National Exposure Information System (Nexis) For Australia: Risk Assessment Opportunities

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EXTENDED ABSTRACT

In August 2002 the Council of Australian Governments (COAG) reviewed natural disaster relief and mitigation arrangements for Australia (COAG, 2003). In response to the recommendation to "develop and implement a five-year national program of systematic and rigorous disaster risk assessments", Geoscience Australia (GA) is undertaking a series of national risk assessments for a range of natural hazards. Fundamental to any risk assessment is an understanding of the exposure including the number and type of buildings, businesses, infrastructure and people exposed to the hazard of interest. Presently there is no nationally consistent exposure database in existence for risk assessment purposes. It is important to emphasise that understanding the risks associated with various hazards requires more detailed information than the population and number of structures at a census district level. The understanding of building type, construction (roof and wall) type, building age, number of storeys, business type and replacement value is critical to understanding the potential impact on Australian communities from various hazards.

The National Exposure Information System (NEXIS) is aimed at providing nationally consistent and best available exposure information at the building level. It requires detailed spatial analysis and integration of available demographic, structural and statistical data. Fundamentally, this system is developed from several national spatial datasets as a generic approach with several assumptions made to derive meaningful information. NEXIS underpins scenarios and risk assessments for various hazards. Included are earthquakes, cyclones, severe synoptic wind, tsunami, flood and technogenic critical infrastructure failure. It will be integrated with early warning and alert systems to provide real time assessment of damage or forecast the impact for any plausible hazards. This system is intended to provide a relative assessment of exposure from multiple hazards and provide the geographic distribution of exposure for regional planning. This will be at an aggregated census district level now and at a mesh block level in the future.

The system is scoped to capture the residential, business (commercial and industrial), and ancillary (educational, government, community, religious, etc.) infrastructure. Currently the NEXIS architecture is finalised and the system provides residential exposure information. The prototype for business exposure is in progress. The system aims to capture ancillary buildings, infrastructure and various critical infrastructure sector exposures in future. More specific building and socio-economic information will be incorporated as new datasets or sources of information become available.

The NEXIS will be able to provide the exposure information for the impact analysis for a region. This database will not support a site specific assessment involving one or two buildings and need more specific information about the particular exposure to estimate the risk at micro level. More detailed information suitable for such analysis will be maintained in reference databases.

1. INTRODUCTION

Geoscience Australia (GA) began the development of the National Exposure Information System (NEXIS) in response to COAG reform Commitment 2 – "establish a nationally consistent system of data collection, research and analysis to ensure a sound knowledge base on natural disasters and disaster mitigation" (COAG, 2003). It was also recognised as a priority for the development of better models and tools to allocate investment across prevention, preparedness, response and recovery (PPRR) and also to assess the impact of emergencies on the community in the Emergency Management Information Development Plan (Harper, 2006). The NEXIS underpins various activities of risk assessment modelling, critical infrastructure failures, early warning systems and several national priority initiatives. This system will provide consistent and best available information at a national scale (for example, the number and type of buildings, businesses, people, critical infrastructure, and institutions such as schools and hospitals) to understand hazard exposure, at all locations in Australia.

Fundamental to any risk assessment is an understanding of the exposure including number and type of buildings, infrastructure and people exposed to the hazard of interest. There is no such database or information in existence at a national level to assess the risk consistently across the nation. The risk assessment outputs previously created for the Disaster Mitigation Australia Package (DMAP) of the Department of Transportation and Regional Services (DoTARs) have provided exposure information at the level of a census district. This information is critical as the Office of Small Business is keen to understand the economic impacts of natural hazards for small businesses. It underpins scenario (event) based risk modelling which provides plausible scenarios for tactical planning purposes like emergency training, planning, response and capacity review. This information is highly significant for the development of probabilistic risk models which predict the relative chance of different scenarios occurring at a particular location. Probabilistic risk definition is particularly helpful to prioritise risk mitigation and preparedness.

The Earthquake Risk Assessment Model (EQRM), wind risk assessment model, tsunami inundation and risk assessment model and Critical Infrastructure Protection Modelling and Analysis (CIPMA) at GA are using NEXIS to estimate the economic impacts of hazards.

2. METHODOLOGY

The purpose of NEXIS is to provide the best and most available current information to multi-hazard national risk assessment projects. The NEXIS' architecture comprises several components and is depicted in Figure 1.

NEXIS-RefDb: A database will be designed to accommodate all the external fundamental reference datasets like Geo-coded National Address Framework (G-NAF), Cadastre, Census, cost factors, housing surveys, Australian business registry, etc. These databases sourced from various organisations like Public Sector Mapping Agency (PSMA), Australian Bureau of Statistics (ABS), Cityscope, local governments and infrastructure sectors. It will be maintained in a centralised corporate database environment with regular updates.

NEXIS-App: Application software will be developed to derive the required information and will consist of several modules e.g. residential, business, ancillary and infrastructure exposure. It selects the best available datasets such as more specific information from survey or local councils and their conversion into NEXIS data templates at building level.

NEXIS-Database: The derived information will be stored and maintained in this database. The database will be replicated for the Critical Infrastructure Project.

NEXIS-Web: A web application will be developed to aggregate the exposure information at Local Government Area/Census District level for the internet. This tool will be used to supply exposure information to external agencies such as the Australian Greenhouse Office (AGO), State and Federal Emergency Services, and the Bureau of Meteorology.

NEXIS-Act: This application will be developed to provide information for various hazards like earthquake, wind, tsunami etc. These activities need slightly different information from the exposure database.

Additionally, an error log report of data from Quality Control (QC) activities will be provided to Internal and External database custodians. The report summarises the limitations of source data for internal users will summarise the limitations to use heuristic judgements based NEXIS. This process will help the external data providers to rectify the errors in their datasets.

The development of nationally consistent exposure information requires detailed spatial analysis and integration of demographic, structural and statistical data. Fundamental to this process are several national and local resolution datasets listed in Table 1.

Table 1. List of fundamental datasets referred to derive the buildings information.

Dataset	Resolution	Data Type	Source
G-NAF		Point	PSMA
Cadastre		Polygon	PSMA/MapInfo
StreetPro		Points	PSMA/MapInfo
Census	Census District	Polygon	ABS
Census Districts / Mesh blocks		Polygon	ABS
Housing Survey	States & Capital Cities		ABS
Business Registry, Others	Postcode	Polygon	ABS
Cityscope	City Buildings	Point	Cityscope
Cost Factors			Cordell/Rawlinson Cost Factors

Accurate location of the buildings and the information associated with them is critical for risk assessments. The NEXIS will be maintained and updated regularly as and when the fundamental datasets like ABS census and G-NAF are revised. It will also be revised to enhance accuracy of attribute values as more data becomes available about building age and structure types.

Available fundamental datasets and some reasonable assumptions are used to populate the building information. A computerised script was developed using Python and ArcGIS version 9.1 to automate the process and develop the database. The process of deriving the information is computationally intensive and difficult to provide quickly. Therefore, the NEXIS database for the entire nation is produced and maintained to clip an area of interest. The variables of the building information vary significantly based on the usage (residential, business (commercial and industrial), ancillary and infrastructure). The development of this generic information system is based on several assumptions and approximations where specific information is not available.

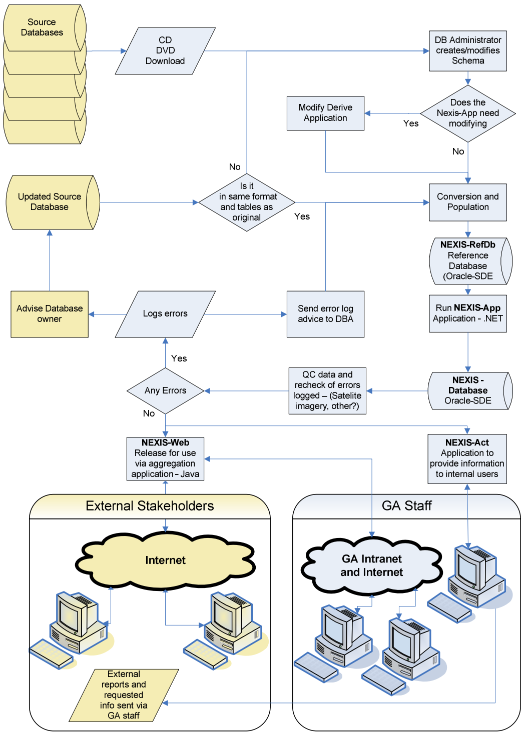

Figure 1. System Architecture for the NEXIS

2.1. NEXIS – Residential Buildings

The residential component is the most significant for the account of the socio-economic impacts on communities and emergency management. The variables required to assess the risk for the residential areas are primarily spatial, structural and demographic.

The spatial location is highly critical for assessing the risk from cyclones, tsunami, flooding and bushfires. National datasets like ABS Census provides demographic information aggregated at Census District (CD) level. But the risk from natural hazards is not uniformly distributed across the CD or local government Areas (LGA). In absence of comprehensive residential exposure information, some generic assumptions were made to derive the information required for risk assessments. The required variables and associated fundamental datasets were summarised in Table 2.

G-NAF is a national address database with latitude and longitude. It covers the entire nation and is consistent across all locations. There are a few known problems with this fundamental dataset but it was considered as the best available source to derive building location. The primary assumption to derive the NEXIS is that every residential address is linked to a residence and every residence is within a building. Then further assumptions are made to remove the buildings where a building is not expected. For example a residential building is unlikely to exist in a block size less than 43 sq. metres or at an address in a cadastre parcel of reserve or parkland.

Table 2. Summarised residential variables and associated fundamental datasets.

Variables	Datasets	Derived Information
Latitude Longitude Address	GNAF	Geo-coded Addresses
Block Size Floor Area	Cadastre	Floor Area (sq. m) was derived based on the location and size of the block
Usage	ABS Meshblocks	Residential, agricultural, commercial, industrial etc.
Building Type	Cadastre, GNAF	Separate house, semi-detached house and apartment
Roof Type	ABS Housing survey	Tiled, metal, fibro
Wall Type	ABS Housing survey	Double brick, brick veneer, fibro, timber, concrete frame
Age	Building approvals	Period of construction
Number of Storeys	GNAF, Cadastre	Based on number of residences and size of the block
Population	ABS Census	Census district average population based on building type.
Household Income	ABS Census	Census district average
Building Value	Cost Factors	Replacement value
Contents Value	Insurance estimates	Based on household income and building value

The ABS has released a beta version of Mesh Blocks with the final version to be released in the future. ABS mesh blocks are another national dataset which provide land usage categories such as residential, rural, commercial and industrial, education, hospital/medical, transport, parkland, agricultural and water. NEXIS will capture the addresses in residential, agriculture and rural areas as residential addresses with some omissions. The locations of these addresses are considered as residential homes and associated with a building.

The number of addresses having the same latitude and longitude were counted to estimate the number of residences in the building. The cadastre database for each state is available and is regularly updated. This spatial layer is overlayed with residential buildings point layer to get the block size for each building. Floor area was estimated based on the location of the building (city area, suburban or rural) and the size of the block. The relationship of the block size and floor area was established by searching from a sample set of buildings across the nation. The floor area for an apartment in a multi-storey building is considered as 120 sq. metres. Multiplying by the number of residences in each building gives an estimate of the total floor area of the building.

The type of the building and the number of storeys were determined based on the number of residences and the size of the cadastre parcel. The building type attributes are aligned with the ABS standard classification for dwelling types Each address in the G-NAF database is considered to be a residence. The number of residences at one geographic location is counted and matched with the block size. An extra rule was also created to fine tune the building type categorization for the buildings. If more than one residence exists in the one cadastre parcel but not at the same location, then those buildings are considered as townhouses and categorised as semi-detached buildings.

Most natural hazard risk assessments estimate the damage to structures based on their wall and roof type. GA's risk models predominantly use a structure type classification that has been extended from the HAZUS classification system (Robinson *et al*., 2005). This classification is based upon the Australian Housing Survey which provides information on the proportion of structural types for each state and territory of Australia (Australian Bureau of Statistics, 1999). These proportions are provided separately for each state or territory's capital city and the rest of the state/territory. The Australian Housing Survey provides proportions of structural types for separate houses, semi-detached structures and apartments (Australian Bureau of Statistics, 1999). To date a single set of proportions for each of these larger building types has been used throughout Australia, however it is envisaged that future work will refine these proportions to account for variability across the country. The random assignments of roof and wall types for buildings are estimated.

The population for each residential building within the NEXIS database are populated from the average population for different types of dwellings extracted from the ABS Census at CD level. The number of residences was multiplied by the average apartment occupant numbers to get the population of multi-storey buildings.

The household income underpins the socio-economic impacts for families due to the disasters. The average household income (ABS household income, 2001) in each census district is categorised into three income groups viz; average ($500-$900 per week), quality ($900-$1500 per week) and prestige (>$1500 per week).

A Replacement Cost Estimate (RCE) provides the cost of rebuilding a property in the event of it being damaged beyond repair. The reconstruction costs can be adjusted for inflation in both capital city and regional centres by applying available cost indices. Replacement cost of structures for the residential component of the NEXIS is estimated using the cost models derived as part of the earthquake risk assessment conducted for GA's multi-hazard risk assessment of Perth (Sinadinovski et al., 2005). Cordell location cost factors (2001) were taken into consideration to set the cost factor. The replacement cost per square meter will depend on the wall type, roof type and floor area. The replacement value for individual structure is estimated by multiplying the floor area and the rate for reconstruction.

From several discussions with a number of insurance organisations, it was apparent that the estimation of the contents value in buildings is difficult. The household income was found to be the best variable to estimate the contents value in general. Typically the contents value in the average income group is 30 percent of the buildings value, 40 percent for quality and 50 percent for prestige.

2.2. NEXIS – Business Buildings

Risk assessment for the business sector from natural disasters is much more complex than residential. The development of a business component prototype is in progress. The risk analysis for businesses is linked directly to structural and inventory damage, business and lifeline disruptions and overall macro economic behaviour. The exposure information requirements to assess the risk for business are different from residential. To derive the required information at a national scale is highly complex and several assumptions for the generic approach have been made where there is no fundamental data available. The business information comprises CBD commercial area, commercial area in non-CBD and industrial buildings and businesses.

Several datasets were referenced to derive the information, which have different levels of accuracy for those variables. Geoscience Australia has surveyed several locations as a part of the post disaster survey and collected building information. It provides highly reliable information for buildings but not the business information. The Cityscope database includes details on every property in the Central Business Districts (CBD) of all major cities in Australia. The focus of Cityscope is largely commercial but also covers the residential properties in Sydney and Melbourne. It is consistent across all the cities and provides information about the businesses, tenants, floor area etc. It lacks information about building structure types. In the process of making nationally consistent business buildings exposure information, a generic approach was developed where the relevant information is missing and not covered by GA Surveys and Cityscope. This generic approach will fill the gaps of information available in the GA Survey and Cityscope databases and also for the areas not covered by these datasets.

The GA Survey database would be the first database in our list to populate the data that is required for commercial buildings. It will contain some business and value estimation information. If GA Surveys do not have this information, then the Cityscope database is queried. The Cityscope database contains some information about structure details (number of storeys, floor area), business and value estimation information. If none of the specific reference databases are available, a generic approach is currently being developed to estimate the building details such as structure details, business information and value estimations.

The building footprints were mapped in the Fyshwick and Hume industrial areas in ACT to develop set rules for the generic approach to estimate industrial exposure. The mapping of industrial areas to derive information is also highly complex.

2.3. NEXIS – Ancillary Buildings

The exposure for ancillary buildings mostly depends on the day and time. The buildings used by the governments (federal, state and local), emergency related (hospitals, emergency services, police), educational (schools, universities) and others (religious, museums, stadiums) are covered in this category of NEXIS. The required information related to ancillary buildings is diverse and is required to capture specific information like capacity of the facility. It will further enhance the capability of temporal changes in population dynamics.

2.4. NEXIS – Infrastructure

Infrastructure related to bridges, ports and critical infrastructure of various sectors includes transportation, energy, communication, banking and finance and water will be captured from existing specific databases. These have been assembled as a central input to modelling the system behaviour and critical infrastructure modelling.

3. RESULTS AND DISCUSSION

The NEXIS residential component is being utilised by a number of natural hazard risk research projects within GA including: Cyclone or severe wind risk assessment modelling; Flood modelling and predicted impacts to residences in Perth; Tsunami risk assessment modelling for WA; and Post-incident analyses following Cyclone Larry in Queensland.

A rigorous quality assessment is built in to the NEXIS to identify the problems and gaps with the system of supplying more meaningful and realistic exposure information. The accuracy is very low when the NEXIS database is derived at buildings level. It is envisaged that the damage estimations are accurate overall at an aggregated census district level and can be used for evaluating relative damages rather than absolute figures. The adoption of G-NAF for the spatial location has provided spatial accuracy. The spatial accuracy of the buildings in the Gold Coast city is depicted in Figure 2.

Figure2. Spatial locations of residential, commercial and industrial buildings in Gold Coast.

G-NAF is a nationally consistent geo-coded addresses database but does not provide consistent building information, such as number of storeys. It is associated with inconsistent data collection methods between states, several gaps in the database (unknown) and lack of consistent building information. G-NAF is being used for spatial location of buildings and address. G-NAF has sparse coverage for remote indigenous communities, which are not incorporated. The problems found through validation are being reported to G-NAF custodians.

Due to lack of information available on buildings, such as number of storeys, age and construction type, assumptions need to be made. A separate house is considered as single storey to estimate the structure replacement value. NEXIS is being used in risk assessment in GA and being evaluated and modified. No information is currently available that allows initial estimates of impact at a building level. This information will help local, state and federal governments identify communities at risk and the possible impacts. These studies can be expanded at the local level if it is determined necessary. End users of information and outputs generated using NEXIS must be made aware of this and further research will be conducted at local levels if accuracy is required.

The number of buildings and the spatial location is validated using high resolution images. NEXIS is capturing more than ninety percent of the buildings in the suburban residential areas. The numbers are about sixty percent in rural areas captured and spatially not located at the building site. NEXIS provides average figures on population demographics. The structure value and contents value aggregated at census district are reasonably accurate in principle compared to GA's existing exposure catalogue (Robinson *et al.*, 2005). There is no consistent information available to validate the accuracy quantitatively. Even the insurance databases have several constraints as to their use as reliable validation benchmarks.

The risk assessment models for earthquake, severe wind and tsunami inundation developed at Geoscience Australia. NEXIS is being used to estimate the risk from several hazards and also critical infrastructure protection models. There is a significant improvement in the assessing the risk. The comparison of risk assessment using exposure catalogue (aggregated to census districts) and NEXIS (building level) for a set of probabilistic return period wind speeds for Sydney and the values are listed in Table 3.

Table 3. Percentage of losses for the Sydney at each of six return periods.

Return Period	Exposure Catalogue	NEXIS
50 Year	0.80	0.72
100 Year	1.11	1.01
200 Year	1.51	1.38
500 Year	2.01	1.85
1000 Year	2.31	2.12
2000 Year	3.01	2.77

4. CONCLUSION

The NEXIS is planned to provide information from a generic approach for all natural hazard risk assessment projects. It is aligned for critical infrastructure protection modelling and analysis and for future use in the upcoming alert systems at GA. The development of strategic alliances with external stakeholders is continuing to capture more specific reference databases and to provide aggregated exposure for areas of interest. Providing high spatial accuracy of building level information enhances the ability to assess the risk, rather than the aggregated Census District level which is currently being used. NEXIS can assist in identifying possible impacts to residential buildings and can be expanded to assess the larger impact to local or state economies. Communities can develop preparation and evacuation plans by identifying buildings at greater risk from a natural hazard due to their location, building age or construction type. NEXIS has been completed for the residential component and is in the process of developing the business component. Further it will be extended to capture ancillary buildings and infrastructure exposure information. Age and number of storeys are very critical in assessing the risk to the buildings. The next version of NEXIS will evolve from a generic approach to a specific reference exposure database. In addition, NEXIS will improve fundamental national datasets such as the ABS Meshblocks and G-NAF by identifying and reporting errors.

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