Yes	Default to last entered if new/ Manual (edit)
DATA Peril	List of Perils based on parent Event (DesInventar). List confined by primary Event.	Text Code	No	Default to last entered if new/ Manual (edit)
OGR Geometry	OGR Spatial Object - Point (required) or Polygon (optional)	OGR	Yes	Map entered
Centroid Latitude	Latitude location for Event	Float	Yes	Auto
Centroid Longitude	Longitude location for Event	Float	Yes	Auto
Location Name	Optional free text name	Text	No	Manual
Element Category	List of Exposed Element types defining template to use for data collection	Text Code	Yes	Manual
Element Sub-Category	Sub-categorisation of Exposed Element based on Element Category selected, to refine definition and used to enable more detailed unit rates. Sub-categories may be more dynamic in nature than the category such as crops.	Text Code	Yes	Manual
n…	Multiple grouped attributes linked to Element Category and based on the Rasor Exposed Element data model	…	…	…
Damage Scale	Grade 1-5 Damage scale (based on EMS-98 and context help descriptions adapted to DATA Main Event types)	Lookup List	Yes	Manual
Proportion Damaged	Percentage of whole	Integer	No	Manual
Estimated Population Affected	A generic estimate of building occupancy, workers or size of community served by the Exposed Element to indicate size of the Exposed Element to assist rapid loss estimation only. Detailed information would be provided in the Act phase within the individual Exposed Element category template/taxonomy.	Integer	No	Manual

Field	Description	Type	Mandatory	Capture
Estimated Loss Value (Local)	Specified Exposed Element loss of revenue or repair/replacement cost in local currency (use approximate exchange rate at time of data upload to server). Overrides unit rate usage.	Float	No	Manual
Estimated Loss Value (USD)	Specified Exposed Element loss of revenue or replacement cost in US Dollars (use approximate exchange rate at time of data upload to server). Overrides unit rate usage.	Float	No	Manual
Recovery progress	Current stage of recovery progress (full time line stored on aggregation and reporting server)	Lookup list	No	Manual
Final Loss Value (Local)	Final cost in local currency (use approximate exchange rate at time of data upload to server), post recovery completion, of the Exposed Element loss of revenue or repair/replacement. (Used to advice future unit rate estimates)	Float	No	Manual
Final Loss Value (USD)	Final cost in US Dollars (use approximate exchange rate at time of data upload to server), post recovery completion, of the Exposed Element loss of revenue or repair/replacement. (Used to advice future unit rate estimates)	Float	No	Manual
Survey Status	States whether the survey is considered to be complete, in progress or cannot complete. Hidden from user and based on validation and template	Lookup list	Yes	Auto
Reason Survey Cannot be Completed	Provision of reasoning the survey cannot be completed such as too dangerous to access, location not found etc	Lookup list	No (Yes, if data invalid)	Manual

Although Table 3-3 defines the 'Core' entity attributes for the Exposed Element, the system features allow for further expansion of the data model to include localised legislation variances and data collection requirements. However, the 'Core' entity attributes described here should be considered 'locked' and a minimum requirement of the system usage to ensure a consistent dataset for assessment and reporting.

3.2.4 Damage cost unit rates entity attributes

Table 3-4 describes the logical attributes for the Exposed Element entity.

Table 3-4: Damage cost unit rates entity attributes

Field	Description	Type	Mandatory	Capture
ID	Primary Key - Unique identification value	Unique value	Yes	Generate d
Category	Exposed Element Type i.e. Building, Agriculture	Text Code	Yes	Manual
Sub-Category	Exposed Element Sub-type i.e. type of building or type of crop. Blank to default to the broader category unit rate	Text Code	No	Manual
Damage Scale	Grade 1-5 scale unit rate i.e. relates to inspection, repair, reconstruction	Integer	Yes	Manual
Average Population Affected	Average for unit rate provided to enable scaling of unit rate.	Integer	Yes	Manual
Unit Rate (USD)	Unit rate cost in US Dollars	Decimal	Yes	Manual
Unit Rate version	Version number or data of latest modification to unit rate costs	Text	Yes	Manual

3.2.5 Workbank entity attributes

Table 3-5 describes the logical attributes for the optional workbank entity. The spatial attributes may be used by the site data collection tool to create the Exposed Element at the same location or seek to link by spatial proximity to the closest workbank item within a spatial tolerance setting of notionally 100m. If a formal relationship is established in the site data collection tool the pre-defined location name and Element category can be pre-filled on the Exposed Element to assist the site user.

If used the workbank reference would provide a means of monitoring locations over time across multiple Events and Emergencies. In high risk areas it is plausible for the same Exposed Element to be affected by multiple Events within the same Emergency, or indeed by multiple Emergencies (e.g. many buildings and people affected by the 2010 Haiti earthquake were impacted later in the same year by Hurricane Tomas).

Table 3-5: Workbank entity attributes

Field	Description	Type	Mandatory	Capture
Workbank Reference	Primary Key - Unique identification value	Unique Value	Yes	Generated
Scan Tag Reference	Scan Tag for an Exposed Element if a definite linkage is intended and creating new Exposed Elements	Unique Value	No	Generated
OGR Geometry	OGR Spatial Object - Point (required) or Polyline/Polygon (optional)	OGR	Yes	Map entered

Centroid Latitude	Latitude location for Event	Float	Yes	Auto
Centroid Longitude	Longitude location for Event	Float	Yes	Auto
Location Name	Descriptive text of provided location (copied to Exposed Element)	Text	No	Manual
Element Category	List of Exposed Element types defining template to use for data collection (copied to Exposed Element)	Text Code	No	Manual (Batch assigned)
Assigned To	Reference only to user expected to be collecting data	Text	No	Manual (Batch assigned)

3.2.6 Exposed Element history entity attributes

The entity attributes for the historic listing of the Exposed Element entity, should match the Exposed Element entity attributes.

3.3 Exposed Element data cycle

The Exposed Element data, representing the physical damage in an Event, forms the primary data to be collected. The data will pass through a data cycle illustrated in Figure 3-4.

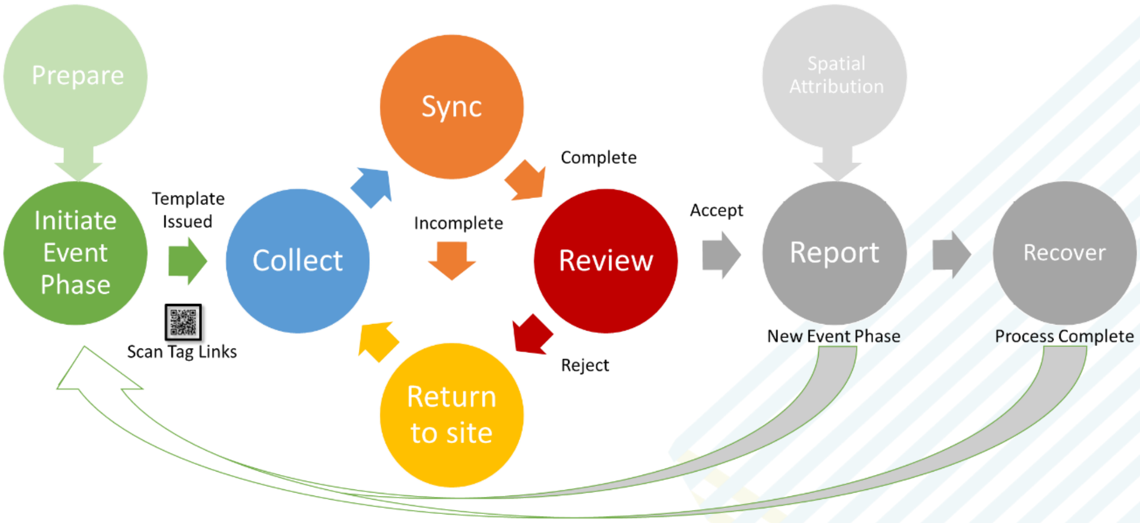

Figure 3-4. Exposed element data cycle

The data cycle begins with a phase initiation linked to the conceptual framework protocol, including the emergency declaration, definition of Emergency and Event and eventual return to the Prepare phase after the process completion. On initiating a phase, the appropriate data form template will be issued to users assigned to data collection and data reset and downloaded on availability.

Site data will have effectively three states: not collected, complete, and incomplete. The incomplete status will allow for any site access and data quality issue out on site. All Exposed Element data are synchronised between assigned users provided inter-communication is established. On successful completion of an Exposed Element record by the data collection team, an optional review of data can occur. The review could either accept, accept after minor edit, or reject an Exposed Element record. Rejection would return the Exposed Element record back to the data collection team for correction based on supplied reasoning. Acceptance would complete the within phase cycle for the Exposed Element enabling reporting and update of any event-wide spatial attribution such as from hazard intensity mapping or administrative boundaries. A new Event or completion of the recovery operation will end the phase data cycle and return the data cycle to the default phase - Prepare.

3.4 Data management

The system should not physically deleted data, but rather mark data as deleted if no longer required. If desired the system administrator could choose to purge the system of deleted data, but this should not occur at the user level.

A data backup regime will need to be established to ensure no data loss can occur in the event of hardware failure.

3.5 Worked examples

Single country, single event

The 2010-11 floods in Queensland caused widespread loss over a 4-6-week period. Although the flooding was caused by several meteorological events contributing to increase river levels, in the proposed model, the event would be categorised as a single Event under the flood Emergency.

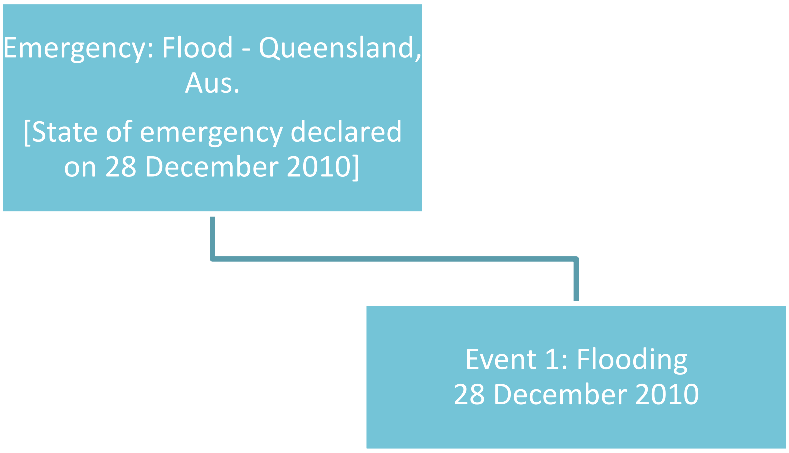

Figure 3-5. Example of Emergency-Event relationship for a single event impacting a single authority (district, county, state, country)

Single country, multiple events

A Mw7.8 earthquake took place in Nepal on 25th April 2015 and was followed by several aftershocks, of which the Mw7.3 12 May was the most damaging. Under the proposed model, The Nepal earthquake would become the Emergency, with the 25th April and 12th May becoming individual events nested in the Emergency.

This example would also apply for the 2016 M6.2 Central Italy earthquakes.

Figure 3-6. Example of Emergency-Event relationship for a damaging loss sequence with multiple impacting 'Events'. In this example, large-scale differentiation between damage caused by 25th and 26th April events will be almost impossible and so the Mw7.8 mainshock may be taken as the main cause of damage.

Multiple countries, single event

In events where more than one country is affected (e.g. the 2014 Sava river flooding in the Balkans, the 2004 Indian Ocean Tsunami), a state of emergency may be declared in multiple countries. In this use case it is expected that for the purposes of damage data collection, each authority would define their own 'Emergency' in the tool, each of which may have multiple Events, depending on cascading or clustered events.

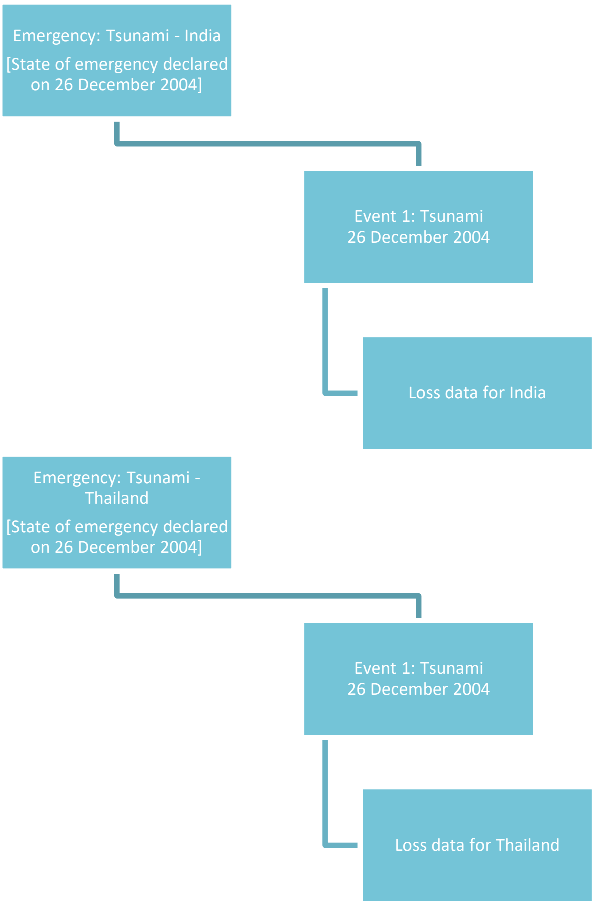

Figure 3-7. Example of Emergency-Event relationship for a single event that impacts multiple countries. In this case, each country that has declared a state of emergency would set up the site data collection tools with an Emergency that has affected their own country

4 System architecture

A system architecture that defines the structure, and behaviour of a system as a logical overview and representation of the system components and inter-relationship.

4.1 Hardware architecture

4.1.1 Site data collection tool / Aggregation and reporting system interface

Figure 4-1 provides a conceptual view of the hardware architecture to be used:

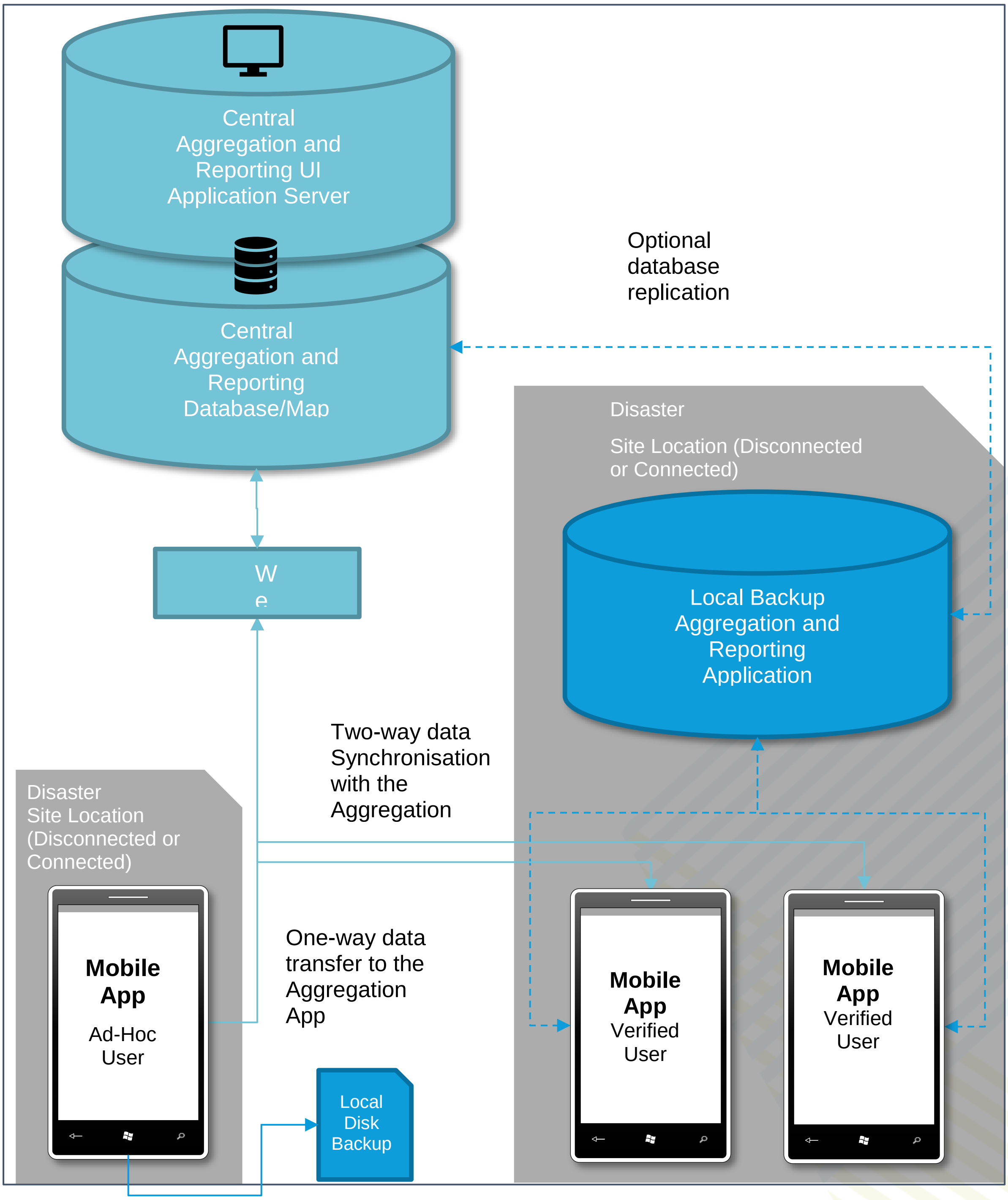

Figure 4-1: Conceptual hardware architecture

4.1.2 Aggregation and Reporting tool implementation strategy options

Consideration has been given to the location of the central aggregation and reporting server and envisaged levels of desired autonomy of individual countries. The implementation strategy would become a part of an individual requirements for a country. A trade-off will need to be considered between the efficiency and cost of implementation against the autonomy and perceived security of a countries data as illustrated in Figure 4-2.

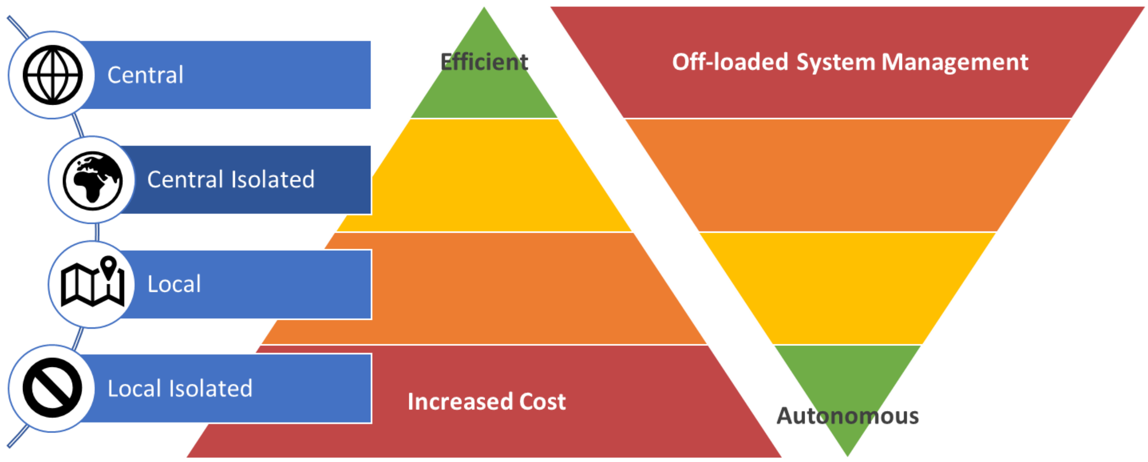

Figure 4-2: Implementation strategy balance

A matrix of options is therefore described in Figure 4-3 which could be used in the implementation strategy decision making but with a clear separation of options for the location of the application and database server.

	Central (Global)	Central (Global) Isolated	Local (Country)	Local (Country) Isolated
Implementation Environment	Single instance for all adopting countries within one hosting environment	Multiple instances for each country within one hosting environment	Instance hosted within the stakeholder country restricted to country based users	Instance hosted within the stakeholder country restricted to an organisation
Application Server	• Preferred option for efficiency to provide one central point of contact for the mobile application and maintaining one code set	• Still centrally managed and supported removing complexity from the country, but many sites to maintain and update so less efficient	• In this implementation the system is managed wholly by the country with support on request. Less efficient and harder to maintain consistency, but greater autonomy for the country	• The country based system could be further isolated to run under a local network, intranet and/or Virtual Private Network within an organization for additional isolation.
Database Server	• Not essential to be in a centrally hosted database but does simplify management and more efficient	• Preferred option for security as isolated from each country, but still efficiency in overall management.	• Here the database could still work with a central application server here providing efficiency, but the database would be under control of the data owner (country)	• As above, but noting data synchronisation from the mobile application would be more complex to setup.

Figure 4-3: Implementation strategy options matrix

A central server would be considered to be a hosted server providing a single point of connection globally. The hosted servers might take the form of a scalable hosting solution such as Amazon Web Services (AWS) or Microsoft Azure, but could be fixed server hosted within a partner organisation. In either scenario, the central hosted server could be connected to from anywhere in the world provided user and device restrictions are met.

A local server would be considered to be a server restricted to a single country with the intention the server would provide a single point of connection for the stakeholder country only. It should be noted the country-based server could still be shared with a centralised and approved support team to provide a more efficient support service pending the degree of autonomy desired.

Within all of the implementation options suggested above the data ownership and responsibility would remain with the individual stakeholder countries. It is the connection, physical location, implementation, maintenance, and support responsibility that would vary.

4.2 Software architecture

4.2.1 Interaction between protocol, software and tools

Figure 4-4 illustrates the interaction between the conceptual framework protocol, the post-disaster data collection software suite and any external software/tools and the inherent data collection process within the protocol.

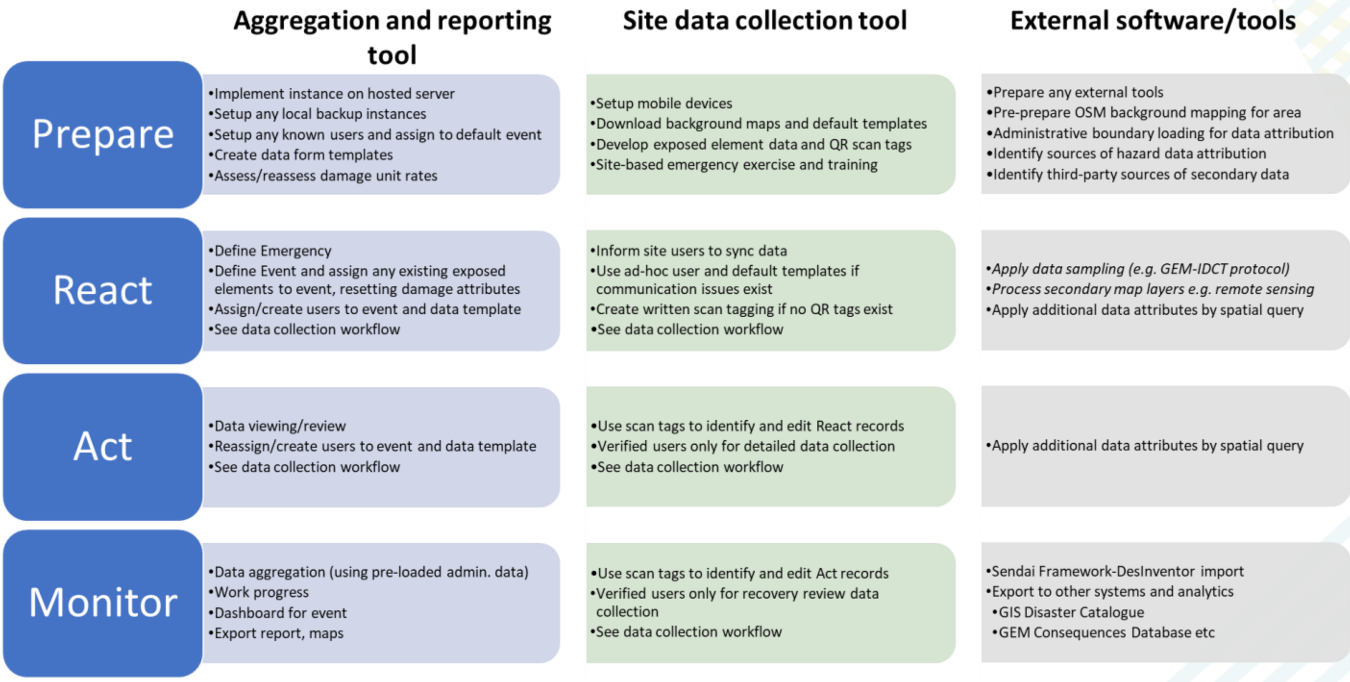

Figure 4-4: Interaction between methodology, software and tools

4.2.2 Interaction between the aggregation and reporting and site data collection tools

The site data collection tool will interface directly with the proposed data aggregation and reporting web application as illustrated in Figure 4-5. This will be the only intended interface for the site data collection tool.

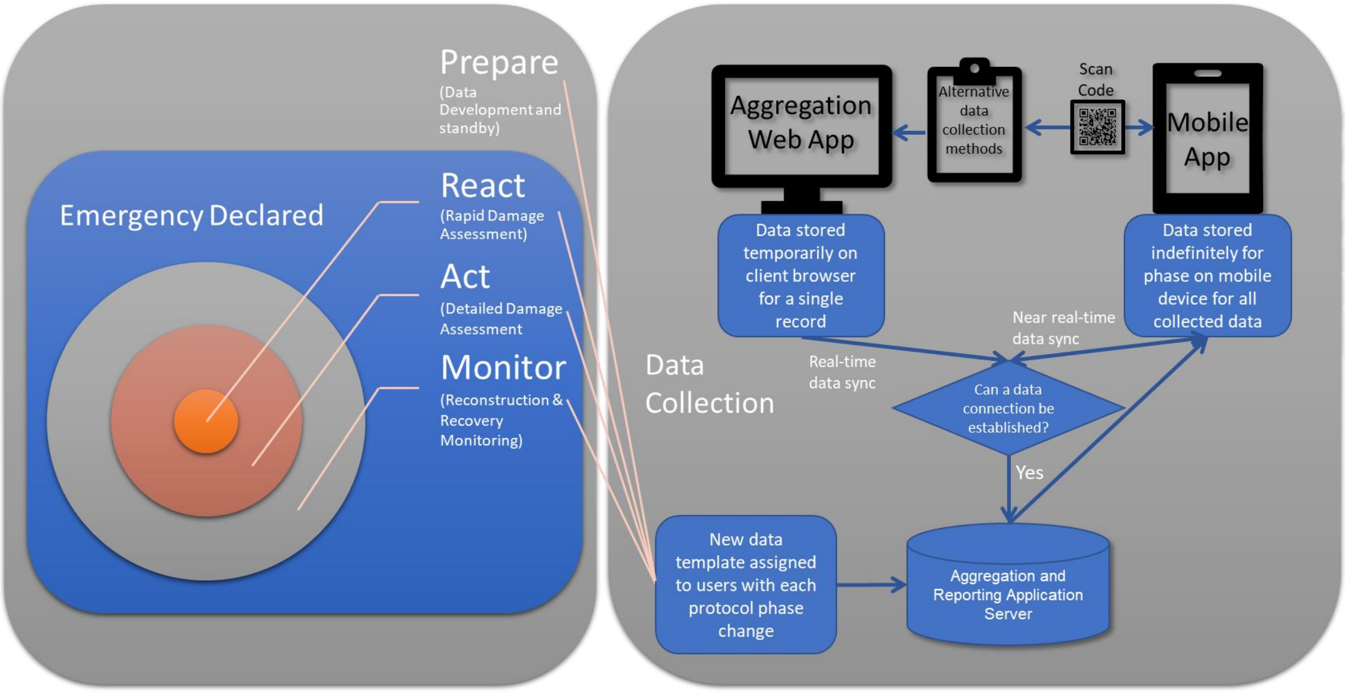

Figure 4-5: Interaction between site data collection tool and aggregation and reporting system using the conceptual framework

The software interface to the aggregation and reporting web application will be used for a number of purposes:

- Definition of a new Emergency or Event, for which data will need to be captured using the site data collection tool;
- Selection and customisation of the data entry screens to be used in-field, linked to the protocol phases, Prepare, React, Act, and Monitor;
- Synchronisation of data to/from multiple site data collection tools;
- Load any offline background maps, satellite images into the site data collection tools;
- Load any ancillary data layers (e.g. sample point locations, ground shaking maps, flood inundation footprints) into the site data collection tools;
- Send the latest data collected in the event to the site tools;
- Receive any new data from the site tools.

As a fundamental part of this interaction, data form templates will be issued to site users at each phase focused on the data collection task in hand. The envisage data form templates are:

- **React Template**: Generic
  - Single simplified generic template for multi-hazard and multi-exposed element data.
- Act: Event linked with country specified modifications
  - **Act: Earthquake template**
  - Earthquake damage focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.

- **Act: Flood template**
- Flood damage focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
- **Act: Landslide template**
- Landslide damage focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
- **Act: Tropical cyclone template**
- Tropical cyclone damage focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.

- Monitor: Event linked with country specified modifications
  - **Monitor: Earthquake template**
  - Earthquake recovery and reconstruction focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
  - **Monitor: Flood template**
  - Flood recovery and reconstruction focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
  - **Monitor: Landslide template**
  - Landslide recovery and reconstruction focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
  - **Monitor: Tropical cyclone template**
  - Tropical cyclone recovery and reconstruction focused multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry.
- **Prepare Template:** Exposed Element Data Development
  - Single multi-exposed element template, visibility of data controlled by the Exposed Element type and sub-type i.e. Building, Lifelines, Crops, Livestock and Forestry

To expand on this for clarity, using Armenia as an example country, the available templates listed within a country for assignment to a user might look like:

- React
- Act: Earthquake (Armenia)
- Act: Flood (Armenia)
- Act: Landslide (Armenia)
- Act: Tropical cyclone (Armenia)
- Monitor: Earthquake (Armenia)
- Monitor: Flood (Armenia)
- Monitor: Landslide (Armenia)

- Monitor: Tropical cyclone (Armenia)
- Prepare (Armenia).

The Exposed Element types and data variances therein are managed within the template and managed on site by the selection of an Exposed Element type and sub-type.

4.3 User interfaces

4.3.1 Wireframe workflow

Figure 4-6 illustrates the conceptual workflow for the site data collection tool and connectivity for the proceeding wireframes.

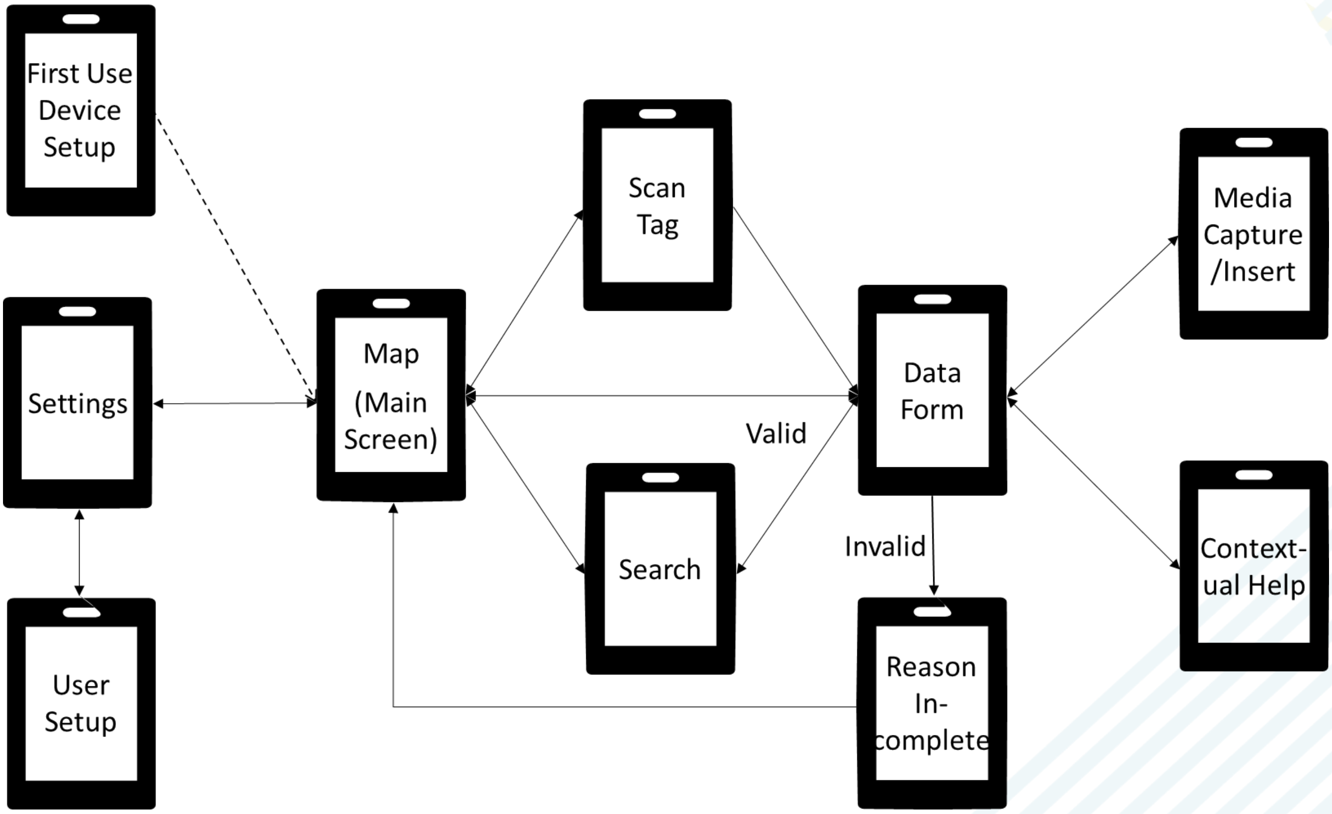

Figure 4-6: Conceptual site data collection tool workflow

First use device setup wireframe

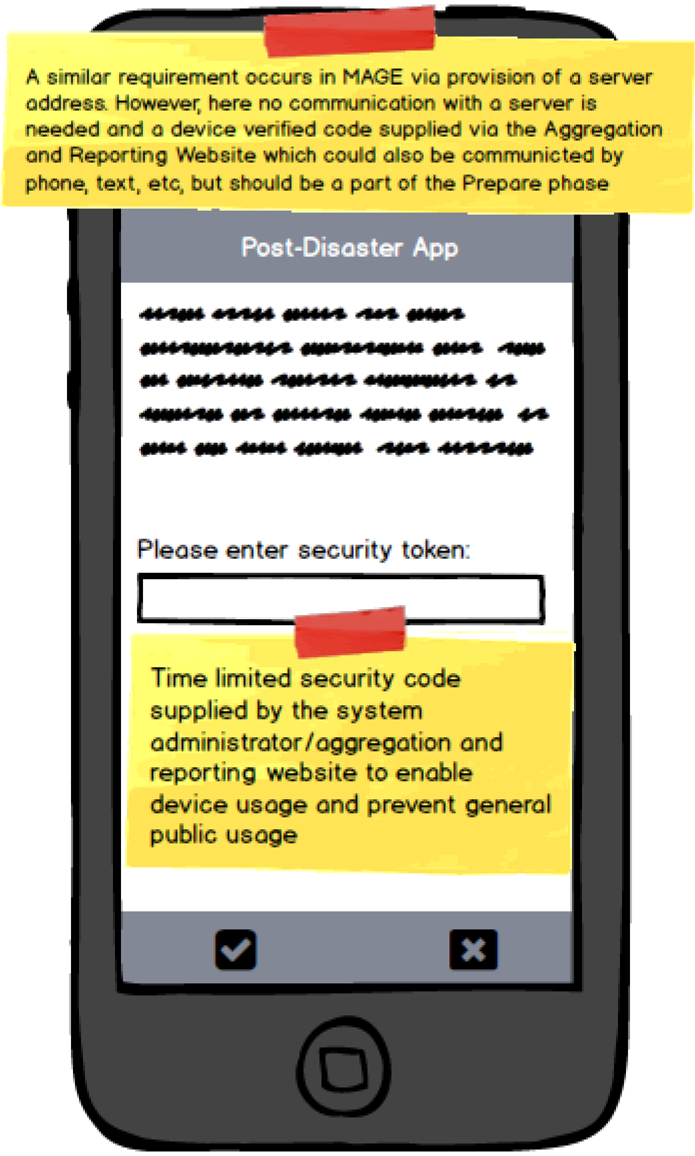

Figure 4-7: First use device setup wireframe

Map (Main screen) wireframe

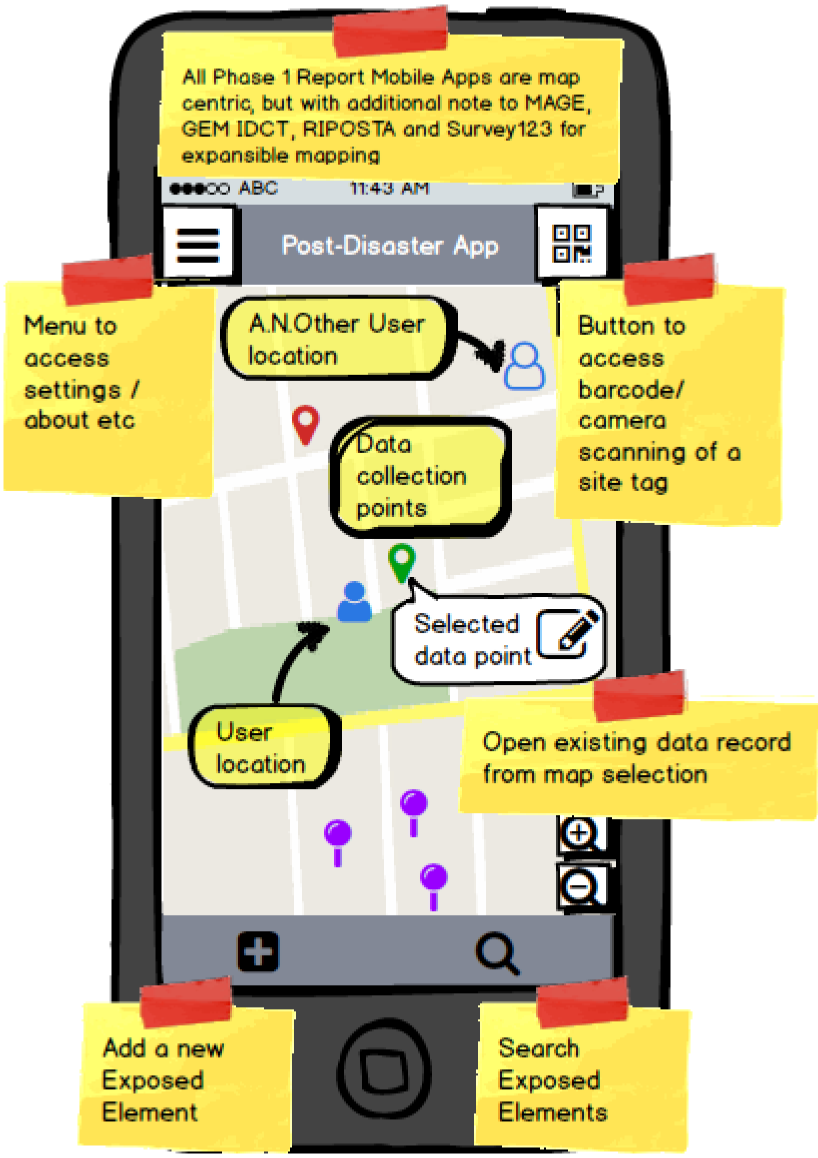

Figure 4-8: Map (Main screen) wireframe

Search wireframe

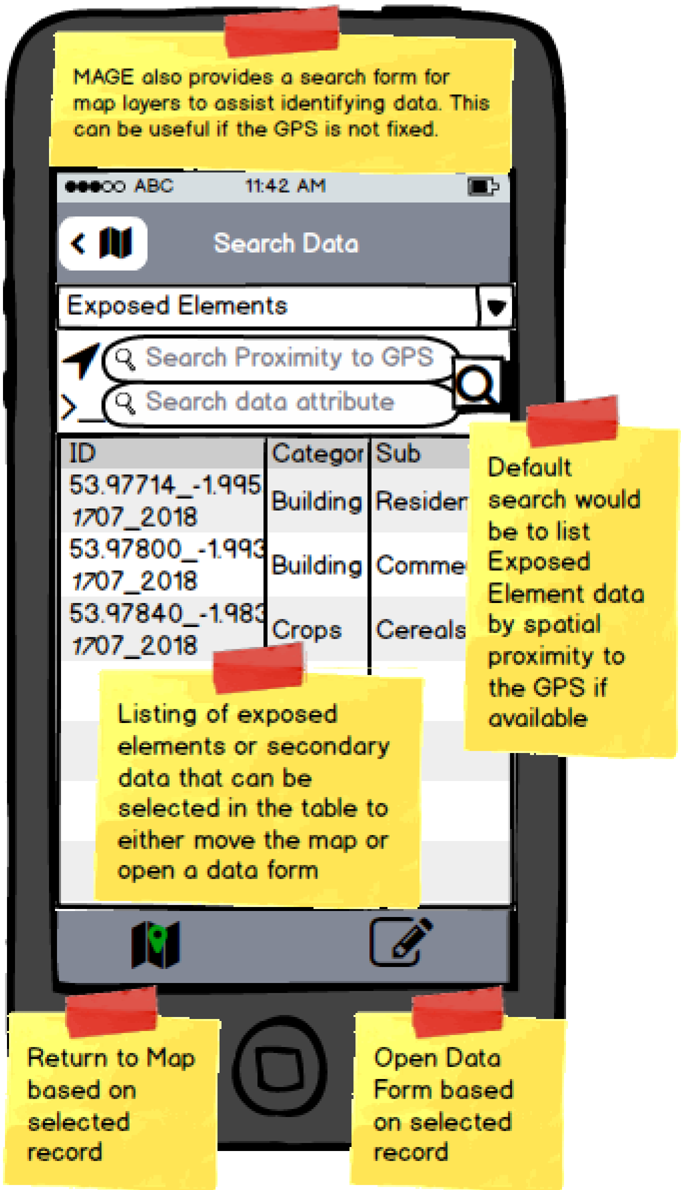

Figure 4-9: Search wireframe

Scan tag wireframe

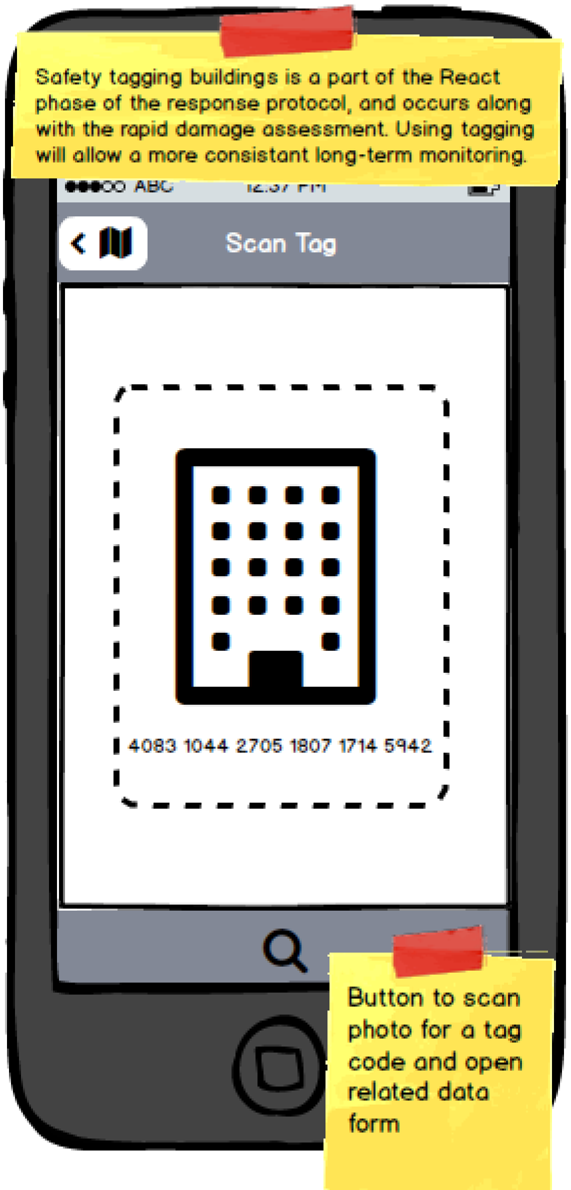

Figure 4-10: Scan tag wireframe

Data form wireframes

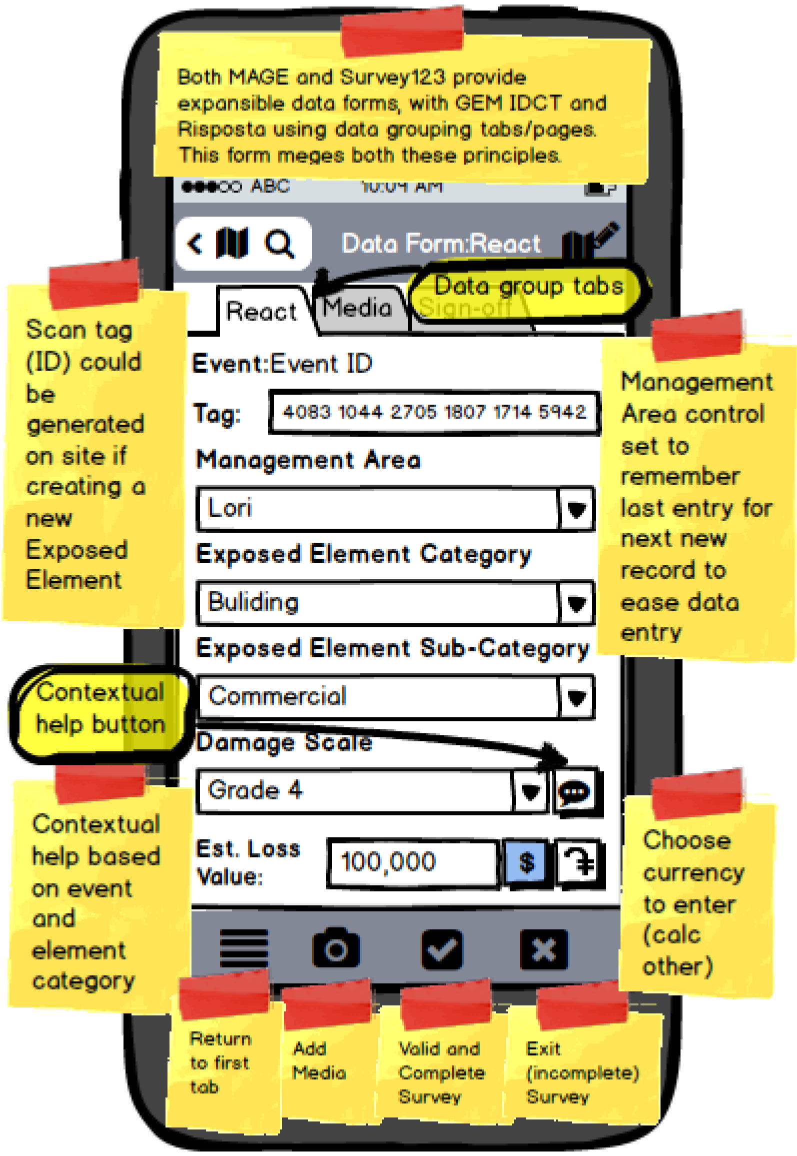

Figure 4-11: Data Form: React wireframe

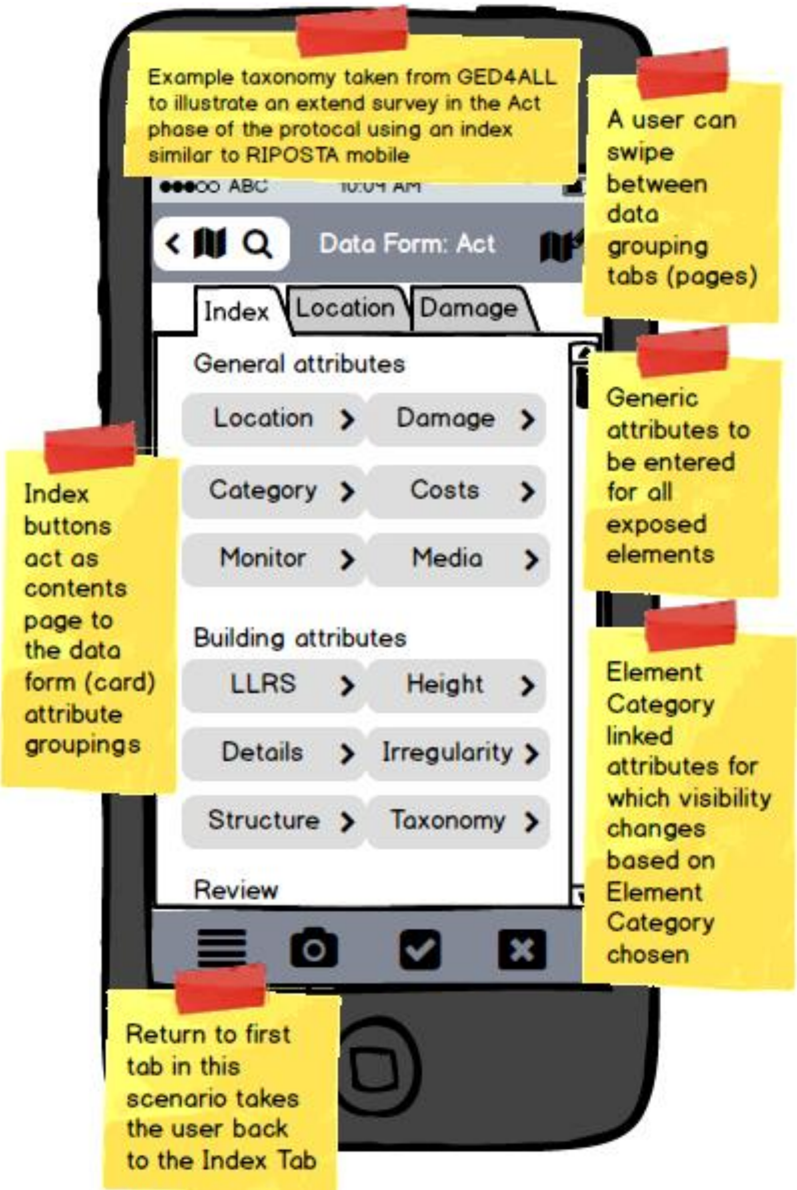

Figure 4-12: Data Form: Act - Index wireframe

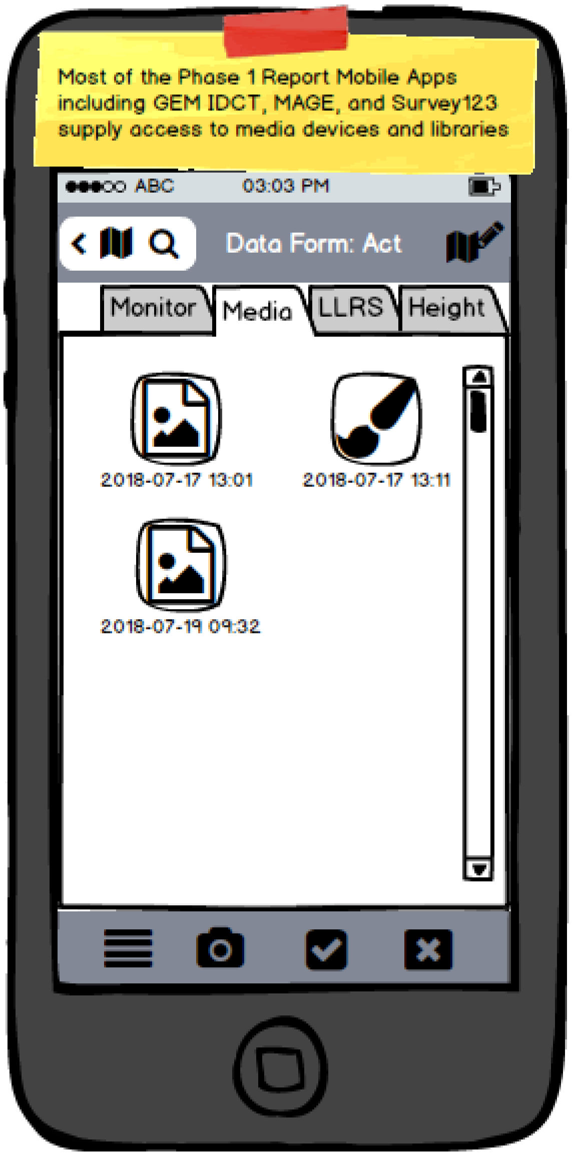

Figure 4-13: Data Form: Act - Media wireframe

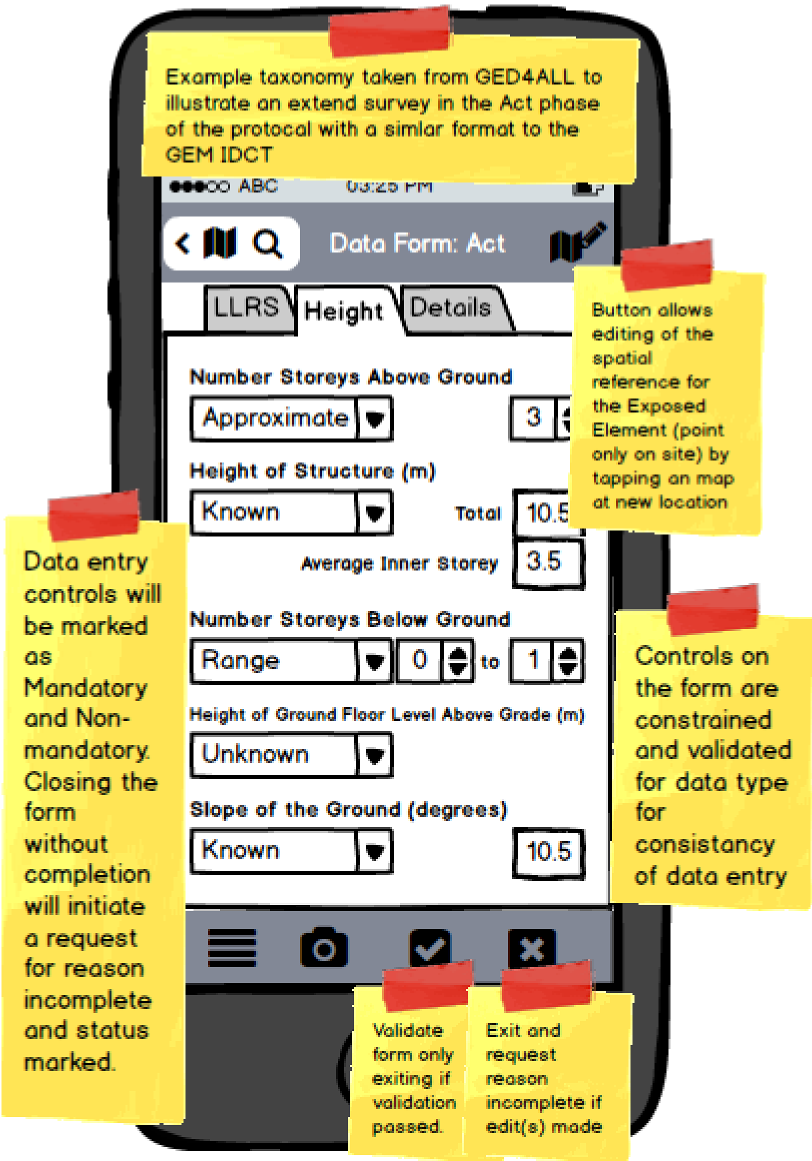

Figure 4-14: Data Form: Act – Element category example wireframe

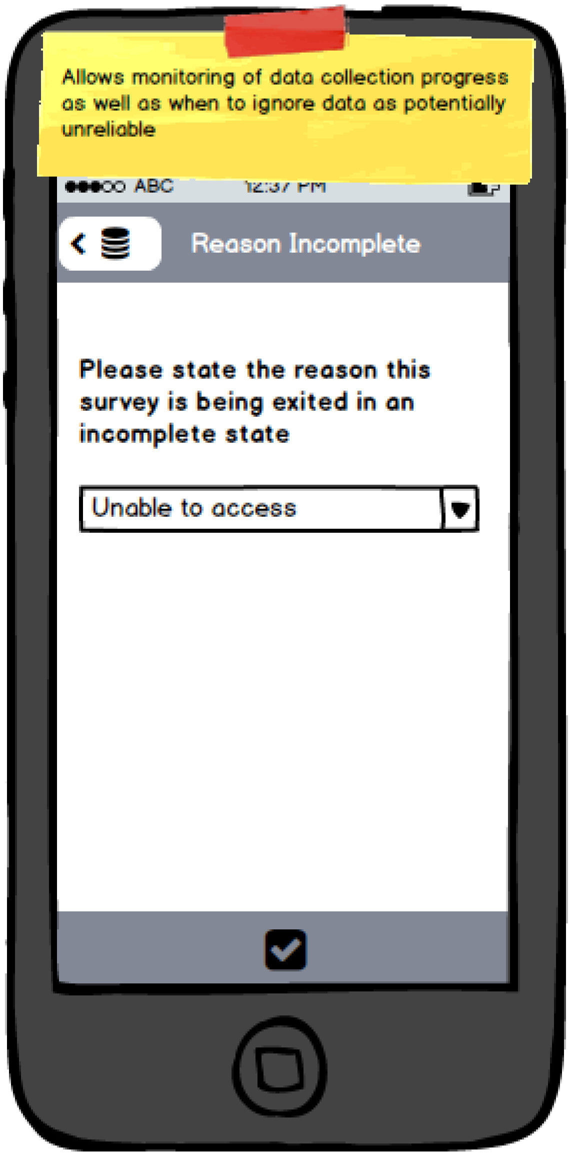

Figure 4-15: Data Form: Request for reason survey incomplete wireframe

5 External interface requirements

5.1 User interfaces

The site data collection tool will be used by a wide variety of users with differing experience and skills in the use of mobile technology or collection of damage data. Therefore, the user interface (UI) is required to be simple and clear to use, and the collection process should be as efficient as practical. There are a range of use cases for collection of data in the different phases of the disaster (Figure 2-1), each with the purpose of collecting damage or safety data. Any more advanced features should be hidden away from the general user.

To achieve this, UIs consistent with the operating system implemented should be used where possible to provide a familiar look and feel. Displayed information will need to be focused on the task in hand with any supplemental information and questions visible only when required.

The envisaged application will have the following core user interfaces:

Table 5-1. Summary of site data collection tool screens

Screens	Description
Login screen(s)	One-off verification(s) of the device and user
Map screen	Central application screen and opening screen displaying location
Search screen	Data attribute filtering/search screen
Scan tag screen	Scan a physical code to identify a data record in the Exposed Element data
Data collection screen	Data entry form(s)

The data entry form should be designed to fit varying screen resolutions for smartphone and tablets in both portrait and landscape rotations. Data entry questions should be clearly defined and logically grouped rather than a continuous list of scrolling questions. A system of showing and hiding groups of questions will be needed to keep questions focused to the user and the required data resolution, for example if a building element is chosen, only questions or drop-list items relating to buildings should be displayed.

5.2 Hardware interfaces

The software will need to interface with the following generic required hardware components:

- Global Positioning System (GPS)
- Camera
- Microphone
- Data connection

It should also be noted the hardware used should be weather-proofed and capable of being used outdoors for extended periods of time. A user check list should be developed alongside the tools to ensure that appropriate ancillary hardware is acquired and brought into the field – e.g. external battery packs allowing for USB charging of hardware in the field.

5.3 Software interfaces

The site data collection tool will interface directly with the proposed aggregation and reporting web application. This will be the only intended interface for the site data collection tool.

The software interface to the aggregation and reporting web application will be used for a number of purposes:

- Definition of a new 'Emergency' or 'Event', for which data will need to be captured using the site data collection tools;
- Selection and customisation of the data entry screens to be used in-field;
- Synchronising of data to/from multiple site data collection tools:
    - Load any offline background maps, satellite images into the site data collection tools;
    - Load any ancillary data layers (e.g. sample point locations, ground shaking maps, flood inundation footprints) into the site data collection tools;
    - Send the latest data collected in the event to the site tools;
    - Receive any new data from the site tools.

5.4 Communications interfaces

All site-server communications will be made using a Hyper Text Transfer Protocol with Secure Sockets Layer (HTTPS) to cater for encrypted transfer of data via web services. Data transfer will be bi-directional unless specifically stated as one-way by user restriction. This process should be automated, with any manual procedures as secondary backup only.

The aggregation server will be responsible for synchronising site data with a central store of data using a simplified time-based rule for merging data. Synchronised data can be requested by the site data collection tool and downloaded to an individual site-based device. This bi-directional synchronisation of data may occur immediately or be queued on a site-based device depending on the status of mobile communications.

6 System features

The overall objectives of the system are:

- Collect site-level data on damage to assets of interest (Exposed Elements) sufficiently to generate a rapid and transparent post-disaster loss estimate
- Provide aggregated Exposed Element disaster statistics compatible with the Sendai framework and other governmental reporting requirements.

The main system functions to achieve these high-level objectives are described in the following section, as an overall conceptual design for the site data collection tool. The application will communicate and transact with a parent aggregation and reporting system. The aggregation and reporting system functions, described separately, should be read in conjunction with this section.

6.1 Security and device verification

6.1.1 Description and priority

The application must be secured to verified users. It is intended the application could be made available on public app stores for download to provide ease of access and installation, but the site data collection tool will not be open to the general public to submit data. Device and user verification will be separated to simplify the end user usage, for an application with only intermittent periods of site use linked to an Emergency.

Device verification and linkage to a server is intended to be carried out by an advanced user to setup devices and create a default data store on a device.

User verification is to be carried out by an end user to link and synchronise with a specific Emergency and Event (see Section 3.1).

6.1.2 Stimulus/Response sequences

This will occur after downloading and installing of the application to a device, a user will need to provide a server address to communicate with and users details to complete a user verification.

6.1.3 Functional requirements

Device verification

Under normal circumstances an installation user will download the application from the standard Android or iOS app stores, and self-install. At this point the system should be inaccessible and only a login page should appear requesting a server address and application key. Separately, the server address and application key should be supplied to the installation user for entry into the application. The server will then verify these details and on success allow the device to communicate with the server based on a supplied token.

Once verified a device will not be required to login again unless the application is re-installed.

A default data model and dataset will be downloaded to the device at this stage but will not be linked to a specific Emergency or Event (as defined in Section 3.1).

User verification

User verification will be separate from the device verification as a user will be linked to an Emergency. As such, a user on a device will have a one-to-one relationship with an Emergency and will only work on one Emergency at a time.

Should the Emergency a user is assigned to on the server change, the data on the device will need to be transferred to and synchronised with the new Emergency.

A user will be provided with a user name (email address) and password. On first usage, over an internet connection, the user will enter and submit users' details to the provided server address to authenticate themselves. The server will then verify the details and on success return a token to the application.

Once verified a user will not be required to login again unless there is a change of user.

A hardware device will be required to access a server at least once under a verified user to download data for a required Emergency or Event. Should a user not have an internet connection or be entered as a user into the server system at time of usage the default data model will be used under an 'ad-hoc' user account. The user linkage to an Emergency and Event will be required to be entered at a later stage.

6.2 Operate in a data connected and disconnected environments

6.2.1 Description and priority

The system will be required to operate both within a mobile data connected environment and disconnected environment. Given the requirement to be used in post-disaster environments, long periods of time without an internet connection could occur and the site data collection tool will need to allow data collection and in-device storage under such circumstances.

6.2.2 Stimulus/Response sequences

Variable mobile network connectivity based on location or potential loss of communications following a loss event.

6.2.3 Functional requirements

Local data storage

All data required to operate the site data collection tool should be downloaded to a device. All data will be collected to a local data store.

In a mobile data connected scenario, data persisted to the local store should be periodically passed to the server at a short and configurable interval as a part of a server transaction discussed in Section 6.3.

In a mobile data disconnected scenario, data will be persisted to the local data store. Data will be stored locally until such time an internet connection can be established to allow transactions to the server.

Local backup/aggregation

It is envisaged a user may not be able to transact data with a server for long periods of time and therefore a method of backing up data to a secondary location will be required.

As a basic backup a cable or Bluetooth connection could allow a local backup of data to a separate secondary device.

Within the disconnected scenario whereby no Wide Area Network (WAN) can be established, it could still be possible to create a Local Area Network (LAN) either via a Wireless LAN or by direct cable connection to a laptop.

As a more advanced backup, a copy of the aggregation and reporting web application could be mounted locally with in a virtualised environment to provide a local transaction of data and backup of multiple devices. This method would also provide an early view of the data prior to a connection to the main server being established. Once communication to the WAN server is established database replication could be used to synchronise data. Any transaction with a local server would be considered by a device as not representing a final transaction which can only occur via a direct connection with a centrally hosted server.

Collect data without user verification

Devices setup for data collection in emergency circumstances may not be used for long periods of time and then require a rapid deployment. End users and surveyors may not be known at the time of device setup, insufficient time to add users or new users may initiate data collection within an emergency area where no data connection exists. In these scenarios, it will be more important not to delay data collection and an 'ad-hoc' user is required. The ad-hoc user will only be able to add new data and synchronise data to a server one-way, but the user would be able to collect data immediately without needing verification. The name of the user should still be collected against data to aid identification of data once data is returned to the server.

In this scenario though, the local device will not know any details of the loss event the data is collected for and will require association to a defined Emergency and Event. This association could occur either by user verification on the device and automatically post populating unassigned collected data or within the aggregation and reporting tool. A report will be required within the aggregation and reporting tool to identify unassigned data and allow batch assignment to an Emergency and Event.

6.3 Automated and prioritised data transaction

6.3.1 Description and priority

On connection with a server, data should be transacted with a server to synchronise data automatically. Data transfer will be prioritised, meaning greater importance is given to the transfer of data records to the server over and above larger media file transfer. This will speed up provision of core data.

6.3.2 Stimulus/Response sequences

Automated data transfer will be initiated by the availability of a data connection to a server.

6.3.3 Functional requirements

Automated transaction

To simplify usage, any manual intervention in transacting data with a centrally hosted server should be minimised and, as such, should occur automatically as a background process. The site data collection tool should periodically check for a server data connection and, on success, initiate data synchronisation with the server.

Prioritised data transfer

Data transfer needs to be prioritised for efficiency. It may be that in areas of very poor mobile signal and low bandwidth only a minimal amount of data can be transferred. Therefore, small and concise data packages should be transferred as a priority so as to not block data transfer. Data synchronisation should be prioritised based on size and bandwidth required to transfer data. It is considered the form-entered data are critical and will be small in size, whereas photographic or multi-media are supporting information and could be synchronised as secondary/tertiary processes.

The priority for data transaction will be:

- Send user location to the central server;
- Send data record updates to the central server;
- Acquire user locations from the central server;
- Acquire data record updates from the central server;
- Send media/large object data to the central server;
- Acquire media/large object data from the central server.

Data from a lower priority task should only be transacted if there is no data of a higher priority queued.

Furthermore, a user should be able to configure if media/large object data should be transacted on a mobile data connection, to conserve data allowance and power consumption. As such media/large object data would only be transferred over a Wi-Fi connection. This should be considered the default setting.

It may also be advised in protocols and training that Airplane Mode is used on the hardware to conserve battery power whilst maintaining a GPS connection. Additional general guidance (e.g. lowering the contrast on displays) and device-specific settings should be provided during training.

User location transaction

A user location based on GPS information at time of data transfer will be sent to the server, which will include the time of acquisition from the GPS along with the WGS84 longitude/latitude co-ordinates and user name. Each successful upload of location will be stored as a new record within a data table for user locations.

Acquisition of user locations will occur by requesting from the server the current location only of all users within the defined Emergency.

Data record transaction

The data records represent the core information to be returned to the server, providing concise data on site observations. This data will require synchronisation whereby, it is possible to both create new records as well as update existing records. Data should be synchronised using a simplistic rule based on time.

When data are collected, standard user information should be collected automatically against any record:

- User name
- Device reference
- Date/Time (using UTC)
- Type of edit (Created/Updated/Deleted).

Data should be uploaded to the hosted server and this user information can be used to decide on the synchronisation action required. The date and time in UTC the data are uploaded should also be recorded on the server on successful upload. Data conflicts can occur whereby a second user updates the same record. In this situation both edits would be stored, but the latest edit would be assumed to be the 'current' and most representative record to simplify conflict resolution.

Priority will be given to uploading data form the device and once each record has successfully been transacted should be marked on the device as synchronised and will not be listed for synchronisation again except on further edit to the record when the record should be submitted for again for synchronisation.

Following transaction of all locally edited data, the device should request any updates from other users are supplied. Again, this should be time based with an initial check for time variance, followed by download of a record on confirmation that a time variance exists.

Media / Large object transaction

Media data such as photographs, video, voice recordings, sketches etc all form 'large object' files or chunks of data. They will generally require a lot more storage space and transfer bandwidth than the first two types of data and therefore need to be treated separately.

As stated earlier, transaction of media data should be configurable and default to Wi-Fi transfer only with mobile data transfer optional.

It can be assumed all media data will be created and will be stored as new records on upload to the server and no further edits made.

Media data from other users should be downloadable using a time-based rule.

6.4 Spatial data

6.4.1 Description and priority

The ability for a user to visually locate themselves and provide an accurate location for the damage being reported is regarded as essential.

6.4.2 Stimulus/Response sequences

Spatialised data will be required, and the application will automatically acquire user location data from a GPS where possible and visualise a location as a 'map' with prepared 'background' maps along with any spatially attributed collected data.

6.4.3 Functional requirements

Global positioning system

Mobile device hardware will be required to have an in-built GPS for usage with the site data collection tool. Most modern mobile devices will be fitted with GPS hardware of typically 2-5m horizontal accuracy. For the intended usage of this application to rapidly collect damage data this accuracy is considered sufficient. If a higher accuracy, particularly with respect to vertical accuracy, is needed for future usage in detailed surveys an external Bluetooth Differential GPS could be considered which would replace the in-built GPS. The provided Location API of the operating system used should provide sufficient information on location from a GPS or alternatively the NMEA GPS format could be used.

Continual usage of the GPS can have a detrimental impact on battery usage, and therefore this should be considered when acquiring the GPS location, to only acquire when required or at a configurable refresh interval.

Map user interface

As an intrinsic focal point of the user interface, a dynamic map should be presented. The mapping should be underpinned by the principles of Geographic Information Systems (GIS) and allow a map that can be user manipulated displaying both vector (defined point co-ordinate data) and raster (image) based data, using the WGS84 coordinate system and datum.

On opening the site data collection tool this should be the initial view to a user, and exampled in several of the Phase I report applications such as:

- MAGE (illustrated below)
- GEM
- DARMsys – Survey 123
- RASOR
- RIPOSTA

Figure 6-1: MAGE map user interface

The map user interface will generally be combined with an application menu system accessible from the top left corner and the map display using as much of the screen real estate as practical. Map controls will be needed to assist user interaction with the map including:

- Pan
- Zoom
- Locate GPS location
- Identify/select.

Further, tools will be needed for data collection in the scenario where the GPS cannot receive a signal or to allow more complex geospatial data entry such as for polylines and polygons. Principally though, points will be used in the site data collection tool for simplicity.

Data attribution

All collected data should be attributed with a spatial location.

As this application is aimed at rapidly and efficiently collecting data on site, data should be collected as point data initially. This will help simplify rapid damage data collection in the React phase (the first 10-15 days of an emergency).

Further consideration will be needed for the scenario where no or very poor GPS signal exists. This can occur in built up areas, within narrow corridors such as transportation cuttings or steep valleys. Should this scenario occur the user should be presented with the map user interface and be requested to 'Manually' position the location under survey based on the supplied background mapping and best estimate. A similar methodology should also exist to edit the location of a previously entered point and 'manually' move the point on the map based on supplied background mapping to a representative location.

Should further, more detailed phases of surveys, occur the spatial representation could be amended to a line or polygon, but this is not considered essential in the initial site data collection and indeed a point reference could conceptually be post-processed against OpenStreetMap (OSM) or similar to assign items such as a building envelope or field boundary.

It should be noted that although it is only intended to collect point data on site, polyline and polygon data may be sent to site in data transactions and the mapping implemented used should also be capable of drawing polyline and polygon data.

Secondary dynamic data

A 'core' of data will be mandated for post-event exposure data collection, but the site data collection tool should be expansible to include secondary supporting data. This secondary data would be intended to supply small amounts of data to site and assumed to be dynamic in nature and transacted alongside the 'core' data.

Such data might include:

Earthquake ground shaking intensity maps (e.g. USGS ShakeMaps);

Flood inundation footprint maps (e.g. those derived from satellite imagery)

Site hazard information;

Workbanks for co-ordinating site data collection.

Background mapping

In order to provide a visual representation of a location, 'background' mapping is required. Generally, this is relatively static data that infrequently changes (examples of which would be OpenStreetMap, Google Maps, Bing Maps or government supplied cartographic maps). These are typically supplied with differing resolution of data to be used at different zoom levels i.e. whilst viewing a whole country to viewing a building on a map. For the purposes of the site data collection the background mapping will not be used for spatial queries and data should be supplied in the most storage efficient and performant format as a 'package' of data.

To reduce the impact of licensing restrictions, OpenStreetMap should be used as the primary source of background mapping data. These data are available for the whole world, however, with inconsistent completeness and source date as it is a public-produced dataset. The choice of background mapping data should be made following a comparison of available official government map data against public data such as OpenStreetMap.

As previously stated, all data, including background mapping, is required to work in an offline disconnected data environment. Therefore, background mapping needs to be delivered and stored to mobile devices. Delivery should occur with mobile device setup with periodic updates while devices are not in site usage.

The MAGE application employs the open standard 'GeoPackage' to achieve this, delivering data in a lightweight SQLite database format which can either be downloaded or copied to a device. This or a similar methodology is recommended and forms a part of the conceptual design.

6.5 Expansible data entry forms

6.5.1 Description and priority

A clear and concise method entering data is required with the ability to select relevant forms for the Emergency and Event context, and expansible to allow customisation of the data forms.

6.5.2 Stimulus/Response sequences

A user will be required to enter observed data for new and pre-existing data. These data need to be entered in a consistent manner within a clear interface. Furthermore, the data collection may vary based on context and detail required. This complexity needs to be hidden from the user to maintain simplicity.

Differing end-user organisations implementing the system may desire to vary the collected data requiring the system to be expansible from the 'core' data model. Secondary datasets, a suggested in section 0, may also be defined with an expansible form.

6.5.3 Functional requirements

Customisable form templates

Traditionally systems and applications are constructed around a fixed and highly structured data model. Changes to the data model occur through code development updates and application version releases. A clear intention of the conceptual design is to build in flexibility for end-users to adapt data models through customisation. This can be done through the usage of configuration files typically using XML to provide a form layout and data linkage 'Template'.

In the Phase I report an example of this is used in the DARMSys Survey 123 application where an open standard 'XLSForm' (and related subset of 'XForm') is used to define the XML configuration through user accessible Excel spreadsheets.

Either the XLSForm standard or similar would form an intrinsic part of the conceptual design to enable end-users to customise data collection beyond the mandated 'core' data model. XLSForm would provide a good basis for a customisable mobile application form implementing a sub-set as required by a final design. The following features all have reference back to this standard.

The actual interpreted layout of the XLSForm is for the implementing application to determine and design based on its implementation.

Data grouping/tabs

A concise data collection form is required for rapid data collection by inexperienced users with a clear definition of what is required of the data entry.

On mobile smartphones in particular screen real estate can be very limited complicating a whole view of the questions to be answered.

The GEM IDCT – Android app, presented in the Phase I report, implemented form 'tabs' to group questions together as illustrated below, whereby the tabs are listed at the top of the IDCT form:

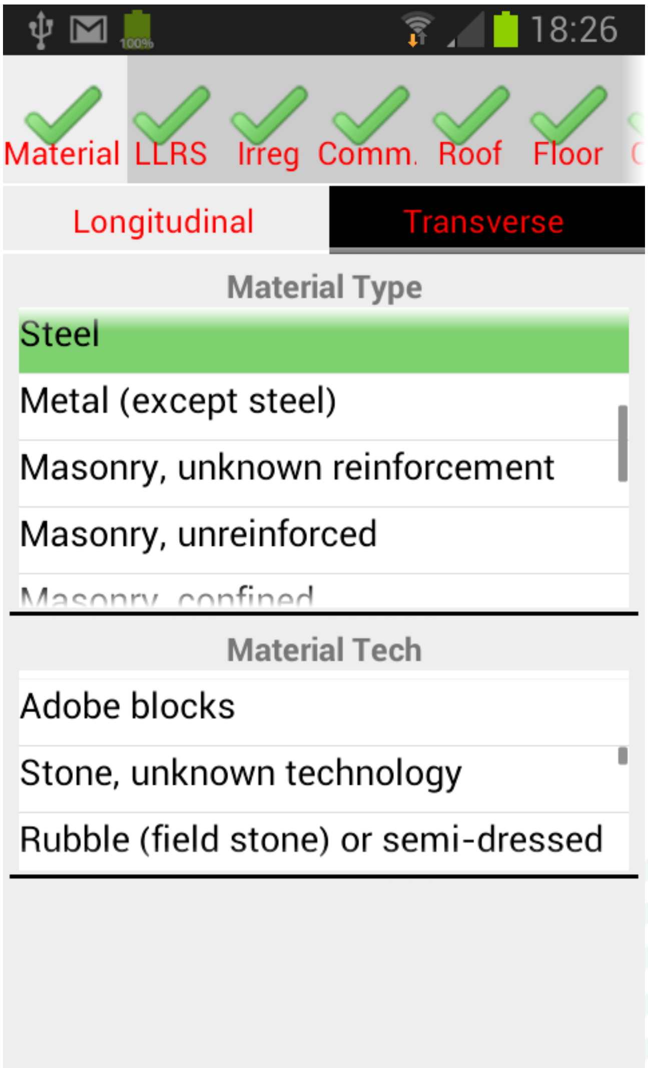

Figure 6-2: GEM Inventory Data Capture Tool (Android) data form

Data grouping can also be used to show and hide data questions based on the answer to a previous question. As such, a data form would evolve leading a user through the data collection.

Visibility of data groups could also be used to define different phases of survey such as an initial survey with minimal data collected marking damage followed by a more detailed survey refining the type of Exposed Element at a more granular level such as building materials and measurements or specific types of crops etc.

The notion of data grouping is available within the XLSForm open standard.

Constrained data entry controls

Data entry should be constrained to pre-defined options taxonomy wherever plausible to ensure consistency of data collection using standard controls such as:

- Drop lists

- Single answer
- Multiple answer

- Check boxes
- Numeric
- Date/time.

Linked with constrained questions should be illustrated contextual help or notes discussed in a following system feature. Contextual help conceptually can vary based on other options within the form such as the type of peril or the type of Exposed Element.

Free text

The ability for a user to provide free 'unconstrained' text should be limited, but the ability to provide a short qualitive assessment can provide useful supporting information and a single comment or description control should be provided. Smartphones allow the ability to dictate information into free text boxes, and although results of speech-to-text interpretation can be variable, this would form a fast way of entering free text.

Media

Photographic information can provide a very important method of describing and visually verifying data. The ability to take and store multiple photographic records against a data record is required, and should contain both the photo image itself and automated metadata to describe the photo including:

- Geo-spatial point location
- Date-time photo taken
- User name
- Device name
- Direction/bearing (where this can be recorded).

As previously stated, photographic media requires more storage space than database records but is more efficient than video media.

The ability to record video media could be provided on the same basis, but usage if implemented should be limited to areas of importance to make transfer of information as efficient as possible.

Template management

Template management in its simplest form will allow the download and upload of templates in the raw format (i.e. XLSForm or similar). More details on this can be found in the FRD for the data aggregation and reporting system (Appendix B of the main report).

6.6 Expansible database

6.6.1 Description and priority

As with the data forms, the data model and hence database for storing data needs to be expansible without a code development effort.

6.6.2 Stimulus/Response sequences

The principle of an expansible database fits alongside the usage of expansible data forms and would allow for users to rapidly extend the data recorded from the pre-defined 'Core' data, given the circumstances and requirements for the organisation or Emergency.

6.6.3 Functional requirements

The traditional method of collecting data involves the use of a 'structured' database with clearly defined tables and fields of data. Code is then generally developed around the database model to provide a fixed user interface. Alteration of the data model then requires application updates and release.

The concept of a 'NoSQL' database introduced the notion of a more flexible or expansible data storage. There are a number of implementations of a NoSQL database but the more relevant would be document-orientated databases making use of JSON or XML documents for storing records of information. An example in the Phase I report of a NoSQL database is within the MAGE application which uses MongoDB.

Within a NoSQL database only the data filled in needs to be transferred and additional items of information can easily be supplied without code redevelopment. The data model will then largely be dictated by the data entry form which in turn can be expansible, as described in the previous feature. This will be beneficial to stakeholders who have specific exposure types or attributes key to their loss estimation.

6.7 Taxonomy and contextual help

6.7.1 Description and priority

The taxonomy or classifications used have previously been developed within international standards and used to compose the applications presented in the Phase I report. These taxonomies should form the basis for the core data model and the associated constrained data entry. Furthermore, to aid data entry a visual and descriptive contextual help should be provided within the data entry form to assist users.

6.7.2 Stimulus/Response sequences

The site users maybe of variable experience both in terms of IT literacy and of post-disaster data collection. Users therefore need clear additional assistance on site to identify and appropriately classify damage scale and hence loss to ensure consistency of data collection.

6.7.3 Functional requirements

Taxonomy

The taxonomy for the system is derived from the type of Emergency, Event and Exposed Element. The definitions for these are not provided from a single source or standard.

The RASOR application, reviewed in the Phase I report, provides the closest combination of taxonomy for Event characterisation introducing the following standards:

- GEM Building Taxonomy - Buildings
- Hazus - Facilities, Infrastructure
- Indicative Crop Classification (ICC) - Agriculture.

An alternative to RASOR, the tool could adopt the multi-hazard taxonomy developed in the GED4ALL project.

As an assessment of physical damages and loss **the site data collection tool does not intend to cover further exposures such as areas of natural interest or land use,** but the potential to build in these items using the expansible database and data forms should remain possible.

Prior to development of the tool, the taxonomies used will need a thorough review to confirm that all forms of perils are supported although it is expected that GED4ALL and RASOR will fit the majority of use cases defined.

The GEM taxonomy for buildings is designed for developing exposure datasets for use in earthquake risk assessment. However, there a number of additional parameters of relevance to non-earthquake hazards, such as roof shape (windstorm), slope (flood, landslide) or height of first floor above grade (flood). These parameters will need to be checked to ensure the key attributes required for loss estimation are included in the data model underpinning the site data collection tool. The system should be flexible enough to be able to change the questions and the descriptive help based on the type of event and exposure. A matrix of taxonomies will exist between Event and Exposed Elements as illustrated in Figure 3-3.

Contextual Help

In order to provide user assistance on site and aid consistency in categorisation, the GEM ICDT application, reviewed in the Phase I report, employs the use of visual and descriptive definition of the building taxonomy provided on site. As such for a given structural component or type of building construction (exposure element) the user is presented with a sketch and description of the elements, as shown below:

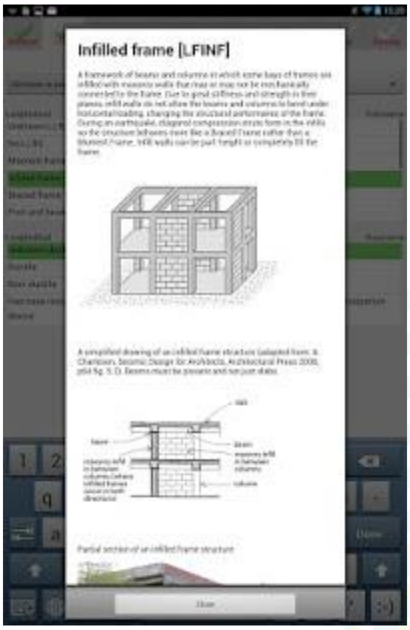

Figure 6-3: GEM Inventory Data Capture Tool (Android) contextual help

Conceptually this methodology of providing contextual help should be adopted by the site data collection tool. The GEM IDCT was not designed for use for detailed damage assessment (it is a data collection tool for building inventories for exposure data development), and so does not have a contextual help for damage data. There is an opportunity here to draw upon literature and resources developed to describe post-event damage classifications, greatly improving the user experience and performance.

Resources exist that should be considered for inclusion in the site data collection tool, including:

- Damage categories - earthquake: EMS-98 and IMS-14 extensions (masonry, RC, steel, timber) – Appendix A.

Damage categories for flood, windstorm, landslide or other perils should also be considered. Development of specific damage taxonomies for these perils would be a beneficial follow-on project and could be incorporated into the tools in the future.

6.8 Quick Response code / Optical Character Recognition code tagging

6.8.1 Description and priority

Repeat survey of physical objects can present difficulties in identifying the correct associated data record to update. As this system seeks to carry out repeat surveys under the React, Act and Monitor phases of the protocol, there is a need to easily and efficiently identifying physical objects within the system. As tagging already occurs within the protocol there is opportunity to assign a data record reference as a physical tag to an object, commonly carried out in the form of barcodes and quick response (QR) codes.

6.8.2 Stimulus/Response sequences

Creation of a new Exposed Element record would require the generation of a unique reference code to remain with the Exposed Element record over all time across events. As such one physical object i.e. building or field etc should be assigned one Exposed Element reference code. Once generated any repeat survey of an Exposed Element can reference this code to load the related data record for update.

6.8.3 Functional requirements

Quick Response codes

Barcodes are the historical method of tagging objects, e.g. food products and allow a numerical reference to be assigned which can be scanned to identify the object on a computer. More recently 2-Dimensional (2D) barcodes have been created such as a Data Matrix and **Quick Response** (QR) Code increasing the reliability and size of information content provided by a code.

The use of a QR code to tag Exposed Elements with a unique reference is proposed. A QR code tag could be positioned alongside safety tagging on Exposed Elements and could be read by mobile hardware via the camera on a mobile device. The QR code would contain the generated unique reference for an Exposed Element referred to as a Scan Tag Reference in Sections 3 and 4.

Preparation may be needed to assign a tag to an Exposed Element which could occur within the Prepare phase of the protocol. Alternatively, it is possible to print QR codes on site using a mobile QR code printer which could be issued as a part of standard issue hardware kit, with QR codes generated from with the site data collection tool and sent to the printer.

Once tagged an Exposed Element QR Code could be scanned directly within the site data collection tool to open the related data form to a user, without needing to identify the location on a map or searching data attributes, simplifying the user experience and providing a more consistent method of monitoring.

As a further consideration, should a public app be considered in the future for crowd sourcing, the use of a QR code would enable an efficient linkage of Exposed Element data for public usage.

Optical Character Recognition code

QR codes provide a clear and widely used method of tagging. However, if preparation has not been possible within the disaster area or logistically difficult, QR codes would not be available in the React phase when Exposed Element records are likely to be created within the site data collection tool. Therefore, consideration could be made to a lower technology method, with the scan tag reference being written out on paper in the React phase when an Exposed Element is initially created. In proceeding surveys, within the Act, and Monitor phases, Optical Character Recognition (OCR) could be used within the site data collection tool to enable the identification of an Exposed Element. The open source Tesseract library is an example of an OCR library which could be used with a mobile device camera to read in a scan tag reference. The use of OCR is potentially less reliable then QR codes, but if the reference is clearly written with no further markings it should be possible for a reference to be read in and act in a similar manner to a barcode. The scan tag reference would be formulated as human readable numeric such as seen on bank cards i.e. 1234 5678 1234 5678.

The OCR code could be used instead of the QR code if more practical or together based on use case.

6.9 Alternate data collection methods

6.9.1 Description and priority

The ideal for collecting data is to do so directly into a digital system in a consistent manner. However, the conceptual system described has dependencies, on items such as power and resources, which may render the system ineffective in a post-disaster scenario. Therefore, alternative data collection methods should be considered. Usage is only intended as a 'backup' and not the primary form of data capture.

6.9.2 Stimulus/Response sequences

Should the site data collection tool be inaccessible, alternative methods may need to be deployed to allow data collection to progress.

6.9.3 Functional requirements

Paper-based form

A paper-based version of the data collection form should be generated. This will be provided as downloadable PDF from the aggregation and reporting website and should be distributed to the survey team members when responding to a defined Emergency and Event.

The current taxonomies noted in Section 6.7 make use of alpha-numeric codes as a short descriptor of a classification. These and any additionally required short descriptor codes should be employed on the paper-based form to ease form filling and provide consistency. A user would provide the short descriptor codes in clear capitals or by check box to avoid any handwriting complications. The contextual help will be supplied as a supplemental document to inform short descriptor usage and aid user decision making as per the site data collection tool.

It is envisaged the paper-based forms can be returned and scanned to aid data entry back into the main system and potentially imported to a database.

However, scanned data may need review before applying to the main system as the following may not be available on site:

- Location in longitude-latitude
- Emergency and Event references
- Date and time will be to local time
- Incorrectly scanned responses.

Due to these limitations, any paper-based survey should be seen as a back-up only and usage discouraged under normal circumstances.

Data capture by the public / crowdsourcing

There are a number of options available for capturing basic damage information from the public. In disaster events, citizens are often the first responders for rescue and emergency relief. In terms of post-disaster damage data collection, especially in the React phase (the first days), some key information can be provided by citizens that can help triage areas of major damage/loss ahead of more structured, planned survey deployments in the detailed damage assessment (Act) phase of the conceptual framework, using the site data collection tools.

One potential option for crowdsourcing is based on centralised text alerts pushed to recipients with a number of basic prompts for data:

1 In the first days of the emergency (React phase), the national or local authority sends out a text message to the local population containing a URL directing them to a website.
2 When clicked, a simple web-page will request permission from the user to share their current location (assuming a smart phone with GPS is being used).
3 Users will see a map on a web-page centred on their current GPS location and be prompted to provide an alternative location – i.e. the location of their house.
4 Users will be prompted to input their construction type – and prompted by a series of graphics (e.g. from the World Housing Encyclopaedia (WHE)3 or the Glossary for GEM Building Taxonomy4).
5 Users will be prompted to input the damage level of the Exposed Element caused by the Event – prompted by a series of graphics (e.g. from EMS-98 or IMS-14 – Appendix A).
6 The central system will then generate an estimation of loss by using assumptions of replacement costs by structure and modifying the proportion of loss according to the damage category.
7 As the React phase progresses and moves into the detailed damage assessment (Act) phase, further prompts to respondents can be made to provide more information, such as photographs. Photographs would not immediately be requested to preserve bandwidth.

The public web page could be extended to a public version of the site data collection tool. This would allow a single data entry per device.

This approach would provide a high-level overview of damage from which a rapid, but rudimentary estimation of loss can be generated. The resulting dataset

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3 http://www.world-housing.net/

4 https://taxonomy.openquake.org/

should be separated from those data collected by the site data collection tool. The use of each dataset is likely going to be time-dependent, with crowdsourced data being most valuable in the hours and days after a loss event occurring. The data captured from a subsequent structured field survey in the detailed damage assessment (Act) phase (using the site data collection tool) is likely to be more detailed and more reliable than unsupervised citizen-derived data. However, there is potential value of citizen-contributed data in the React phase to aid prioritisation and targeting of more structured surveys.

This approach relies on several assumptions:

- Requires that cellular data availability is available post-event and users have access to smart phones to view image prompts;
- Requires that local data protection regulations are adhered to;
- Relies on users being receptive to passing information directly to the local or national authority. We should acknowledge that this may come with an implicit assumption of the contributing citizen that they will directly benefit (either through emergency assistance or compensation) from providing data, or that relief and detailed damage;
- assistance will be made available more rapidly as a result of their contribution;
- The system may be open to potential misuse or misreporting of information. There is no quality assurance of these data;
- Loss estimates will have large uncertainties due to the lack of quality assurance, use of assumptions on local construction categories and associated replacement costs.

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7 Other non-functional requirements

7.1 Performance requirements

Delays in software response can lead to user frustration and degradation in the quality of data returned. The site data collection tool should remain responsive to the user at all times. However, there will be occasions where a longer process is required, and the user interface may become unresponsive. Should a scenario exist where the user interface becomes or could become unresponsive adequate user feedback should be supplied in the form of messages or progress indicators.

7.2 Safety requirements

Usage of the site data collection tool should not put the user at risk and the ability to manually define locations is required to permit data entry from safe locations remote from the user location. Opportunity should also be given to a user to report inability to carry out a survey, such as due to site access issues, with an incomplete status. This aspect of the data capture processes should be strongly reinforced during training and possibly even include a splash screen within the application that is shown when first used and then periodically after a period of non-use.

7.3 Security requirements

Effort should be made to secure communications with the use of SSL certificates for encryption of traffic.

As the system is intended for global usage, the data protection requirements of individual countries will need to consider any localised variations, but the principles of the European Union General Data Protection Regulation (GDPR) should be implemented as a higher level of data protection and some implementation occurring outside of the European Union.

Authentication will be required at both a device level to enable software usage and user level to enable fully functional and event-focused data collection.

7.4 Software quality attributes

As discussed within the content of the system features, the key characteristics of the software are:

- Low cost implementation and open source
- Expansibility
- Usability
- Consistency
- Rapid site deployment.

7.5 Business rules

A hierarchy of ‘System Administration’ super-user roles will be setup to manage the site data collection tool:

- System Administrator
- System Manager
- User Manager.

A system administrator user role will be required within the system to maintain the system as a whole. A system manager user will also be required to create

Events, provide customisation of the system as required. A further role of user manager should be provided for the verification and management of users. This will form a hierarchy of functionality with a system administrator enabled for all functions. These users are defined for the aggregation and reporting system but will have the ability to affect the site data collection tool.

A log of verified users will need to be kept within the system. A verified user will be associated to a single Event or no Event for the site data collection tool, and association will be manged by the system users.

8 Other requirements

Internationalisation

Although the initial assumptions for the system is to use English as the default common language of communication, expansibility for language should be considered as the application is intended for global usage.

As the system is to be designed to be natively expansible, this functionality should be used to provide future internationalisation.

With the exception of free text comments, all response data should be returned using language neutral codes, with any data questions, drop-list taxonomy and contextual help modified by a language user setting.

The user interface should make use of icons where possible, to visualise an action and where text is required within the application an application settings file will be required to alter the supplied text based on the user defined language. Should the user defined language not exist for any part of the system, the system will always default to English.

8.1 Server linkage

Conceptually, the system could be used against numerous servers provided the correct data interfaces where implemented on the server to transfer data. The configurations and responsibility for connected servers remains for definition, and a part of any individual countries implementation strategy as discussed in Section 4.1.2. In theory it would also be possible for a third-party application to connect to the server provided the web interface protocol is met, should a country wish to use a different mobile application. However, data validation and consistency may vary under these circumstances and therefore integration should be considered carefully.

Additionally, but sperate to the above, localised backup servers may be used.

The system should be flexible to the connections of the various servers, minimising any site user interaction to define these. Where possible, device setup should occur in advance of an emergency (ideally in the Prepare phase) and by a trained user.

9 MoSCoW analysis

The following table provides a prioritisation of the identified system features using the Must have, Should have, Could have, Won’t have (MoSCoW) nomenclature. An estimate of effort using a High Medium, Low scale is also provided based on a new code development.

Report Section	Feature (hyperlinked to text)	MoSCoW	Effort
6.1 Security and device verification			
	Device verification	Must	Medium
	User verification	Must	Medium
6.2 Operate in a data connected and disconnected environments			
	Local data storage	Must	High
	Local backup/aggregation	Could	High
	Collect data without user verification	Should	Medium
6.3 Automated and prioritised data transaction			
	Automated transaction	Must	High
	Prioritised data transfer	Should	Medium
	User location transaction	Could	Low
	Data record transaction	Must	Medium
	Media / Large object transaction	Must	Medium
6.4 Spatial data			
	Global positioning system (GPS)	Must	Low
	Map user interface	Must	High
	Data attribution	Must	Medium
	Secondary dynamic data	Could	Medium
	Background mapping	Must	High
6.5 Expansible data entry forms			
	Customisable form templates	Must	High
	Data grouping/tabs	Must	Medium
	Constrained data entry controls	Must	Medium
	Free text	Must	Low
	Media	Must	Low
	Template management	Must	Medium
6.6 Expansible database			
	Expansible database	Must	High
6.7 Taxonomy and contextual help			

	Taxonomy	Should	Medium
	Contextual Help	Should	Medium
6.8 Quick Response code / Optical Character Recognition code tagging			
	Quick Response codes	Should	Medium
	Optical Character Recognition code	Could	High
6.9 Alternate data collection methods			
	Paper-based form	Could	Medium
	Data capture by the public / crowdsourcing	Won’t	High

References

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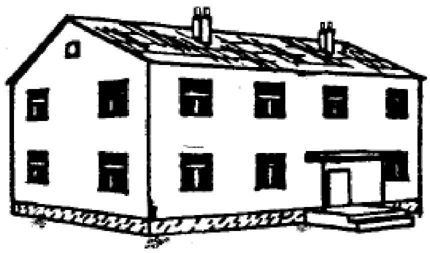
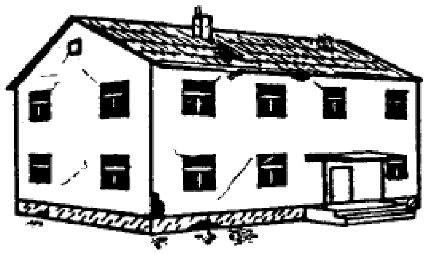
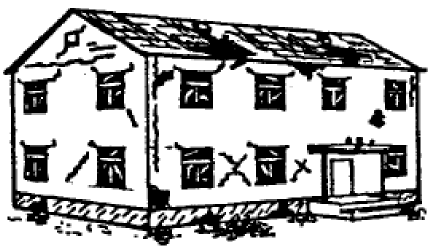
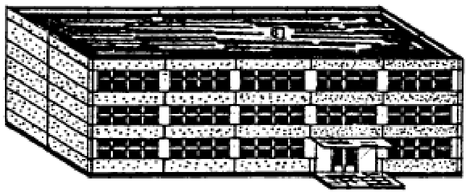
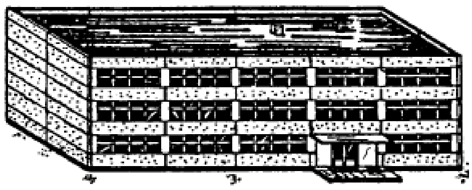
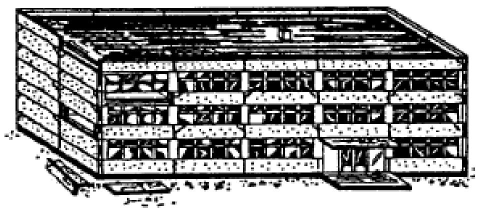
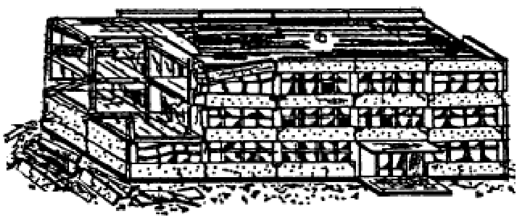
A Appendix A: Examples of contextual help for damage classification

The following information should be provided in the site data collection tool for describing damage based on the peril of interest and the structural type of the damaged asset.

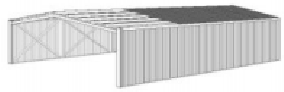
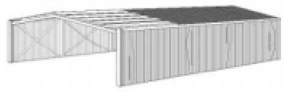
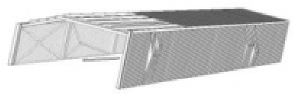
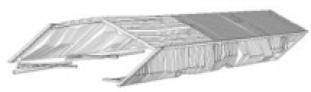
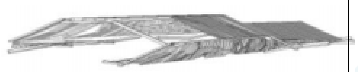
A.1 Masonry- EMS-98 (from Grünthal, 1998)

Classification of damage to masonry buildings	
	**Grade 1: Negligible to slight damage** **(no structural damage,** **slight non-structural damage)** Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
	**Grade 2: Moderate damage** **(slight structural damage, moderate non-structural damage)** Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage,** **heavy non-structural damage)** Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
	**Grade 4: Very heavy damage** **(heavy structural damage,** **very heavy non-structural damage)** Serious failure of walls; partial structural failure of roofs and floors.
	**Grade 5: Destruction** **(very heavy structural damage)** Total or near total collapse.

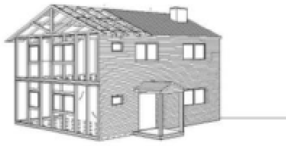
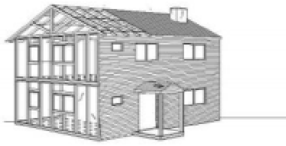
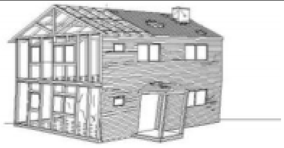
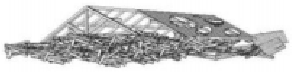
A.2 Reinforced concrete - EMS-98 (from Grünthal, 1998)

Classification of damage to buildings of reinforced concrete	
	**Grade 1: Negligible to slight damage** **(no structural damage,** **slight non-structural damage)** Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infills.
	**Grade 2: Moderate damage** **(slight structural damage,** **moderate non-structural damage)** Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels.
	**Grade 3: Substantial to heavy damage** **(moderate structural damage,** **heavy non-structural damage)** Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Spalling of conrete cover, buckling of reinforced rods. Large cracks in partition and infill walls, failure of individual infill panels.
	**Grade 4: Very heavy damage** **(heavy structural damage,** **very heavy non-structural damage)** Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns. Collapse of a few columns or of a single upper floor.
	**Grade 5: Destruction** **(very heavy structural damage)** Collapse of ground floor or parts (e. g. wings) of buildings.

A.3 Steel - IMS-14 (from Spence and Foulser-Piggott, 2014)

	EMS-98 Definition	Proposed IMS-14 Elaboration	Proposed modifications for sub-classes	Diagrams
Grade 1	Negligible to slight damage (no structural damage, slight non-structural damage	Fine cracks in plaster over frame members or at the base. Fine cracks in partitions and infills		
Grade 2	Moderate damage (slight structural damage, moderate non-structural damage	Few cases of failure or distress of frame members, bracing members or structural connections in a few cases; Cracks in partition and infill walls; failure of brittle cladding and plaster	In light steel frame structures a few rod braces may have yielded. (Light-steel frame structures)	
Grade 3	Substantial to heavy damage (moderate structural damage, heavy non-structural damage	Visible leaning of building or individual storey; some broken or buckled members in roof trusses; some distortion of columns or damage at connections; failure of some bracing members; Large cracks in partition and infill walls, failure of individual infill panels	Many braces have yielded (Light-steel frame structures). Masonry infilled frames may exhibit crushing of masonry around beam-column connections.(Masonry infilled frame structures)	
Grade 4	Very heavy damage (heavy structural damage, very heavy non-structural damage)	Building or individual storey leaning heavily; many failed members and/or connections; roof members shifting on column support; major distortion of columns.	Most infill walls exhibit large cracks. Masonry infill may bulge out-of-plane and some masonry may be dislodged and fall (Masonry infilled frames)	
Grade 5	Destruction (very heavy structural damage)	Collapse or partial collapse of entire structure Large permanent lateral displacement		

A.4 Timber/wood - IMS-14 (from Spence and Foulser-Piggott, 2014)

	EMS-98 Definition	Proposed IMS-14 Elaboration (for lightweight timber structures)	Proposed modifications for subclasses	Diagrams
Grade 1	Negligible to slight damage (no structural damage, slight non-structural damage	No damage to structural frame. Few hairline cracks in internal walls or brick. Fall of small pieces of plaster.		
Grade 2	Moderate damage (slight structural damage, moderate non-structural damage	Little or no damage to structural frame. Small cracks in plaster or plasterboard edges; cracks in brick veneers; ; cracks of some masonry chimneys.		
Grade 3	Substantial to heavy damage (moderate structural damage, heavy non-structural damage	Some frame distortion visible. Veneers fail and expose frame. Large cracks in plaster or plasterboard edges. Roof tiles detach. Some chimneys fracture at roof line. Failure of individual non-structural elements (partitions, gable walls). Some shifting of unsecured foundations.	Small cracks or wood splitting at bolted connections (heavy timber frame structures).	
Grade 4	Very heavy damage (heavy structural damage, very heavy non-structural damage)	Serious frame distortion. Total failure of brick veneers. Toppling of most masonry chimneys. Houses not secured to foundations shifted off. Failure of some cripple walls	Partial collapse of soft-storey configurations (soft-storey structures). Slack or broken braces (braced timber frame structures).	
Grade 5	Destruction (very heavy structural damage)	Total or near total collapse of entire structure		

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+44(0)1756 799919
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