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Comparative analysis of current guidance for the evaluation of building retrofit investments

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Abstract

The built environment must adapt to a rapidly changing context and, since buildings have relatively long lives, this must primarily be achieved through retrofitting the existing building stock rather than by replacing it. We therefore need robust approaches to evaluating the cost-effectiveness of retrofit investments. Some guidance for performing investment appraisals of building retrofit proposals is available for specific types of retrofit, for example, the economic evaluation procedure for energy systems in buildings in the form of the EN 15459 standard. In this preliminary study, three existing evaluation methods are reviewed and compared. On this basis, recommendations for the development of a robust, general approach to the financial and economic evaluation of building retrofits are made.

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Keywords: building retrofit; construction investment; cost benefit analysis; discounted cash flow techniques.

1. Introduction

Social, environmental and technological changes are leading to an increasingly complex and dynamic context for the built environment. (Anderies, 2013; IPCC, 2013; The Royal Society, 2014) This necessitates changes in what we build and how we build it. However, in contrast to the rapidity of some of these changes, buildings and infrastructure have a relatively long life and the renewal of the existing building stock takes place over decades if not centuries. Therefore, adaptations cannot take place through new buildings alone and the primary mode of adaptation is and will continue to be through retrofitting existing buildings.

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Whatever the purpose of a particular adaptive retrofit, there is a need to determine whether the retrofit represents a worthwhile investment. This calls for a robust approach to the evaluation and comparison of costs and benefits.

There is general agreement on the appropriateness of discounted cash flow (DCF) techniques for investment appraisal. (Ryan & Ryan, 2002; Vimpari & Junnila, 2014) In addition, there have been a number of recent examples of DCF methods being used for the evaluation of retrofits for various purposes. These include the evaluation of energy saving measures to determine national cost-optimal solutions as obligated under the European Union's Energy Performance of Buildings Directive (2010/31/EU), studies relating to the cost benefit analysis of property level flood mitigation measures in the United Kingdom and guidance for benefit cost analysis of multi-hazard mitigation measures under a United States' Federal Emergency Management Agency's support program. (FEMA, 2009a; Atanasiu et al., 2013; Rotimi et al., 2014)

In this preliminary study, three such approaches are described, critically analysed and contrasted to identify commonalities and differences with the aim of suggesting some bases and concepts for the development of a generally applicable and robust retrofit investment appraisal method.

2. The three cost benefit evaluation methods identified

From a search of the literature, three approaches which are currently in use or recently used and which are documented in sufficient detail to allow detailed review were identified. These are:

1. EN 15459 Energy Performance of Buildings – Economic evaluation procedure for energy systems in buildings; (EN 15459, 2007)
2. A methodology applied by the consulting firm Royal Haskoning for a study assessing the economic case for the implementation of property level flood mitigation measures in England; (Royal Haskoning, 2012)
3. The Federal Emergency Management Agency's (FEMA) guidance for benefit-cost analyses of hazard mitigation projects. (FEMA, 2009a)

These three approaches were then reviewed and compared in terms of their:

- input data sources and basic assumptions;
- cash flow and discount rate derivations; and,
- calculation and output metrics.

3. Review of method 1: EN 15459

The Energy Performance of Buildings Directive (2010/31/EU) obliges EU member states to establish cost-optimal levels for minimum energy performance requirements. While the EN 15459 calculation method adopted is intended for use by national authorities (rather than investors) to develop national level requirements applicable to the majority of buildings on the basis of a limited number of identified reference buildings, it nevertheless represents a widely applied approach to the economic evaluation of building retrofits for energy savings and is therefore applicable to this study. (CA-EPBD, 2013; EC, 2012; EN 15459, 2007)

The EN 15459 standard for the Energy Performance of Buildings – Economic evaluation procedure for energy systems in buildings is explicitly recommended as the calculation method for the derivation of cost-optimal solutions by the guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. (CA-EPBD, 2013; EC, 2012) Indeed, this standard is one of a series of standards prepared in support of the European Commission's previous EPBD Directive (2002/91/EC) and aimed at European harmonization of the methodology for energy performance of buildings calculations. (EN 15459, 2007)

The EN 15459 adopts a deterministic approach to economic evaluation. A static discount rate is applied (though the calculation method does suggest provision for dynamic considerations in terms of variable rates over the calculation period, it does not actually detail this and examples of implementation show a fixed rate applied throughout the calculation period with a sensitivity analysis carried out using alternative trial values of discount rate; for example, see Atanasiu et al. 2013). Although it is labelled 'economic' the evaluation undertaken is largely financial by nature and does not attempt to evaluate or quantify any secondary effects nor consider any elasticity in utility.

3.1. Input data sources and basic assumptions

The calculation period (referred to in the standard as 'scheme life') is typically 30 – 50 years depending on the remaining expected life of the building under consideration. However, it is defined in the EU's cost-optimality calculation regulations as 30 years for residential buildings. (EN 15459, 2007; EC, 2012; Atanasiu et al. 2013)

3.2. Cash flows and discount rates

The cost / benefit valuation data includes system and product installation and replacement costs and replacement periods. The calculation allows the scheme life and system / component lives to differ. However, if the scheme life terminates while systems / components still have remaining service life, then residual, terminal values for these components are calculated for their remaining life on the basis of straight line depreciation. These terminal values are then considered as a benefit but, other than these, the method appears to focus exclusively on costs and no benefits appear to be included.

The energy consumption and component cost information are derived according to European standard methodologies and provide deterministic (as opposed to probabilistic) single value (point estimates) inputs. While only those construction costs which relate to energy are taken into consideration.

EN 15459 assumes the real interest rate as a constant discount rate and various price development rates (e.g. for energy types, products, human operation, added costs) are applied in order to adjust costs over the scheme life. It is worth noting that the discount rates actually used in country analyses have ranged between 2-4%. (Atanasiu et al. 2013) Taxes are explicitly taken into account (they are included) in the costs though this arguably shouldn't be the case for an economic evaluation as taxes are a benefit or cash inflow to the public purse.

3.3. Calculations and outputs

The principal metric calculated is the 'global cost'. This is defined as "*the sum of all costs including investment costs, system operation, maintenance and replacement costs, energy costs, disposal costs, less remaining value all expressed in present value terms and per m2 of building floor area.*" An alternative metric, the global cost expressed in terms of an annuity is also defined in EN 15459. This metric enables the convenient comparison of schemes with different lives. (EN 15459, 2007)

In terms of its use in the determination of national cost-optimal energy performance solutions for EU member states, it is intended to allow the solution with the lowest overall (akin to life-cycle) energy cost to be identified from a group of alternative solutions. (CA-EPBD, 2013)

4. Review of method 2: Royal Haskoning's assessment of property level flood mitigation measures

Floods are the most common and most costly of all natural disasters (FEMA, 2009a). In the UK context, flooding presents a complex challenge which calls for intervention at various levels, including that of individual properties (White et al, 2013). Although a single, specified approach for property level actions does not seem to be in place, some of the analyses commissioned by the UK's Department for Environment, Food and Rural Affairs (DEFRA) and related initiatives and organizations provide examples of cost benefit calculations in this realm. The method selected for description here is that used by Royal Haskoning in a report commissioned by the Committee on Climate Change which drew on previous analyses carried out for DEFRA (Royal Haskoning, 2012; Rotimi et al 2014)

Property level flood protection measures as retrofits to existing buildings come in two forms – those that increase a building's resistance to flooding (e.g. by preventing flood waters entering the building – door seals, air brick covers, toilet seals) and those that increase a building's resilience (i.e. measures that minimize damage and promote recovery from a flood event – waterproof fittings and finishes, raised electrical sockets, raised washing machines and built-in ovens). (Kazmerczak & Connelly, 2011) The purpose of the Royal Haskoning study was to identify the adaptation actions that would be cost effective for society to undertake today to manage flood risk in England given current conditions and also when accounting for future climate scenarios.

4.1. Input data sources and basic assumptions

The input data largely draws on previously published surveys and national databases with costs updated to 2011 using the Consumer Price Index. Some current information from manufacturers is included. Similarly to the recorded use of EN 15459 for the derivation of cost-optimal energy saving measures packages above, the Royal Haskoning analysis was applied at the national level (rather than to specific, individual properties). This was achieved by a generalized assessment of flood risk, with average property type characteristics. Four standard types of residential properties plus typical shops and offices were identified as were standard menus of resistance and resilience measures appropriate for each of the typical property types. Two assessments were made – an economic assessment (from the perspective of society) and a financial assessment (from the perspective of the individual household / property owner).

Protection measures up to a level of 0,6m above the property threshold level were considered as higher levels than this would suggest a likelihood of wall failures under hydrostatic pressure. Two alternative flood duration scenarios were considered: a short term (less than 12 hours) scenario and a long term (more than 12 hours) scenario. A calculation period / scheme life of 20 years was adopted.

4.2. Cash flows and discount rates

'Upper', 'lower' and 'best' estimates of costs for the property level measures were made with respect to a specified reference year. Maintenance costs for measures were included as a simple, annually applied percentage of capital cost (ranging from 2-5%) based on manufacturers' information. However, no replacements were considered to take place within the scheme life / calculation period. The cost of surveys to determine the flood protection measures required was included.

Benefits of the property level mitigation packages were taken to be the damages from flooding *averted* as a result of the measures in comparison to those which would be incurred for an unprotected property. These flood damage costs for the residential models included the monetary damages to building fabric and inventory, the cost of clean-up, temporary accommodation, absence from work, and stress and ill health. The non-residential models (for offices and shops) included the monetary damages to building fabric and inventory, services, moveable equipment and stock, and the cost of clean-up. Rotimi et al. (2014) suggest that some intangible benefits were left out from the Royal Haskoning analysis and that these omissions constitute a weakness in the approach.

The benefits calculations took into consideration the probability of floods, their inundation levels and durations through the derivation of damage / loss functions for properties depending on their levels of protection and their levels of inundation (flood depth), application of flood frequency-depth relationships from previous studies together with their annual exceedance probabilities. The benefits were then calculated as a function of reduced damage costs (which have been assessed, analyzed and documented as average figures from previous floods) resulting from the various resistance and resilience measures undertaken. In this way, the mathematical expectation of damage (and damages averted) was derived in the form of a *Weighted Annual Average Damage* value.

This approach was only applied to those properties which are considered to be vulnerable to flooding: i.e. those with an annual probability of flooding greater than a threshold value (0,1% Annual exceedance probability for coastal flooding, 0,5% for fluvial (river) flooding. These probabilities take into account community level flood defenses that are in place. The analysis did not consider surface water flooding.

For the economic assessment, a discount rate of 3,5% was used in conjunction with prices excluding value added tax (VAT) while for the financial assessment, a discount rate of 8% was applied with prices including VAT. In both cases, these values were determined from standard UK government guidance on cost benefit analysis – the Treasury Green Book and the Financial Accounting Standards Board's Accounting Standards Codification (ASC).

4.3. Calculations and outputs

The total cost was calculated over the full 20 years and discounted to present value terms. For each property type, the benefit to cost ratios were calculated for each of the property level measures packages for each of the annual exceedance probability levels. This gave the level of flood probability for which the measures delivered a benefit to cost ratio of 1 or more. Some consideration of uncertainty was also included in the method by including a factor for the reliability of the protection measures (in the form of applying a percentage reduction in average benefit).

This calculation method also specifically accounted for climate change projections in terms of increased numbers of properties being at significant risk of flooding according to three (low, medium and high) climate change / emissions scenarios. The 50th percentile values for each of these 3 scenarios had been established by previous research carried out for the Committee for Climate Change.

5. Review of method 3: FEMA guidance for benefit-cost analyses

The FEMA guidance is intended primarily for applications for public assistance in investing in mitigation measures. It takes the form of a software-based suite of tools with accompanying written information for benefit cost analysis to determine the cost effectiveness of FEMA funded mitigation projects for natural hazards - earthquake, fire (wild land / urban interface fires), flood (riverine, Coastal A Zone, Coastal V Zone), hurricane wind, and tornado. These include property level mitigation measure retrofits. The part of the tool specifically relating to the cost-effectiveness of the project proposals is considered here but this is dependent on all other aspects (property vulnerability, building type, scope of work, time schedule, etc.) of the project proposals as well. The following overview is based on the user guidance according to FEMA (2009a), FEMA (2009b) and FEMA (2011).

5.1. Input data sources and basic assumptions

With regard to hazard event return periods, there are 2 options – if full data for the project area is available in existing databases, then the built-in full data modules will automatically determine damage frequency and severity. Alternatively, damage frequencies can be determined on the basis of 2 or more historical examples of the hazard events for which mitigation measures are being proposed. The method for this 'Limited Data' approach is separately documented (FEMA, 2009b) and provides us with insights into the general approach to hazard and vulnerability input data. Namely, that return periods coupled with their severity (damage costs expressed in present value terms with the help of the FEMA inflation calculator) are derived for hazards (e.g. flood or wildfire). Note, however, that these assessments appear to assume that no betterment in terms of mitigation actions takes place over time (which seems quite unlikely). Generally, standard base values for all inputs are provided but analysts may enter any alternative values provided that these are substantiated with documented evidence. Unlike the two other approaches reviewed which identify typical building types, the FEMA approach relates to specific properties and, therefore, the specific building characteristics relevant to the specific hazards must be input, for example: property soil types and seismic resistance classification of buildings for earthquake mitigations, elevations of floors with regard to flooding.

5.2. Cash flows and discount rates

Mitigation project cost estimates are made on a project-by-project basis using current market prices. Costs considered include pre-construction and non-construction costs, construction costs, management costs, ancillary costs and annual maintenance costs. All these costs are adjusted according to project timing using an inflation calculator and the result is a point cost estimate in present value terms. It should be noted that this is somewhat in contradiction to the Federal Office of Management and Budget (OMB) guidance (OMB, 2014) for the investment analysis of federally funded projects which encourages the consideration of uncertainty and the use of probability distributions for both costs and benefits. As in the Royal Haskoning approach, benefits are measured as the future losses prevented or reduced by a mitigation project. These are expressed in present value terms.

The project useful life – an estimate of the effective life of the mitigation project - can be made either using FEMA standard values or (with additional justification) the analyst's own input values. FEMA standard values for building retrofits depend on building types and vary from 25-50 years.

Damage costs / averted costs are estimated on the basis of the Damage Frequency Assessment – this is a method to determine the base level – the annual probability and average cost of damage per event from which loss reductions (benefits) can then be measured. Costs considered include:

- direct building damage costs (as % of Building Replacement Cost);
- occupants displacement costs;
- loss of rent;
- loss of business;
- debris removal;
- life disruption costs;
- costs of lost services for institutional facilities (schools, hospitals, etc.)

though note that FEMA has a threshold of 50% above which it considers replacement to be preferable to repair.

The standard discount rate applied in the FEMA methodology is 7% and this is imposed by the OMB. According to the OMB discount rate guidance for federal programmes: *"In general, public investments and regulations displace both private investment and consumption. To account for this displacement and to promote efficient investment and regulatory policies….constant-dollar benefit-cost analyses of proposed investments and regulations should report net present value and other outcomes determined using a real discount rate of 7 percent. This rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years."* (OMB, 2014)

5.3. Calculations and outputs

The decision criterion applied in this methodology is cost-effectiveness measured in terms of the investment having a benefit to cost ratio equal to or greater than 1.

6. Discussion and Recommendations

Despite the different intentions responsible for the derivation of the three methods reviewed above, consideration of these approaches suggests a number of points relevant to the derivation of a generic retrofit evaluation methodology:

Defining the nature (financial or economic) of the investment being assessed. It is of considerable importance whether the investment is by an individual (in which case a financial appraisal is appropriate) or by a public agency (so that an economic appraisal measuring costs and benefits to society). This determines which costs and benefits are relevant. Particularly in the case of the EN 15459 methodology (which purports to be an economic appraisal), the extent to which wider economic costs and benefits including secondary effects are taken into account appears to be minimal. In addition, some purported benefits (the notional residual values of built-in components) seem inappropriate to include.

Discount rate selection. In Europe and the US, where the examples come from, the existing building stock is largely privately owned and, therefore, a typical building retrofit investment would be likely to be a private investment or a private investment subsidized with public funds. In either case, the discount rates applied in the Royal Haskoning financial appraisal (8%) and the FEMA methodology (7%) appear more reasonable than those applied in the EN 15459 (2%-4%) and the Royal Haskoning economic appraisal (3,5%). In general, for financial and economic cost benefit analyses, the higher, financial analysis discount rates reflect private sector investment return expectations whereas the lower, economic analysis rates reflect the social time preference rate. (OMB, 2014; HM Treasury, 2011) However, the EN 15459 method specifically relates to market interest rates which are currently very low and, indeed, in Sweden, the current (February 2015) central bank benchmark interest rate is negative. The lower rates tend to raise the assessed value of future benefits relative to (up-front) investment costs and favor the implementation of more retrofit projects.

Costs and Benefits. There is a general reliance on point estimates of construction / installation costs which is simplistic – even the Royal Haskoning approach of low, high and best estimates is preferable though still far less appropriate than probabilistic approaches. In all cases, the benefits are influenced by behavioral factors and they are generally uncertain so that, once again, probabilistic / stochastic approaches would be preferable.

Calculation period. In all cases, the calculation periods are relatively long. Where these are coupled with the choice of low discount rates this makes a considerable difference to the valuation of future costs and benefits relative to current ones. With typical real estate investment appraisal using calculation periods of 10 years, there are strong arguments for using shorter calculation periods to assess building retrofits in general. (Vimpari & Junnila, 2014)

Cash flows. Of the three approaches reviewed, that of EN 15459 makes the greatest effort to take into account component replacement cycles and maintenance costs within the calculation period. Yet, its inclusion of the depreciated residual values of system components at the end of the calculation period as a benefit (cost reduction) seems wrong. In general, all the methods appear wanting in this respect and a more precise consideration of cash inflows and outflows is required.

Calculation outputs. The EN 15459 approach outputs a global cost metric (something similar to a total lifecycle cost) expressed in present value terms with an alternative expression of the same as an annuity while both the Royal Haskoning and the FEMA methodologies express their results in terms of benefit to cost ratios. Particularly with regard to the Royal Haskoning analysis, this raises the problem that it does not effectively facilitate decision-making between retrofit packages of different scales if they have benefit to cost rations greater or equal to 1(i.e. they are confirmed as being worthwhile investments). It would make sense to apply a wider range of appraisal metrics such as net present value, internal rate of return and (discounted) payback period as well as the benefit to cost ratio.

Risk and uncertainty. By the very nature of hazard events like floods or earthquakes, if and when they will occur in the future (and particularly within the calculation period) is uncertain and so is the magnitude of the events when they do happen. Since both the Royal Haskoning and FEMA approaches dealt with hazard mitigation, they therefore, to some degree, took uncertainty into account. However, both these methodologies rely on relatively simple mathematical expectation calculations to determine probable costs and benefits. However, the extent to which uncertainty and risk is accounted for is only partial and is insufficient in the sense of investment decisions where the level of risk affects the level of acceptable returns. (Keown et al, 1996)

Together with probabilistic cost and benefit data, it would be appropriate to consider ways to take risk into account, for example, by applying risk-adjusted discount rates as well as conducting more thorough sensitivity analyses to determine the calculation results' sensitivity to changes in the input assumptions.

7. Conclusions

There is a need for retrofits to buildings in order for the built environment to adapt to a changing context. This calls for robust methods to evaluate the cost-effectiveness of retrofit investments. In this preliminary study, three approaches relating to the investment appraisal of retrofits have been reviewed and compared. This comparison suggests that all three of these methods are limited and indicates that a general methodology could be made more robust through improvements in a number of areas. These include:

- defining more precisely the nature of the specific retrofit investment and the characteristics of the particular investor;
- more appropriate choices of discount rates and calculation periods as well as identification of relevant costs and benefits based on the investment and investor characteristics;
- a more thorough and probabilistic treatment of risk and uncertainty; and,
- a more comprehensive range of calculation metrics to enable better decision-making.

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References

Anderies, J., 2013. Embedding built environments in social–ecological systems: resilience-based design principles. Building Research & Information, December 2013, 1-13.

Atanasiu, B., Kouloumpi, I., Thomsen, K., Aggerholm, S., Enseling, A., Loga, T., Witczak, K., 2013. Implementing the cost-optimal methodology in EU countries: Lessons learned from three case studies. BPIE - Buildings Performance Institute Europe. Available online at: http://vbn.aau.dk/files/173315199/BPIE_Implementing_Cost_Optimality.pdf (Accessed 07 January 2015)

CA-EPBD 2013. Implementing the Energy Performance of Buildings Directive, Concerted Action EPBD. Available online at: http://www.epbd-ca.org/Medias/Pdf/CA3-BOOK-2012-ebook-201310.pdf (Accessed 07 January 2015)

EC 2012. Guidelines for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements, (2012/C 115/01). Available online at: http://www.buildup.eu/sites/default/files/content/EU%20guidelines%20regarding%20cost%20optimal%20regulation_EN_1.pdf (Accessed 07 January 2015)

EN 15459 2007. Energy performance of buildings – Economic evaluation procedure for energy systems in buildings. European Standard EN 15459, approved November 2007.

EU 2010. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Available online at: http://www.eceee.org/buildings/EPBD_Recast/EPBD_recast_19May2010.pdf (Accessed 07 January 2015)

FEMA 2009a Benefit Cost Analysis Reference Guide June 2009, Federal Emergency Management Agency, Department of Homeland Security, Washington, D.C. Available online at: http://www.fema.gov/media-library-data/1396550224865-548160e5f22dabb793d8a045fa89f5fe/bca_reference_guide_508_final.pdf (Accessed 07 January 2015)

FEMA 2009b FEMA Benefit-Cost Analysis Re-engineering (BCAR), Damage-Frequency Assessment (DFA, (Limited Data Module/Unknown Frequency Determination), Methodology Report, version 4.5, May 2009, Federal Emergency Management Agency, Department of Homeland Security, Washington, D.C.

FEMA 2011 Supplement to the Benefit-Cost Analysis Reference Guide June 2009, Federal Emergency Management Agency, Department of Homeland Security, Washington, D.C. Available online at: http://www.fema.gov/media-library-data/1396549910018-c9a089b8a8dfdcf760edcea2ff55ca56/bca_guide_supplement__508_final.pdf (Accessed 07 January 2015)

HM Treasury 2011 The Green Book, Appraisal and Evaluation in Central Government, United Kingdom Treasury Guidance, TSO, London Available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf (Accessed 13 February 2015)

IPCC (Intergovernmental Panel on Climate Change), 2013. Working Group I contribution to the IPCC fifth assessment report. Climate Change 2013: The Physical Science Basis. First Draft Underlying Scientific-Technical Assessment, 30 September 2013.

Kazmerczak, A., Connelly, A., 2011. Buildings and flooding: a risk-response case study, EcoCities Project, University of Manchester, Manchester, UK. Available online at: http://www.adaptingmanchester.co.uk/sites/default/files/EcoCitiesBuildingsandFlooding.pdf (Accessed 07 January 2015)

Keown, A., Scott, D., Martin, J., Petty, J., 1996. Basic Financial Management (7th Edition), Prentice Hall, New Jersey

OMB 2014. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, US Federal Office of Management and Budget Circula No.A-94 revised. Available online at: http://www.whitehouse.gov/omb/circulars_a094 (Accessed 07 January 2015)

Rotimi, J., Proverbs, D., Lamond, J., Wassell, P., 2014. Application of the concept of cost benefits analysis (CBA) to property level flood risk adaptation measures, Structural Survey, Vol. 32 Issue 2, pp.102-122.

Royal Haskoning, 2012. Assessing the Economic Case for Property Level Measures in England, Committee on Climate Change, Peterborough. Available online at: http://archive.theccc.org.uk/aws/ASC/2012%20report/Royal%20Haskoning%20PLM%20Report%20Final.pdf (Accessed 07 January 2015)

Ryan, P., Ryan, G., 2002. Capital Budgeting Practices of the Fortune 1000: How Have Things Changed?, Journal of Business and Management, Volume 8, Number 4, Winter 2002

The Royal Society, 2014. Resilience to Extreme Weather, The Royal Society Science Policy Centre report 02/14, available online at https://royalsociety.org/~/media/policy/projects/resilience-climate-change/resilience-full-report.pdf (Accessed 07 January 2015)

Vimpari, J., Junnila, S., 2014 Value influencing mechanism of green certificates in the discounted cash flow valuation, International Journal of Strategic Property Management, 18:3, 238-252

White, I., O'Hare, P., Lawson, N., Garvin, S., Connelly, A. 2013. Six steps to flood resilience – guidance for local authorities and professionals. Manchester. Available online at: http://www.sed.manchester.ac.uk/research/cure/research/documents/SMARTeST-Six-Steps-To-Flood-Resilience-Local-Authority-Professionals.pdf (Accessed 07 January 2015)