ABSTRACT

Flood vulnerability functions for buildings (often called stage-damage functions) relate flood damage to the depth of inundation in the building. These functions are generally used in assessing flood risk and in evaluating cost-effective mitigation strategies for flood risk management. Flood vulnerability models are usually developed for a certain location by following empirical, analytical or heuristic procedures. They can be developed for a representative building type (detailed approach) or representing a mix of building types (generalised approach).

Geoscience Australia (GA) has developed a suite of flood vulnerability functions for a range of building types (detailed approach) that covers residential, commercial, industrial and community building land use types. These functions are best used in detailed micro level studies and are applicable to the highest resolution of building exposure information with flood vulnerability directly attributed to individual buildings.

This paper describes research with the National Flood Risk Advisory Group (NFRAG), the Australian Institute for Disaster Resilience (AIDR), state and local governments and industry to translate detailed vulnerability information into practical guidance for flood risk managers undertaking studies under the floodplain-specific management process as outlined in the AIDR Handbook, *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management*.

This research derives generalised vulnerability functions for a mix of building and land use types. The generalised curves can be utilised at meso or macro level study and are intended to be applied at a resolution of built environment information readily available to floodplain managers.

Peer-reviewed article

Flood vulnerability functions: detailed vs generalised approach

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Introduction

Globally floods have impacted many communities in the past, which, in extreme cases, have resulted in vast devastation and widespread disruption to the communities. In Australia, floods cause more damage on an average annual cost basis than any other natural hazard. Figure 1 shows the Average Annual Losses (AAL) by disaster type in Australia from 2007 to 2016 (DAE 2017).

The fundamental causes of this level of damage and the key factor contributing to flood risk, in general, is the presence of vulnerable buildings constructed within floodplains due to ineffective land use planning. The Bushfire and Natural Hazards Collaborative Research Centre project entitled 'Cost-effective mitigation strategy development for flood prone buildings' (BNHCRC 2019) examines the opportunities for reducing the vulnerability of Australian residential buildings to flood.

Aims and objectives

Within this BNHCRC project, a utilisation sub-project is initiated to develop vulnerability functions which are compatible with the level of detail of exposure information generally available to floodplain managers. This research focuses on assessing the flood vulnerability, as a crucial input to a flood risk assessment. This utilisation project aims to provide advice on assessing flood impact and risk to floodplain managers, insurance industry and other who may not have access to detailed building exposure information. It involves developing and testing a number of resolution options (from asset specific vulnerability assessments to a more generalised method) in a case study. This paper presents the outcomes of the utilisation project to develop generalised vulnerability functions which could represent typical Australian building stock at meso and macro level.

Approaches to develop vulnerability functions

Flood vulnerability functions (often termed as stage-damage functions) for key types of buildings provide information about building susceptibility to damage and associated repair costs due to an event. Vulnerability functions are critical input in flood risk analysis and therefore a fundamental requirement to use these functions is to represent the building stock within the study area appropriately.

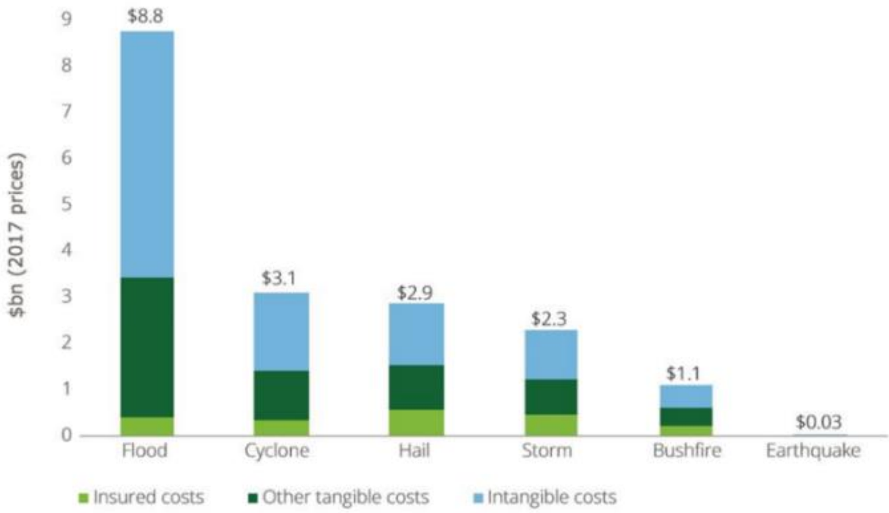


Figure 1: Average Annual Losses by Disaster Type in Australia from 2007 to 2016 (DAE 2017).

Detailed vulnerability functions

For this research study detailed vulnerability functions are sourced from Geoscience Australia (GA) which included flood vulnerability functions for residential, commercial, industrial and community building types (29 functions in total). These functions have been developed by using analytical approach. The main development steps included:

- Development of building categorisation schema to classify building stock into a limited number of typical building types,
- For each building type a representative floor and architectural plan is selected,
- For each building type the building fabric is divided into several components,
- For each component of each typical building type, the repair work to reinstate the building is identified at ten inundation depths,
- Each item of repair method is quantified and costed,
- For each inundation depth a Damage Index (a ratio of repair cost to replacement Cost) is calculated, and
- Finally, a vulnerability function is developed by plotting Damage Index on Y-axis and Inundation on X-axis.

Generalised vulnerability functions

For this research study six generalised vulnerability functions are developed at Statistical Areas Level 1 (SA1) level by aggregating selected GA's detailed vulnerability functions. This aggregation of GA's detailed vulnerability functions is based on exposure properties of representative SA1 areas for a mix of residential, commercial, industrial and community building types. The basic steps involved in the developing the generalised vulnerability functions are:

- Developing and comparing exposure data at different scales (SA1 and Mesh Block levels),
- Identifying appropriate level of assessment (in this study SA1 level is selected),
- Selecting six representative SA1 areas with predominant residential, commercial, industrial typologies and a mix of these,
- Development of aggregated Damage Index (weighted) at ten inundation depths, and
- Developing six generalised vulnerability functions for these selected SA1 areas.

Case study: Launceston

Launceston is floodprone and located within the Tamar River floodplain at the confluence of the Tamar, North Esk and South Esk Rivers in Tasmania. The suburb of Invermay in Launceston is the case study area for this research. Figure 2 shows the location map to show the study area in Tasmania. The exposure database is compiled for all buildings in the study area (1,276 in total) within the mapped PMF extent by sourcing building attributes from GA's National Exposure Information System - NEXIS (GA 2017).

This database is supplemented by a desktop study utilising Google street view imagery to record additional building attributes. Floor height information is provided by the Launceston City Council for all buildings within the 500 ARI extent map (LCC 2016).

Spatial scale of study

As mentioned in the previous section that spatial scale of study is an important factor while conducting flood risk assessment. For this comparative study two spatial scales have been explored for selection i.e. Mesh Blocks level and Statistical Area 1 (SA1) level as defined by ABS (2019). Mesh Blocks are the smallest geographical area and broadly identify land use such as residential, commercial, primary production and parks, etc. SA1 are the geographical areas built from whole Mesh Blocks and have generally been designed as the smallest unit for the release of census data. SA1s have a population of between 200 and 800 people with an average population size of approximately 400 people (ABS 2019).

Figure 3 and Figure 4 show the spatial boundaries within the study area at mesh block level and SA1 level, respectively. There are 91 mesh blocks and 20 SA1 areas in the study region. A mesh block level study requires data at a more refined level (quite close to micro level study) which many a times is not available to floodplain managers. Therefore, SA1 level is selected for developing generalised vulnerability functions.

Figure 2: Location map of study area, Launceston (Tasmania).

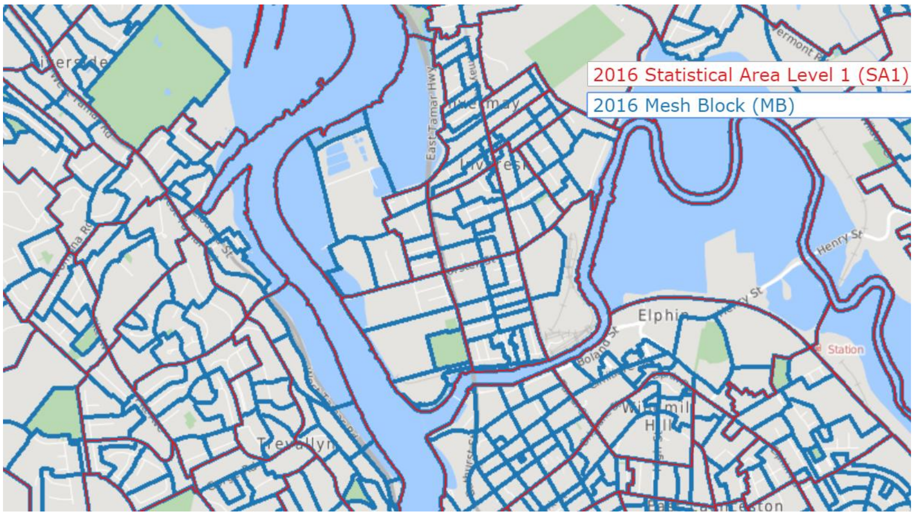


Figure 3: Spatial scale of Mesh Block areas (blue boundaries) in the study area (ABS 2019)

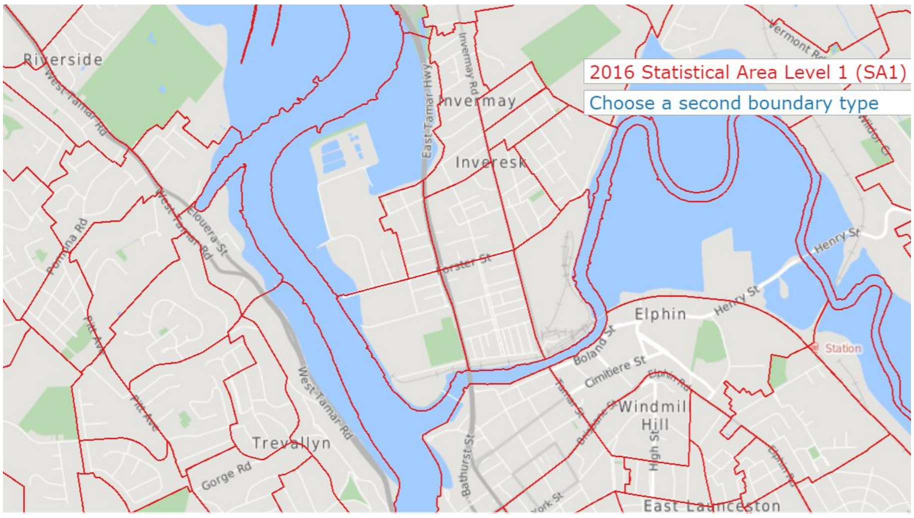


Figure 4: Spatial scale of SA1 areas (red boundaries) in the study area (ABS 2019).

Development of generalised vulnerability functions

After analysing the SA1 level exposure data, six typical SA1 areas are selected to represent the building stock in the study region. The selection of six SA1 areas is based on the exposure characteristics of each SA1 area which includes building usage (residential, commercial and industrial), wall material (weatherboard, veneer masonry, cavity masonry, concrete and metal), number of stories (single or double) and building age (pre-1960s and post-1960s). Table 1 presents the generalised function name and description of the representative SA1 areas.

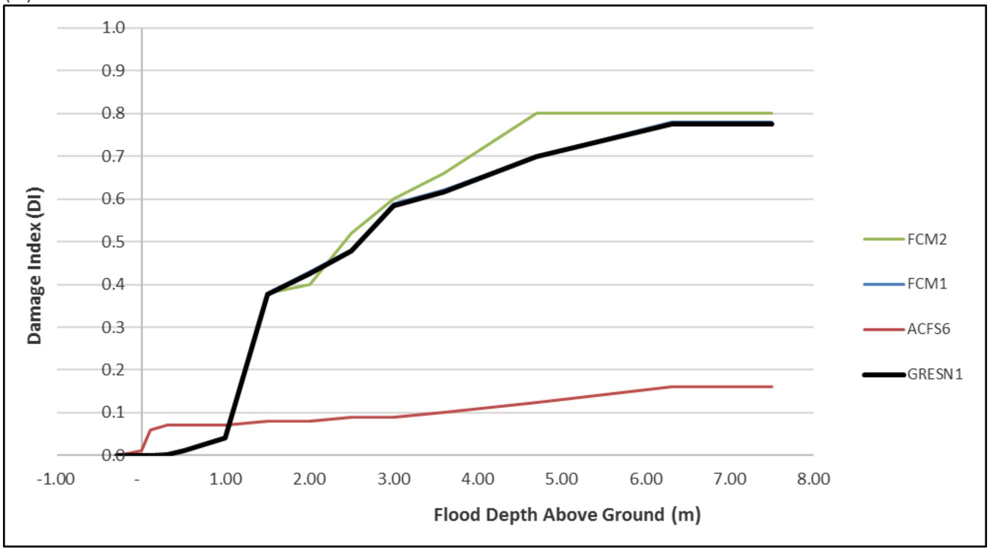
Suitable functions from GA's suite of detailed functions are then chosen to generate generalised functions by weighted aggregation. Figure 5 shows the resultant generalised vulnerability functions (thick black curves) along with a comparison of detailed vulnerability functions chosen to be aggregated.

The derived generalised vulnerability functions are based on the weightage of the sourced detailed functions which strongly depend on the land use types, number of stories, building materials and age. The generalised functions for residential SA1s are found to be the most vulnerable followed by functions for commercial and industrial SA1 areas.

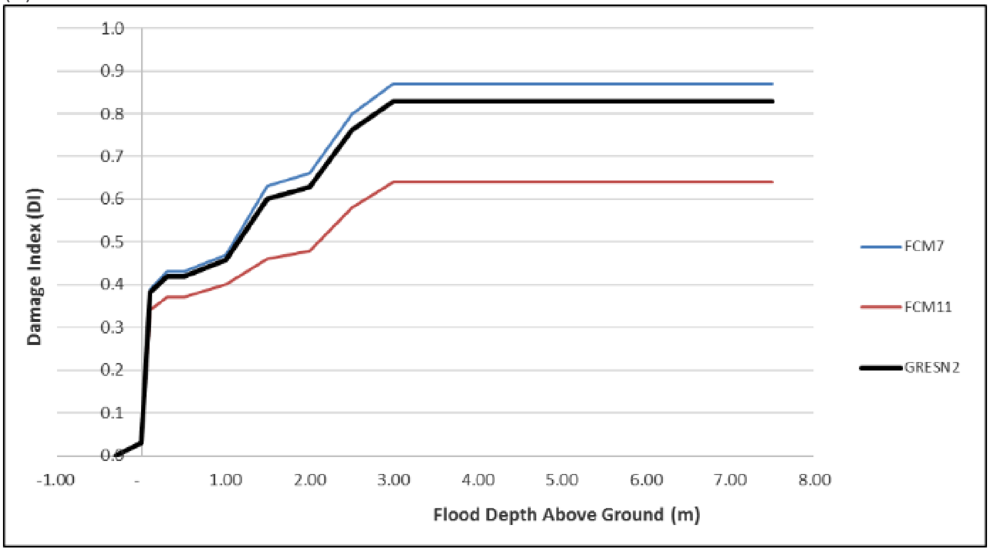
Table 1: Typical characteristics of generalised vulnerability functions

Sr Nr	Generalised vulnerability function name	Description (typical characteristics)
1	GRESN1	Usage: Residential Wall material: Weatherboard Storeys: Single storey Age: Pre-1960s
2	GRESN2	Usage: Residential Wall material: Brick veneer Storeys: Single storey Age: Post-1960s
3	GRCN1	Usage: Mostly residential but with commercial and industrial mix Wall material: Mix of weatherboard and veneer construction Storeys: Single storey Age: Post-1960s
4	GRCN2	Usage: Mix of residential, commercial and industrial Wall material: Mix of weatherboard and masonry construction Storeys: Single and double storey mix Age: Pre and post-1960s mix
5	GCOMN2	Usage: Commercial Wall material: Masonry construction Storeys: Single and double storey mix Age: Pre and post-1960s mix
6	GINDN1	Usage: Mostly industrial but with slight commercial and residential mix Wall material: Mostly metal construction Storeys: Single storey Age: Pre and post-1960s mix

(A) GRESN1



(B) GRESN2



(C) GRCN1

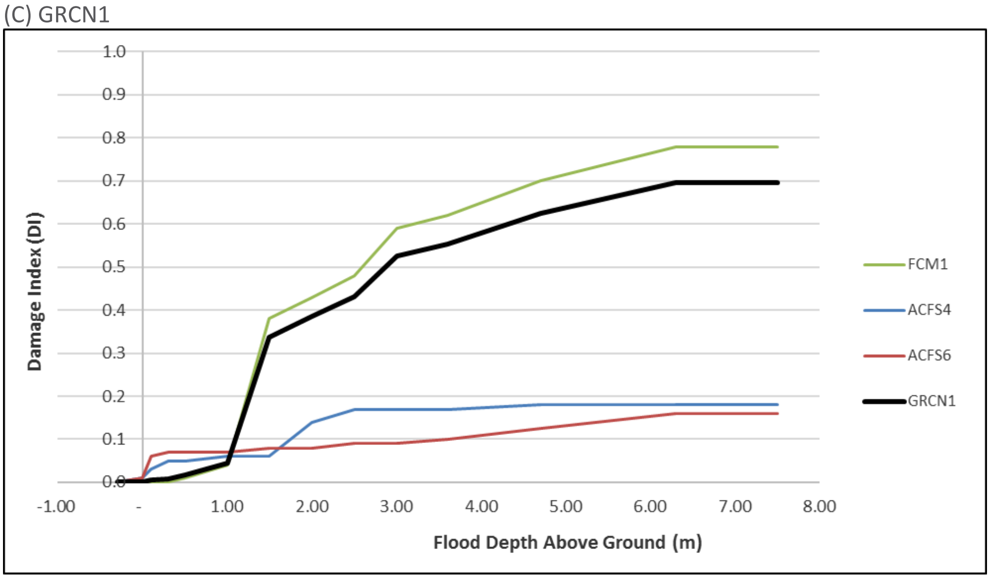
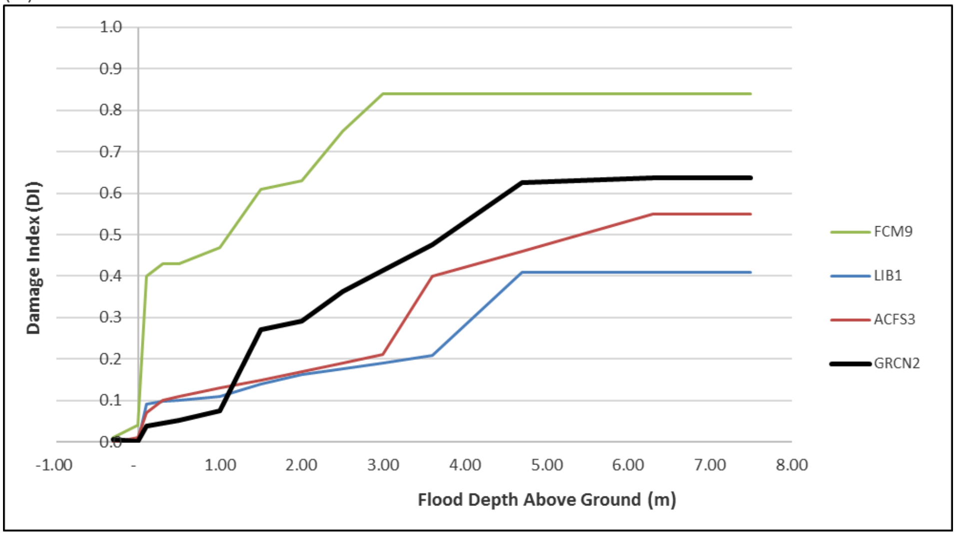
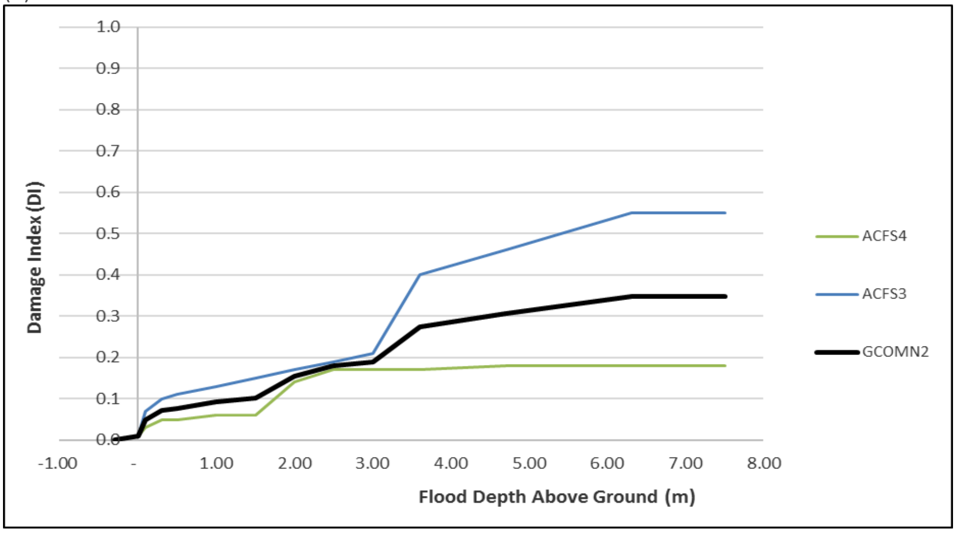


Figure 5: Flood Vulnerability functions: detailed and generalised.

(D) GRCN2



(E) GCOMN2



(F) GIND1

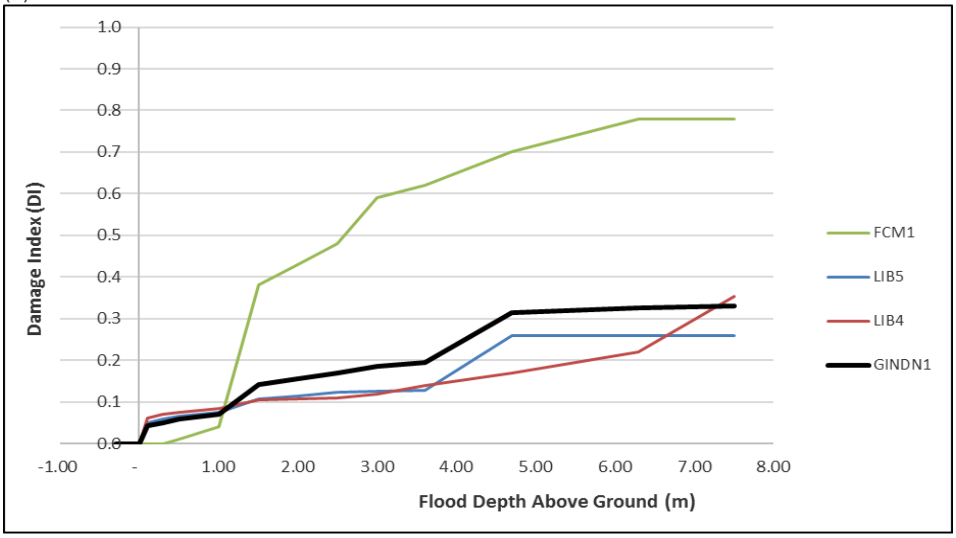


Figure 5: Flood Vulnerability functions: detailed and generalised (cont.).

Summary

Flooding is a major hazard in Australia, accounting for the largest economic losses of any single hazard (DAE 2017). Flood vulnerability functions should ideally be developed for typical building types of each study area which can represent the local building stock accurately (Te Linde et al., 2011). However, since developing these detailed functions is time consuming and expensive, the generalised functions, presented in Figure 5 and described in Table 1, are the alternatives available for meso to macro level studies.

This study has focused on developing generalised vulnerability functions at meso-scale which require less detailed exposure information. Within the utilisation project a more detailed study will be conducted to assess the application of the generalised vulnerability functions. Furthermore, the usefulness of generalised approach in assessing flood risk will be investigated along with analysis of the increased uncertainty associated with the simpler but more practical approach.

Research utilisation

The potential utilisation of this research could include:

- There is broad potential for the use of generalised functions by those who do not have access to detailed building exposure information. Users could include floodplain managers, insurance companies, flood consultants, state emergency services and impact modellers.
- The curves would allow consistent comparisons to be made across jurisdictions where exposure information may otherwise be inconsistent, benefitting decision makers in comparing flood impact and risk.
- The publication of the finalised generalised functions and use instructions through Australian Institute for Disaster Resilience (AIDR) will allow for widespread dissemination and access.

Acknowledgements

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