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## Weighting the perceived importance of minimising economic, social, and environmental/cultural risks in flood risk management

Zeinab Bedri

*Technological University Dublin, zeinab.bedri@tudublin.ie*

John O'Sullivan

*University College Dublin, jj.osullivan@ucd.ie*

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**WEIGHTING THE PERCEIVED IMPORTANCE OF  
MINIMISING ECONOMIC, SOCIAL AND  
ENVIRONMENTAL/ CULTURAL RISKS IN FLOOD RISK  
MANAGEMENT**

**(Final Report: 27<sup>th</sup> November 2015)**



**UCD Dooge Centre for Water Resources Research,  
School of Civil Engineering**

**University College Dublin**

**Dr. John O'Sullivan & Dr. Zeinab Bedri**

University College Dublin  
Newstead  
Belfield

Phone: 01 7163213  
Fax: 01 7167399  
Email: [jj.osullivan@ucd.ie](mailto:jj.osullivan@ucd.ie)

## **Executive Summary**

A new national flood policy adopted in Ireland in 2004 set out that a range of flood-related impacts should be taken into account in planning flood risk management strategies and projects, including impacts on people, properties, the environment and cultural heritage. This was reinforced by the 2007 EU 'Floods' Directive that is aimed at the reduction of adverse consequences of flooding for human health, the environment, cultural heritage and economic activity.

In 2006, the Office of Public Works (OPW) began the National Catchment-based Flood Risk Assessment and Management (CFRAM) Programme through a series of pilot studies. A Multi-Criteria Analysis (MCA) Framework was developed through the pilot studies that integrated a number of objectives related to a wide range of potential impacts and benefits into the core of the process of appraising and selecting suitable flood risk management measures for a given area or location, and then for prioritising national investments for different schemes and projects. This MCA Framework, that provides a systematic process of developing a non-monetised but numerical indicator of benefit and impact, has since been implemented nationally in the preparation of the Flood Risk Management Plans (FRMPs).

A key feature of the MCA is that it should represent societal values. To this end, nationally representative quantitative research was undertaken to determine global weights that reflect the perceived importance of each of the objectives for reducing economic, social and environmental / cultural risks in flood management strategies. Saaty's Analytical Hierarchy Process (AHP), in conjunction with a pairwise comparison of criteria relating to these risks, was utilised to determine weights. In excess of 1,000 structured interviews were completed where the relative importance of these objectives were assessed using a seven-point scale. Consistency ratios were calculated for response matrices and where values exceeded 0.2, responses were excluded from the analysis.

The weighting given to each of the 13 specific objectives identified, broadly followed expectations, with risk to people followed by risk to homes and properties being respectively the first and second most important, although some were given greater or less weighting than expected.

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## **Introduction**

A major review of national flood policy adopted in Ireland in 2004 set out that a range of flood-related impacts should be taken into account in planning flood risk management strategies and projects, including impacts on people, properties, the environment and cultural heritage. This was reinforced by the 2007 EU 'Floods' Directive that is aimed at the reduction of adverse consequences of flooding for human health, the environment, cultural heritage and economic activity.

The Office of Public Works (OPW) is the State's lead agency for flood risk management in Ireland and in 2006, commenced the Pilot Catchment-based Flood Risk Assessment and Management (CFRAM) Projects, prior to commencing the National CFRAM Programme (<http://www.cfram.ie/>). The CFRAM programme aims to assess flood risk, through the identification of; (i) flood hazard areas and the associated impacts of flooding, and (ii) viable measures and options for managing the flood risks for localised high-risk areas. Flood Risk Management Plans (FRMPs) and associated Strategic Environmental Assessments (SEA) that set out the measures and policies that should be pursued to achieve the most cost effective and sustainable management of flood risk are also being prepared.

A Multi-Criteria Analysis (MCA) Framework was developed through the CFRAM pilot studies that integrated a range of objectives related to human health and society, the environment and cultural heritage and the economy into the core process of selecting suitable flood risk management measures for a given area or location, and then for prioritising national investments for different schemes and projects. This MCA Framework, that provides a systematic process of developing non-monetised but numerical measures of benefit and impact, has been implemented nationally in the preparation of the FRMPs.

In support of this MCA framework, The School of Civil Engineering, UCD, was commissioned to undertake a collaborative study with the OPW to determine global weights that reflect the perceived relative importance of a range of criteria pertaining to the importance of economic, social and environmental / cultural aspects of flood management strategies. The methods, analysis and results of the study, which involved quantitative research in a national consultation exercise undertaken by Behaviour and Attitudes Ltd., an independent research organisation engaged by the OPW, is presented in this report.

## **Methods**

A questionnaire survey developed jointly by University College Dublin (UCD) and OPW was used for the public consultation exercise. A pilot study of circa. 25 samples was first undertaken and the feedback from the pilot study was used to improve the questionnaire. When finalised, the questionnaire was completed in just over 1,000 structured interviews conducted with a representative cross-section of members of the public. These were door-to-door interviews, arranged by and undertaken by Behaviour and Attitudes Ltd. ([www.banda.ie](http://www.banda.ie)) on behalf of the OPW. The questionnaire used in these structured interviews is in Appendix A.

The questionnaire included a pairwise comparison of the various flood risk management objectives together with the collection of standard demographic criteria relating to the

respondent. Section 1 of the questionnaire related to the objective of minimising the economic risk that may result from flooding. Respondents were presented with a further four sub-criteria related to economic considerations (homes and businesses, transport infrastructure, utility infrastructure, and agriculture) and were asked about their opinion as to which of the economic sub-criterion was more or less important compared to the other.

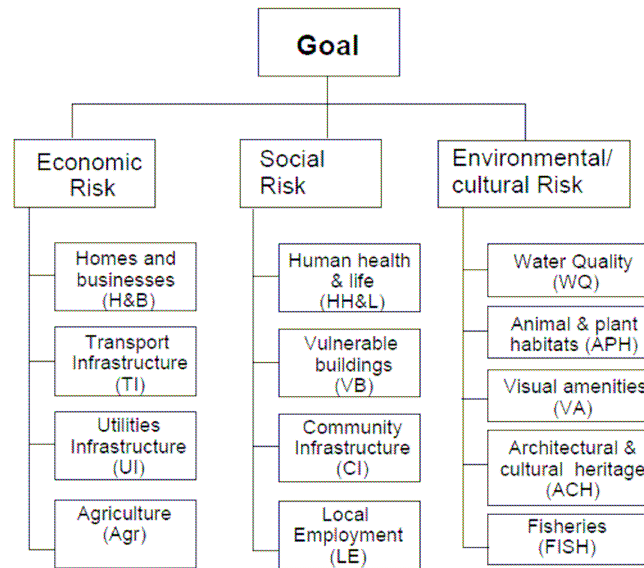
Similarly, Section 2 of the questionnaire related to the minimising of social risk from flooding and sought respondent’s opinion on the relative importance of four related sub-criteria. Section 3 related to minimising the environmental and cultural risks and compares five environmental sub-criteria. The OPW had previously determined that equal weighting should be given to each of three groups of objectives (namely, economic, social and environmental / cultural risk), having taken into account the UN Pillars of Sustainability, the requirements of the EU 'Floods' Directive and experience from the Pilot CFRAM Projects.

The pairwise comparisons in all three sections were analysed using Saaty’s Analytical Hierarch Process (AHP) (Saaty, 1990 and 2003) to identify and weight the sub-criteria (or objectives) that are deemed most important by the public. Firstly, the one-to-seven scale assigned by the personnel of Behaviour and Attitudes (B&A) Ltd. for the survey responses was converted to a seven-point Saaty scale (see Table 1 below).

**Table 1 Conversion of the Behaviour and Attitudes Ltd. (B&A) scale to Saaty’s scale**

| <b>Section 1: minimising Economic risk (pairwise comparison between the two economic criteria: homes &amp; businesses and transport infrastructure)</b> |  |                     |                         |                     |   |                     |                          |
|---|--|---------------------|-------------------------|---------------------|---|---------------------|--------------------------|
|   | <b>Minimise risk to homes and businesses</b> |                     |                         |                     | <b>Minimise risk to transport infrastructure (e.g. roads, railways)</b> |                     |                          |
| Scale   | Very much more important                     | Much more important | Slightly more important | Of equal importance | Slightly more important   | Much more important | Very much more important |
| B&A   | 1  | 2                   | 3                       | 4                   | 5   | 6                   | 7                        |
| Saaty   | 7  | 5                   | 3                       | 1                   | 1/3   | 1/5                 | 1/7                      |

The decision hierarchy was subsequently structured (Figure 1) with its ‘goal’ at the highest level of the hierarchy. As mentioned, the objective was to determine global weights that reflect the perceived importance of each of the objectives for reducing economic, social and environmental / cultural risks in flood management strategies and as such, the intermediate levels of the hierarchy consist of these criteria, with the associated sub-criteria at the lowest level of the hierarchy.



**Figure 1 Decision hierarchy of the MCA framework**

Each section of the questionnaire (corresponding to one of the three objectives) was analysed separately. Based on the individual questionnaire responses, pairwise comparison matrices were constructed for the criteria under each objective. These matrices were then analysed to obtain the priority weightings of each criterion.

As part of the analysis, the Consistency Ratio (CR) was computed for the response matrices. The CR measures how consistent the judgements have been relative to large samples of purely random judgements. While a consistency ratio of less than 0.1 is considered desirable, this is often difficult to achieve because of the complexity of the compared elements and the limited ability of human thinking. Therefore for the current analysis a consistency ratio threshold of 0.2 was used, and where values exceeded this ratio, responses were excluded from the analysis.

To aggregate individual judgements into a single representative judgement for the entire group, two methods are presented; the arithmetic mean and the geometric mean. The arithmetic mean is more frequently used but in exercises that rely on ‘expert’ opinions, geometric means are also used in determining global weightings.

## Results

Table 2 shows results of the analysis of Section 1 of the questionnaire that compares the four criteria / alternatives for minimising the economic risk of flooding. The results demonstrate that setting the maximum acceptable consistency ratio to 0.1 has excluded approximately 70% of the questionnaire responses from the analysis, while increasing it to 0.2 has included almost 60% of the responses in the analysis. This however has not affected the order of the priorities given by the public to the four criteria (left column of Figure 1) where those interviewed agreed that minimising the risk to homes and businesses (H&B) was the most important criterion for minimising the economic risk of flooding. Minimising the risk to utilities infrastructure (UI) (e.g. electricity, telecommunications, water) and agriculture (Agr (including animals and farmland)) were deemed of lesser importance, while minimising the



risk to transport infrastructure (TI) (roads, railways, etc.) was considered the least important criterion.

**Table 2 MCA weightings of the criteria of objective 1 – Minimising Economic Risk**

| Consistency ratio (CR) | No of responses | Arithmetic (AR) mean |       |       |       | Geometric (GEO) mean |       |       |       |
|------------------------|-----------------|----------------------|-------|-------|-------|----------------------|-------|-------|-------|
|                        |                 | H&B                  | TI    | UI    | Agr   | H&B                  | TI    | UI    | Agr   |
| < or = 0.10            | 307             | 0.377                | 0.176 | 0.232 | 0.215 | 0.389                | 0.174 | 0.231 | 0.206 |
| < or = to 0.2          | 594             | 0.395                | 0.165 | 0.229 | 0.211 | 0.410                | 0.163 | 0.226 | 0.201 |
|                        | 1003            | 0.387                | 0.167 | 0.242 | 0.204 | 0.405                | 0.165 | 0.241 | 0.189 |

When increasing the CR threshold to 0.2, the weighting given to the H&B criterion has shown to also increase with corresponding but small decreases in the weightings for the other three criteria.

Aggregates of individual responses yielded similar weightings when computed using both the arithmetic (AR) mean and geometric (GEO) mean. For a consistency ratio threshold of 0.2, the analysis yielded weightings of 0.395 and 0.41 for the H&B criterion using the AR mean and the GEO mean respectively while the TI criterion was given weightings of 0.165 and 0.163 for the AR mean and the GEO mean respectively.

Table 3 shows the weightings given by the questionnaire interviewees for the relative importance of four criteria (middle column of Figure 1) for minimising the social risks of flooding; human health and life (HH&L), vulnerable buildings (VB), community infrastructure (CI), and local employment (LE).

**Table 3 MCA weightings of the criteria of objective 2 – Minimising Social Risk**

| Consistency ratio (CR) | No of responses | Arithmetic (AR) mean |       |       |       | Geometric (GEO) mean |       |       |       |
|------------------------|-----------------|----------------------|-------|-------|-------|----------------------|-------|-------|-------|
|                        |                 | HH&L                 | VB    | CI    | LE    | HH&L                 | VB    | CI    | LE    |
| < or = 0.10            | 274             | 0.425                | 0.269 | 0.172 | 0.133 | 0.435                | 0.272 | 0.166 | 0.126 |
| < or = to 0.2          | 625             | 0.454                | 0.279 | 0.152 | 0.115 | 0.466                | 0.283 | 0.143 | 0.109 |
|                        | 1003            | 0.452                | 0.278 | 0.152 | 0.118 | 0.464                | 0.286 | 0.139 | 0.111 |

Here the results also indicate that the number of responses included in the analysis have more than doubled when increasing the CR threshold to 0.2. This has not however, affected the order of the priorities given by the public to the four criteria where minimising the risk to human health and life was considered the most important criterion for minimising the social risk of flooding. Minimising the risk to vulnerable buildings (e.g. hospitals, care homes) and community infrastructure (e.g. schools and community centres) were deemed to be of lesser importance, while minimising the risk to local employment (e.g. local businesses and tourist attractions roads, railways) was considered the least important criterion. The increase in the CR threshold from 0.1 to 0.2 resulted in a small increase in the weightings of the two criteria (HH&L and VB) deemed to be the most important by survey participants. This corresponded to small decreases in the computed weightings for the CI and LE criteria.

Aggregates of individual responses using the GEO mean yielded slightly higher weightings for HH&L and VB than the AR mean.

The relative importance of the five criteria for minimising the environmental and cultural risk of flooding are presented in Table 4. The five criteria are in the right side column of Figure 1 and include minimising risk to the water quality of rivers, lakes and sea (WQ), minimising the risk to protected animals and habitats (APH), minimising the risk to visual amenities such as landscapes, urban settings and scenic views (VA), minimising the risk to features of architectural and cultural heritage (e.g. historic sites and museums) (ACH) and minimising the risk to fisheries (FISH).

The results of the analysis demonstrate that setting the consistency ratio threshold at 0.1 would exclude approximately 60% of the questionnaire responses from the analysis while setting the CR ratio to 0.2 includes 65% of the responses. The weightings given by the questionnaire interviewees to the five criteria demonstrate that priority was given to minimising the risk to water quality (WQ), and the protection of animals and habitats (APH). Minimising the risk to fisheries were deemed to be of less importance, while minimising the risk to visual amenities and features of architectural and cultural heritage were deemed least important by participants. The increase in the CR threshold from 0.1 to 0.2 resulted in an increase in computed weightings for the two criteria perceived to be most important, namely WQ and APH, and this corresponded to a decrease in the weightings of VA, ACH and FISH.

**Table 4 MCA weightings of the criteria of objective 3 – Minimising Environmental/ Cultural Risk**

| Consistency ratio (CR) | No of responses | Arithmetic (AR) mean |       |       |       |       | Geometric (GEO) mean |       |       |       |       |
|------------------------|-----------------|----------------------|-------|-------|-------|-------|----------------------|-------|-------|-------|-------|
|                        |                 | WQ                   | APH   | VA    | ACH   | FISH  | WQ                   | APH   | VA    | ACH   | FISH  |
| < or = 0.10            | 407             | 0.268                | 0.246 | 0.137 | 0.130 | 0.219 | 0.267                | 0.251 | 0.133 | 0.125 | 0.224 |
| < or = to 0.2          | 651             | 0.282                | 0.250 | 0.132 | 0.125 | 0.211 | 0.283                | 0.256 | 0.128 | 0.121 | 0.211 |
|                        | 1003            | 0.279                | 0.254 | 0.134 | 0.130 | 0.203 | 0.279                | 0.265 | 0.131 | 0.124 | 0.201 |

Aggregates of individual responses using the GEO and AR means yielded similar weightings for WQ and FISH criteria. Also aggregates using the GEO mean resulted in higher weightings for the APH criterion and lower weightings for the VA and ACH criteria.

## 1. Conclusions

This study presents an MCA of a public consultation exercise conducted under the CFRAM programme in order to identify the relative importance of various flood risk management objectives and assign relative weightings to these objectives. The MCA appraisal outcomes will inform the national prioritisation of preferred options and measures for flood risk management.

A questionnaire survey developed jointly by UCD and OPW was used for data collection. A pilot study of circa 25 samples was first collected and the feedback from the pilot study was then used to improve the main questionnaire in which just over 1000 structured interviews were conducted with members of the public. The door-to-door interviews were conducted by Behaviour and Attitudes Ltd. ([www.banda.ie](http://www.banda.ie)) on behalf of the OPW.

The questionnaire included a pairwise comparison of the various flood risk management objectives along with some demographic information. The pairwise comparisons in the questionnaire were analysed using Saaty's Analytical Hierarch Process (AHP) (Saaty, 1990 and 2003) to identify and weight the objectives deemed to be most important by the public.

The results of the analysis revealed that minimising the risk of flooding to homes and businesses was deemed the most important economic criterion. With regards to minimising the social risk of flooding, the public agreed that the protection of human health and life was considered a priority. Also, and from an environmental perspective, minimising the risk to the water quality of rivers, lakes and seas ranked most highly.

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