Exposure data development framework: Real-time Individual Asset Attribute Collection Tool (***RiACT***), inventory repository & asset repository web portal

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ABSTRACT: The paper presents an integrated and extensible framework for the capture and regurgitation of data that describes the characteristics and location of assets within our communities. The framework, referred to as Real-time Individual Asset Attribute Collection Tool (***RiACT***), Inventory Repository, and Asset Repository Web Portal, enables the capture by direct field observation of asset attributes, the real-time transfer of these observations to the Inventory Repository and/or the download of attributes of any specific asset of interest to the observer whilst they are in the field.

It is envisaged that the data stored within the Inventory Repository would have a variety of potential uses including forming the basis of a reliable asset module for loss modelling projections, pre-event building evaluation rankings (such as those required for earthquake prone evaluations) and/or post-event damage and condition assessments required for any subsequent building safety evaluation surveys. Hence, the Inventory Repository alongside Asset Repository Web Portal will be created in a manner which is an easily accessible platform for data management and sharing with other dataset needed for building or infrastructural evaluations.

The methodology of the asset collection tool and inventory repository and website are illustrated, with discussion on the communication protocol between them. Some applications, such as the integration of the Inventory Repository with loss modelling tool, the implementation of building performance evaluation are underway and will also be discussed to illustrate the potential of the integrated framework.

1 INTRODUCTION

Historical experience has demonstrated that earthquakes can inflict severe damage and loss to the built environment, including buildings and infrastructures, when they hit urban areas. To build an earthquake-resilient community (by mitigating of and responding to loss and damage induced by earthquakes), practitioners and researchers – through field investigation, along with theoretical and experimental studies – have substantially improved our understanding of the effects of earthquakes in the recent decades. Of them, field investigation is the most valuable as any observational data collected after the events provide truthful information.

Though new understanding and knowledge continue learning from earthquake reconnaissance, issue on efficient and precise damage data collection and management after events has long been recognised (Greene et al. 2004). Shortly after disasters, a rapid damage distribution would likely assist emergency response and recovery. By comparison, a comprehensive database composed of general building characteristics (location, construction material and age, loading system, height, and occupancy, for example), alongside damage observation, would provide lessons to refine current design specification,

as well as to improve building vulnerability understanding and loss modelling.

The importance and value of data collection and management were again emphasised in the Canterbury earthquake sequence (Galloway and Hare 2012), in which the condition of a large number of buildings needed to be evaluated and reported as quickly as practical.

In recognition of the above essential and urgent needs on data capture and management, and by taking the advantage of the rapid development of information technology (IT), several digital tools to directly record observation of the built environment at risk of earthquake impacts have been proposed.

Early in 2004, the Earthquake Engineering Research Institute (EERI), by working with Accela (www.accela.com), published a beta version of electrical data collection and mapping system (ERS) (Greene et al. 2004). ERS provided electric "guidesheets", and was designed to be installed on laptop, desktop or handheld PDA (personal digital assistant).

Recently, the Global Earthquake Model foundation (GEM) has developed a set of open-source tools that allow GEM users to populate exposure data for its risk model (i.e. GEM OpenQuake (Silva et al. 2013)). DO Android, was one of the GEM "Direct Observation" field tool which was developed by GEM Inventory Data Capture Tools (IDCT) team in partnership with the UK Earthquake Engineering Field Investigation Team (EEFIT) (Foulser-Piggott et al. 2013). The DO Android was a Java-driven, open-source application, designed for devices with Android operation system (Android OS) (www.android.com). Its map-based interface and tabs design provided a user-friendly environment. However, all the IDCT tools, including the DO Android were designed to collect building information followed the standardised scheme defined in GEM Building Taxonomy (Brzev et al. 2013), which in some way created barriers for its use with other applications.

As discussed above, many data capture tools have been proposed, developed and published in the past decade, such as EERI ERS and GEM DO Android tool. Improvement on data collection and management has progressed since their development. Challenges and limitations however remain. For example, support is no longer available for the EERI ERS tool development since its first publication in 2004. Hence its application might be limited due to its out of date technology. GEM DO Android, by contrast, was developed using the current information technology of portable devices. Specific strengths of this option is the use of the widely available Android OS, the display and use of devise-enabled global positioning system (GPS) and maps, and built-in relatively high resolution cameras. However, the collected building information (i.e. attributes specified in DO Android tool) was restricted to GEM taxonomy and not easily modified. In addition, data acquired was stored on each collection device and needed to be manually uploaded and merged following each field trip.

This paper presents an integrated and extensible Exposure Data Development Framework, referred to as real-time individual asset attribute collection tool, inventory repository, and asset repository web portal, which is intended to reduce the above obstacles in data collection and its subsequent management. In following sections, the development and implementation of this framework, as well as its components, will be discussed. Application examples will be presented as well to illustrate the efficacy of this approach.

2 EXPOSURE DATA DEVELOPMENT FRAMEWORK

The schematic representation given in Figure 1 illustrates the proposed framework and how its components are combined to achieve the main goal of this development. Real-time individual asset attribute collection tool (***RiACT***) uses its real-time telecommunication and its georeference (i.e. GPS) and photo-taken (i.e. on-board camera) abilities to collect the characteristics and/or damage conditions of each individual building. Upon completion of each record, it is stored within the tool and also transmitted via internet connection to the Inventory Repository (***IR***). Meanwhile, the recorded information can be modified, and new assets (individual building) added to the ***IR*** via the asset repository web portal (***WEB***) either as individual records or batch upload from spreadsheet compatible (i.e. comma-separated-values, CSV) files. The repository (***IR***) can updated with the additional building information, including pictures, plans or other PDF (portable document file) files. These can, on request from the mobile station, be downloaded to ***RiACT*** to enable the field inspection team full

access to previously available building data upon which new or modified data (i.e. damage conditions) can be added and managed.

In the rest of this section, concept and workflow of the exposure data development framework was presented. The three major components 1) real-time individual asset attribute collection tool (***RiACT***), 2) inventory repository (***IR***), and 3) asset repository web portal (***WEB***) were discussed. The development and methodology of each component were illustrated, followed by discussion on the communication protocol among them.

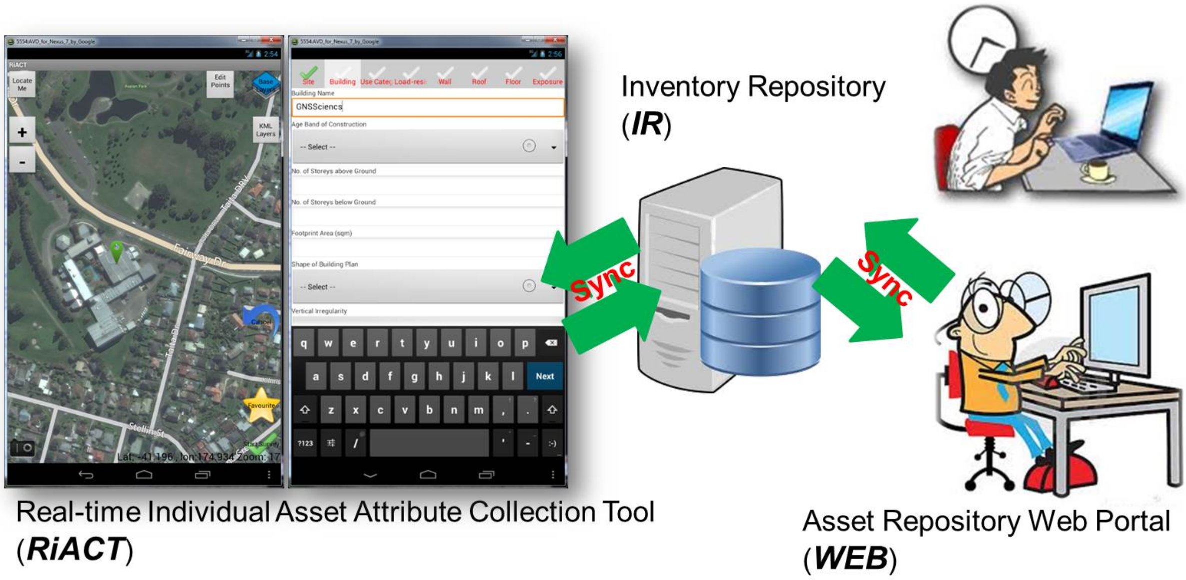

Figure 1. Schematic of the proposed integrated exposure data development framework.

2.1 Real-time individual asset attribute collection tool (*RiACT*)

As discussed previously, challenge and limitations (restricted application and tedious data management in GEM DO, for example) remain in data capture tool, though its recent significant development. To remove the above obstacles, a next-generation data capture tool, referred to as Real-time Individual Asset Attribute Collection Tool (***RiACT***), was proposed. Its methodology, development, and features were illustrated below.

By taking advantage of open-source feature of GEM DO Android, as well as eliminating duplication of effort, ***RiACT*** was developed based on the publicly available DO Android tool. However, significant enhancements have been introduced and implemented in ***RiACT*** tool, as detailed below.

1) *Accurate georeferencing*: in data capture, individual asset needs to be referenced to a single point location (e.g. either its address or coordinates). By using the device-enabled GPS ability to acquire its location on the fly from either maps or satellite images, ***RiACT*** provides a more efficient, reliable, and user-friendly way (i.e. seeing and locating the asset of interest via high-resolution satellite images) to record the correct georeferenced asset location – a huge advance over earlier data capture systems.

2) *Real-time data collection*: as self-explanatory in its name, ***RiACT*** was not only designed as a local server to store all the captured data, but also able to communicate in real-time through WiFi or 3G with the Inventory Repository (***IR***) once the internet is accessible.

3) *Efficient data recording*: again with its communication ability, ***RiACT*** sped up data capture procedure by downloading any existing attributes known about the building/infrastructure of interest, allowing the field inspection team to verify/amend this data and enhance it with additional missing attributes.

4) *Flexible and reliable data archiving*: similar to DO Android, ***RiACT*** allows users to export

recorded data into various formats, such as database (i.e. *.db3) and comma-separated-values (i.e. *.csv) files. ***RiACT***, however, with its telecommunication ability was able to manage data more efficiently and reliably, namely merging and storing all the perishable data automatically into repository.

In addition to above enhancements which were attributed to its real-time communication ability, other key enhancements of ***RiACT*** were its easily accessible development environment and its adoptability to other applications. Similar to GEM DO Android tool, ***RiACT*** was a completed Java-driven application for devices with an Android OS, and was developed for the purpose of collecting attributes of interest for individual assets. As mentioned previously, applications of GEM DO Android might be limited due to its predefined attributes which need to consist with the GEM Building Taxonomy. To extend its applications, different methodology was adopted in ***RiACT*** in order to provide a more flexible and easily-accessible development environment.

5) *Easily accessing and editing*: in GEM DO Android approach, building attributes were grouped into different categories (i.e. roof, floor, occupancy, etc.). Each category was then designed as an individual tab. Generally, each tab might compose of different number of attributes, and even their formats might differ from each other (i.e. text, integer or decimal number, and dropdown menu). The number of design (also the programming) increases with the increases of tabs as well as attributes. It is therefore complicated when editing or adding attributes and/or tabs is needed. To lower the above barrier, an easily-accessible development environment was proposed by defining the above tabs and attributes in only two separated *.XML files. The reason to adopt the Extensible Markup Language (XML) (www.w3.org/XML/) was that an XML document is string of characters. Therefore, it can be opened or edited as easily as other text files. Figure 2 shows an example of a design tab (i.e. the Building tab) and its relevant source code in XML format.

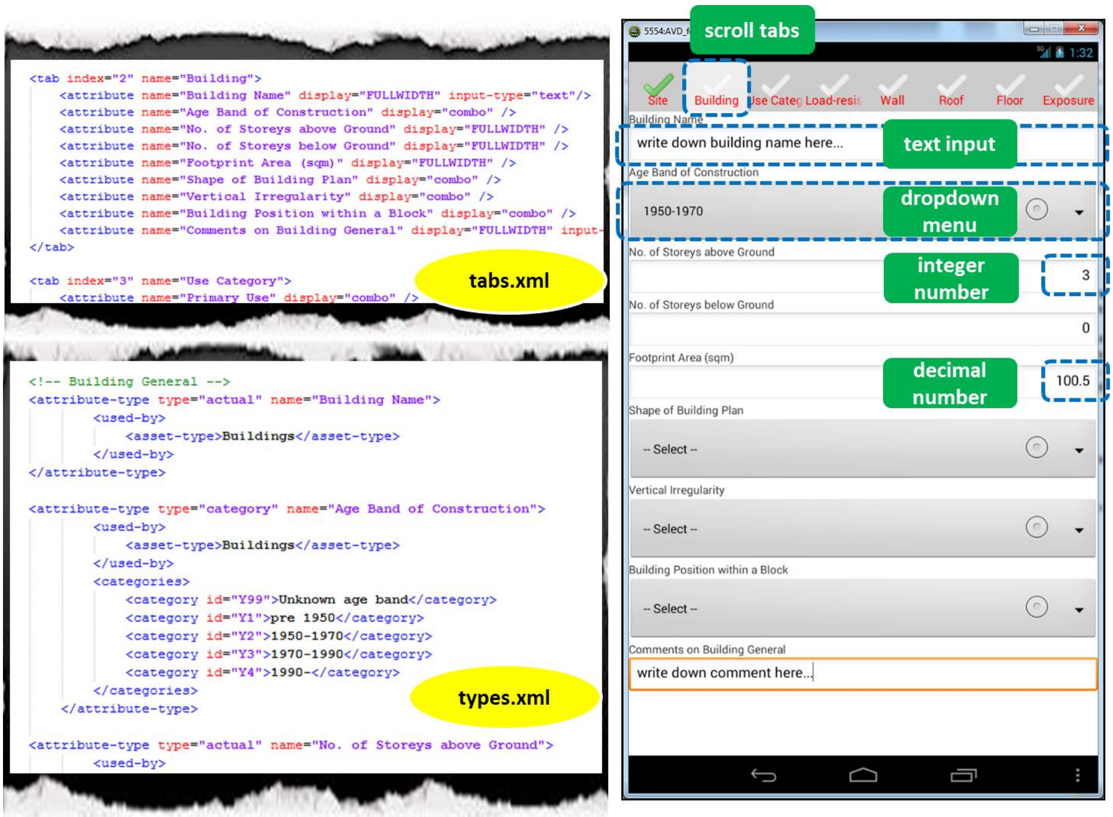

Figure 2. Layout of "Building" tab along with its relevant source code.

6) *Extensible with calculation capacity*: as mentioned previously, the data capture tool is originally designed to collect attributes of interest for individual assets. However, its applications have been broadened by implementing some calculation capacity. For example, when conducting pre-event

building evaluation rankings (such as the initial evaluation (assessment) procedure (IEP) required for initial seismic assessment (ISA) (NZSEE 2013)), the ability to calculate and present the percentage of new building standard (%NBS) and building ranking of the surveyed building, immediately after collecting all the required attributes whilst in the field, is informative for the surveyor. The required calculation capacities have been implemented in ***RiACT***. Other calculation requirements can be easily added to ***RiACT*** if needed.

In this section, refined approaches utilized in ***RiACT*** were discussed. All the above-mentioned enhancements have been developed. With its real-time communication and easily accessible environment, ***RiACT*** facilitates data capture and management, as well as extends its applications.

2.2 Inventory repository (*IR*)

The main role of the Inventory Repository (***IR***) is to archive all the building/infrastructure data which can be captured in the field, or recorded via website, or both. In addition, it is intended to provide a unique and flexible platform to manage various data. To do so, three key modules, namely Master Repository, Project Repository, and Attributes Customisation module were proposed and developed, as shown in Figure 3.

As described in previous section, ***RiACT*** can communicate with ***IR*** in real-time once the internet is accessible. To facilitate the uploading and downloading requests as well as to meet various applications (i.e. different attributes of interest or different level of data), the Project Repository module was designed to stored data for each individual project. For example, projects entitled “Building/Infrastructure asset” and “Building/Infrastructure damage” store data before and after events. On the other hand, the Attributes Customisation module was designed to suit various applications. For example, the RiskScape module can grab information from Master Repository and then reformat them to be compatible with RiskScape (Schmidt et al. 2011). The IEP module was designed to be able to retrieve required attributes from ***IR***, and conduct building performance evaluation. The GEM module is able to generate a GEM-Building-Taxonomy-compatible string, which describes the characteristics of a building. Nevertheless, data in both Project Repository and Attributes Customisation module were archived in the Master Repository, the highest hierarchical module in ***IR***. It is worth noting that a building/infrastructure identify system was implemented in the Master Repository to facilitate its mega-data management. Hence, a unique identifier (also storage space) is assigned to the same building/infrastructure, though its attributes might be retrieved from various Project Repositories.

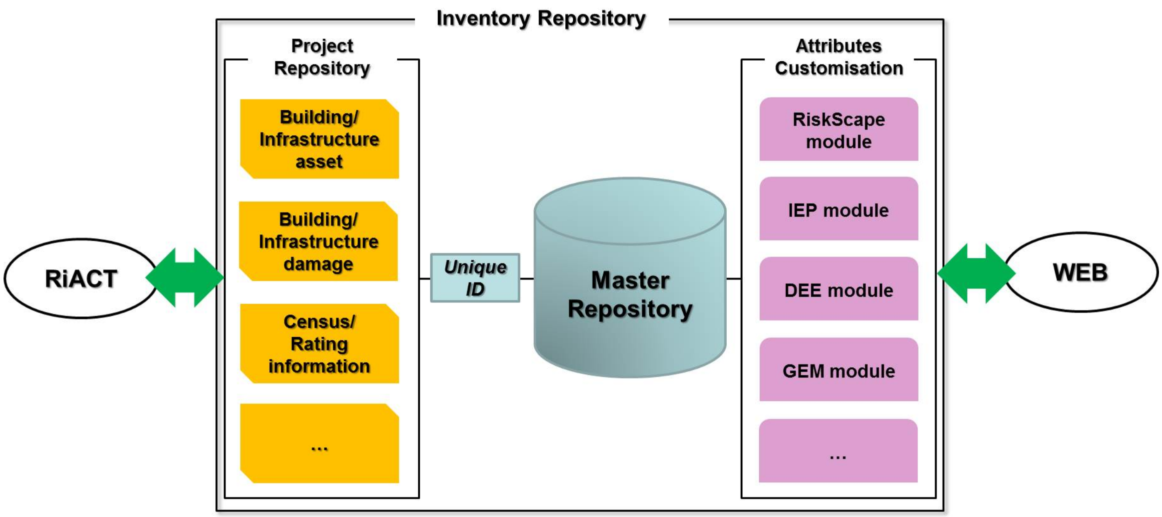

Figure 3. Inventory Repository structures.

2.3 Asset Repository Web Portal (*WEB*)

As an extension of the inventory repository component, and in conjunction of providing an easily accessible platform for data management and sharing with other dataset needed for building or infrastructural evaluations, an Asset Repository Web Portal has been developed. This website contains the recorded building or infrastructural information. There are several advanced features contained in WEB. Among those features are:

1) ***Data security protection***: a confidential website with login information requirement is designed. Access to portfolio(s) (sets of data) varies from account levels.

2) ***Data entry***: building and infrastructural data can be edited/added via the portal, and can be synchronised with the inventory repository.

3) ***Result presentation***: report context and format can be developed to suit its application needs, such as the standardised IEP reports.

For each datasets (portfolio), the spatial distribution of the contained assets is presented on a map, as shown in Figure 4. By clicking on the individual building of interest, all the information (including images) achieved in inventory repository is presented and ready available for editing/adding via the portal, as shown in Figure 5.

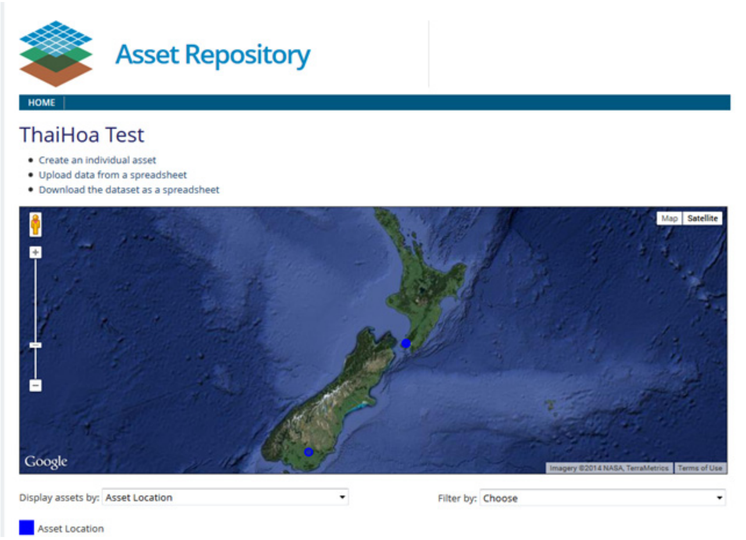

Figure 4. Spatial distribution of all assets within a portfolio.

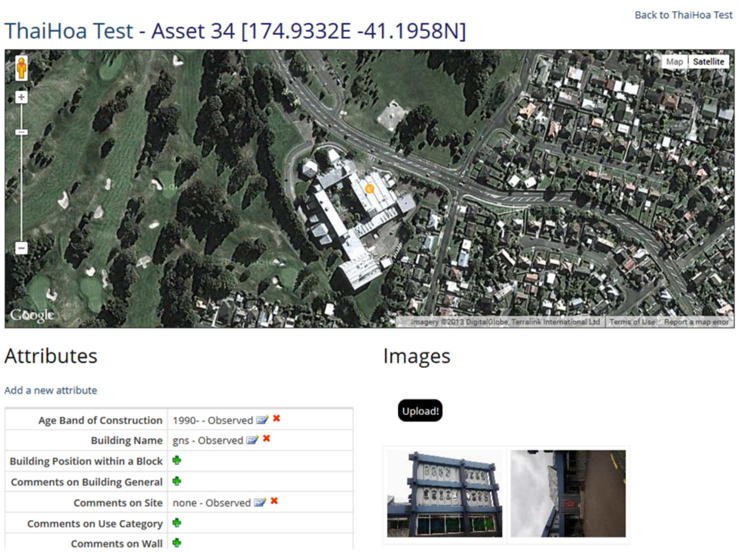

Figure 5. Recorded attributes, including images of the selected asset.

2.4 Development and implementation

Exposure data development framework has been developed, following the above-proposed methodology and communication protocol. The three key components – ***RiACT***, Inventory Repository, and the Asset Repository Web Portal – have been developed and tailored to build the framework and the communication among them. Several potential applications are underway to demonstrate the feasibility and potentials of ***RiACT*** as well as the inventory repository. Some preliminary results were presented and discussed in the following sections.

3 APPLICATION EXAMPLES

It is envisaged that the data stored within the Inventory Repository (***IR***) would have a variety of potential uses including forming the basis of a reliable asset module for loss modelling projections, pre-event building evaluation rankings (such as those required for earthquake prone evaluations) and/or post-event damage and condition assessments required for any subsequent building safety evaluation surveys.

To demonstrate the efficacy of the proposed integrated framework, applications such as the integration of the Inventory Repository with loss modelling tool and the implementation of building performance evaluation are underway and. Preliminary results of these applications will be discussed below.

3.1 Reliable asset module for loss modelling

Earthquake loss modelling, by projecting probabilistic and/or deterministic damage and loss in a feature event can support the emergency and mitigation planning, the management of post-event response and recovery, as well as risk communication with the public. Generally, the results of loss modelling solely rely on its three components, namely, asset inventory, hazard model, and fragility functions. Of them, the quality/reliability of asset inventory and fragility functions would likely be improved by the proposed exposure data development framework. In the following, a pilot implementation in Vietnam, which is being used to demonstrate the proposed framework, will be described.

The objective of this application is to develop building assets for areas within Vietnam for the purpose of performing consequence studies due to dam failure flooding (Damwatch et al. 2012). As stated, ***RiACT*** will be used to collect Vietnam building attributes, and is for loss due to dam failure flooding. Hence, attributes of ***RiACT*** were first modified to capture Vietnam building features by considering local construction practices, also new attributes were added to collect information needed for flooding analysis, such as the ground floor height.

At time of writing, ***RiACT*** tool has been modified and readily available to collect building characteristics in Vietnam. However, field implementation has been proposed several times due to recent devastating typhoons in central Vietnam. Field test report on ***RiACT*** as well as inventory repository and asset repository website will be published when available.

3.2 Building performance evaluation

Though continually understanding of building and infrastructure performance during earthquakes and improving on their design requirements, the majority of existing buildings and infrastructures were designed and built with less understanding of their seismic behaviour than we currently possess. In New Zealand, IEP, a qualitative, attribute base, and rapid building evaluation procedure, along with a guideline developed by New Zealand Society for Earthquake Engineering (NZSEE 2013) has been widely used by territorial authorities (TAs) to identify and improve the seismic performance of existing buildings. A spreadsheet based IEP report form has been developed to help standardise the data being generated, to review building performance, as well as to produce reports.

An alternative IEP tool, namely IEP on ***RiACT*, **has been proposed, though the above achievement. Its real-time communication and calculation capacity, along with data management and sharing abilities of ***IR*** and ***WEB***, were believed to assist TAs to get knowledge of their building stock and to speed

their post-event response and damage evaluation by using building characteristics and its pre-event capacity archived in repository, as well as to provide a comprehensive database for research or practical needs. Preliminary achievement was shown in Figure 6, with its field test evaluation continued currently.

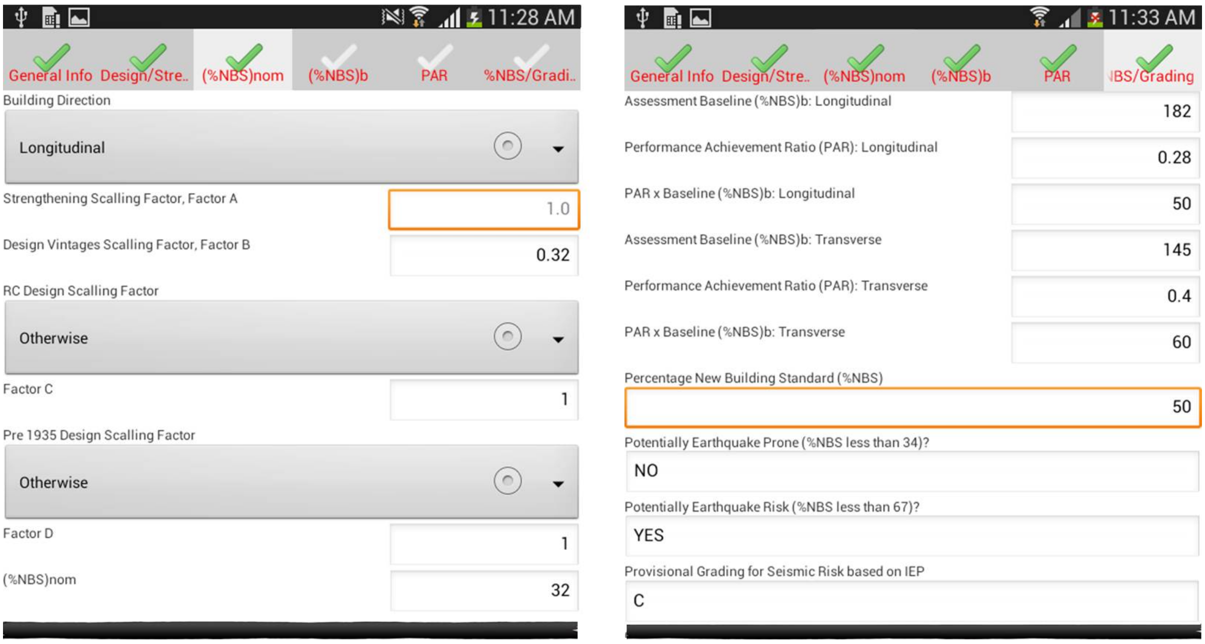

Figure 6. The proposed IEP on *RiACT* tool.

4 CONCLUDING REMARKS

The proposed exposure data development framework served as a user-friendly and an easily accessible platform through which impact assessment results can be improved by using more accurate asset module, pre- and post-event building performance can be efficiently evaluated by synchronising with the inventory repository, which will then facilitate the management of and response to disaster. It differs from other data capture tool, such as GEM DO Android in that ***RiACT*** and the inventory repository provide a flexible and easily-adaptable environment.

The preliminary results of the two application examples demonstrated not only the successful development of the proposed integrated framework for data collection, but also the achievement of the objectives of this development. However, more applications are being conducted to further demonstrate the feasibility of this framework, such as post-event building evaluation. Its results and findings will be published when available. In addition, by providing this integrated and unique platform, it will facilitate territorial authorities and research institutes to manage and investigate the archived data, respectively.

The final but the most important effort of this development is that though the proposed framework was first designed to directly record observation of the built environment at risk of earthquake impacts, it can be easily adopted by other extreme events such as flood, wind, tsunami, and fire toward building a safer and resilient community.

5 ACKNOWLEDGMENTS

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