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Development of damage functions for flood risk assessment in the city of Colombo (Sri Lanka)

Priyan Dias[a]*, N.M.S.I. Arambepola[b], Kumari Weerasinghe[c], K.D.N. Weerasinghe[d], Dennis Wagenaar[e], Laurens M. Bouwer[e], Hans Gehrels[e]

[a]*University of Moratuwa, Moratuwa, Sri Lanka*
[b]*Asian Disaster Prevention Centre, Bankok, Thailand*
[c]*Central Engineering Consultancy Bureau, Colombo, Sri Lanka*
[d]*University of Ruhuha, Matara, Sri Lanka*
[e]*Deltares, Delft, Netherlands*

Abstract

Depth vs. damage curves were developed for a flood risk assessment carried out in Colombo, Sri Lanka. The major elements of the damage assessment comprised building fabrics, building contents, distributed infrastructure and vehicles. Current approaches to damage function development were improved on by separating damage to building fabric and contents; using actual building footprints rather than assigning building functions to city zones; assessing infrastructure damage accurately; and incorporating damage to vehicles. Information sources included infrastructure agencies, bills of quantities for buildings, expert consultations, household surveys and insurance agencies. The building fabric was assigned three categories, namely semi-permanent, single storey and two storey. The building contents were classified into 7 types based on function as warehouse/storage, industrial, shops, offices, residential, educational and health. The proportion of contents asset values to that of the fabric ranged from 1.67 for warehouse/storage to 0.20for educational. Both 'what-if' analyses and historic data were used to generate the curves. Data were obtained as losses per unit area or unit length; or as point losses.For the 140 square km urban area, the generated flood damages ranged from USD 37 to 549 million for return periods from 5 to 100 years, with average inundation depths ranging from 0.48 m to 1.28 m (and outliers up to 5.8 m). The total non-residential to residential building damage increased with return period (and together accounted for 75-85% of damage). The residential contents to fabric damage ratio was generally around 1.5. The percentage damage to infrastructure was not very significant, although that to vehicles was, especially at lower return periods.

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* Corresponding author. Tel.: +94-77-555-4740; fax: +94-11-2650567.
*E-mail address:*priyan@uom.lk

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1. Introduction

Flood risk assessment involves (i) generating probabilistic synthetic flood scenarios for various return periods; (ii) creating hazard scenarios defined by spatial distributions of inundation depths; and (iii) estimating the damage caused by such inundation via depth-damage curves. This paper reports the development of such curves during a flood risk assessment for Colombo, Sri Lanka for the combined effects of riverine, sea level and rainfall variations.

The comprehensive review by Merz et al. [1] states that “Much more attention is given to the hazard assessment part, whereas damage assessment is treated as some kind of appendix within the risk analysis.” The greatest inaccuracies in loss estimation also arise from uncertainties in asset values and depth-damage curves [2]. Hence, particular attention was paid in this study to developing accurate damage functions. The above review [1] also raises various issues and alternative approaches that had to be considered in the present study too; e.g. (i) the choice between using historic damage data to develop curves as opposed to ‘what-if’ approaches (i.e. computing damage indices based on various assets likely to be located at different heights); (ii) the choice between using depreciated asset values as opposed to replacement costs for damage assessment; and (iii) the question of separating building fabric and contents damages (which they recommend).

A study for Jakarta, quite similar to the present one, is reported by Budiyono et al. [3]. They indicate that different studies have generated widely differingdepth vs. damage functions. However, their entire study has used only 12 damage curves, 8 of them for various classes of buildings. There is no specific treatment of infrastructure such as roads and utilities. The authors also describe the methodology for developing damage curves as being essentially of two steps, the first being to consult experts for obtaining preliminary curves and the second being a (one-day) workshop to consult a much wider group for validating or improving on the preliminary curves.

Another study that considered earthquake, flood, storm surge, tsunami and wind storm hazards,carried out in Bangladesh [4], covered damage to residential buildings, roads & bridges and schools & hospitals. It also estimated human casualties, both death and injury. The residential buildings were classified into 3-4 categories. The flood damage is not covered so well, and is presented mainly for the above types of residential buildings. The damage curves are S-shaped with the steepest slopes at intermediate inundation depths, and can be generated by using the recommended parameters for a general equation obtained from CIMNE [5]. The use of such mathematically idealized curves may however increase generality as the expense of accuracy.

Komolafe [6] has studied the May 2010 flood in the Kelani Basin in Sri Lanka, covering both hydrological and damage aspects. Where the damage curves are concerned, historic data through household surveys has been used to assess the fabric damage to residential and commercial buildings. The fitted curves for these buildings are of the logarithmic type, although there is a lot of scatter. It should be noted that Dias [7] proposed negative exponential curves (rather than logarithmic ones) for total damage; and the widely accepted S-shaped cumulative lognormal distribution ones for characterizing fragility curves – in his case for tsunami as opposed to flood damage.

The Disaster Management Centre [8] report on the May 2010 flood in Sri Lanka distinguishes between immediate damage and longer term (economic) losses. The most significant damage is reportedly incurred by transport (mostly road) infrastructure, housing (with fabric and contents damage computed separately) and irrigation infrastructure; other categories considered are water supply & sanitation, telecommunications, electricity, health, education, industry, commerce, religion & culture and agriculture (which suffers the greatest economic loss).

The Geoscience Australia study [9] for the Global Assessment Report (2015) [10] also contains fabric damage curves for a wide variety ofstructures, covering the natural hazards of earthquake, severe wind, flood, volcanic ash and tsunami, all obtained from expert consultation, both in workshop and post-workshop modes. Hence these curves are based on expert opinion as opposed to evidence; nevertheless they can be used for cross checking.

The above indicates that there is global (e.g. [10]), regional (e.g. [9]) and national (e.g. [3,4,6]) interest in damage functions, inclusive of the production of review literature (e.g. [1,2,5]). This study attempts to improve the generation of damage functions through the various approaches spelt out below.