

DECISION SUPPORT FOR INTEGRATING DISASTER RISK MANAGEMENT STRATEGIES INTO CONSTRUCTION PRACTICE

Lee Boshier¹, Andy Dainty, Patricia Carrillo, Jacqueline Glass and Andrew Price
Department of Civil and Building Engineering, Loughborough University, UK

Threats to society and the built environment are diverse and include extreme natural and human induced hazards. Hazards such as floods, storms and terrorist attacks may not only threaten the lives of many people but can result in disasters that threaten economies and long-term development. Consequently, the UK government has recognised the importance of promoting the resilience agenda. Within this agenda there is growing acceptance that professionals involved with the construction industry need to understand the principles of, and become more engaged in, Disaster Risk Management (DRM). The outputs from a three year project, that has utilised a pluralistic methodology, are presented in the form of a decision support framework (DSF). The DSF will assist key stakeholders to integrate DRM strategies into the planning, design, operation and maintenance of the built environment. The central component of the DSF is 'Pre-Empt for Projects' – which assists key stakeholders (in the earliest design phase) to: identify a range of threats; assess the implications of any identified threats; and undertake mitigative adaptations if necessary.

Keywords: decision-support, design management, risk management, resilience.

INTRODUCTION

Since the built environment and urban infrastructure provide the core framework for most human activity, it is crucial to develop them with an effective measure of resilience so they can withstand and adapt to the threats of natural and human-induced hazards (Boshier 2008). Threats to society and the built environment are diverse and include extreme natural hazards (such as floods and windstorms) and human induced hazards (such as terrorist attacks). The impacts of disasters caused by such hazards can drain millions of dollars every year in relief, rehabilitation, reconstruction and insurance costs for many nations. In the past two decades alone direct economic losses from disasters totalled US\$629bn (World Bank 2004); the 2007 summer floods in the United Kingdom (UK) resulted in £3bn in insurance claims (Association of British Insurers 2008).

The way in which the built environment has expanded over the past 30 years, with little apparent regard to the evolving climatic conditions (or how humans alter their environment and are thereby positively and negatively affected) has placed much development in a precarious position. It seems clear that an unrelenting desire to build and develop has contributed towards many disasters and/or has exacerbated their effects (Lewis 1999; Wisner *et al.* 2004). A number of analyses reveal the reciprocal

¹ L.Boshier@Lboro.ac.uk

and multifaceted relationship which exists between development and disasters which in some respects determine people's vulnerability (see Wamsler 2008; Wisner *et al.* 2004). For example, the number of people living at risk of devastating floods worldwide is set to double from one billion in 2004 to two billion by 2050 (United Nations University 2004). Within the UK, according to the Association of British Insurers (2005), if house-building rates were to increase to levels recommended in the Barker report (Barker 2004), almost 200,000 homes would need to be built each year on previously developed land for the next 10 years, much of which will be located in the floodplain (see DEFRA 2004).

The proactive attributes of DRM

The observed shift in the way disasters are being managed has been illustrated by the move away from the reactive attributes of Disaster Management towards the more proactive concept of Disaster Risk Management (DRM) that should be 'mainstreamed' into long-term developmental initiatives. The United Nations' International Strategy for Disaster Reduction (UN/ISDR 2004) has adopted a notion of DRM that can be summarised into four mutually interconnected phases, being: 1) Hazard identification; 2) Mitigative adaptations; 3) Preparedness planning; and 4) Recovery (short-term) and reconstruction (longer-term) planning. DRM should be concerned with people's capacity to: manage their natural, social and built environments; and take advantage of it in a manner that safeguards their future and that of forthcoming generations. DRM needs to be holistic; it must ensure that associated strategies are viewed as a 'shared responsibility' towards the attainment of resilience that includes issues such as hazard mitigation and land-use planning. The concept of hazard mitigation begins with the realisation that many disasters are not unexpected (Mileti 1999), and the impacts of many natural and human-induced hazards can therefore be reduced. It is common to discuss two types of hazard mitigation, namely:

- structural mitigation – such as the strengthening of buildings and infrastructure exposed to hazards (via building codes, engineering design and construction practices, etc.); and
- non-structural mitigation – includes directing new development away from known hazard locations through land use plans and regulations, relocating existing developments to safer areas and maintaining protective features of the natural environment (such as sand dunes, forests and vegetated areas that can absorb and reduce hazard impacts).

Part of the 'shared responsibility' that is required could be achieved by embedding construction professionals, who possess the knowledge and experience of how to design, build, retrofit and operate what are typically bespoke built assets, into the DRM framework (Bosher *et al.* 2007). The construction sector in the UK should play an important role in the structural elements of hazard mitigation (and adaptation), while developers and planners should be able to positively influence the non-structural elements (Bosher *et al.* 2007; Wamsler 2008). However, there is little evidence that DRM has been a priority for construction professionals in the UK, which may explain the inability of the industry to mitigate the effects of natural and human-induced threats. Thus, involving, in an integrated way, the multitude of disciplines responsible for how the built environment is delivered is critical to the mainstreaming of DRM and the principles of resilience into long-term development (Bosher and Dainty 2009). This paper presents some key findings of the PRE-EMPT project that has set out to pro-actively address strategic weaknesses in integrating DRM strategies via the

development of a hazard mitigation and resilience toolkit for the construction sector. The toolkit is aimed at supporting the decisions of construction professionals that are responsible for the planning, design, operation and maintenance of the built environment in the UK.

THE PRE-EMPT PROJECT

The aim of the PRE-EMPT Project has been to support the development of a more resilient built environment through the structured integration of hazard mitigation strategies into the construction decision-making process. Buildings and developments in any geographic location can be subject to a wide variety of natural phenomena such as windstorms, floods, earthquakes and other hazards. While the occurrence of some of these events cannot be predicted precisely, their impacts are well understood and can be managed effectively through a comprehensive programme of hazard mitigation planning. The fundamental goal of mitigation is to minimise loss of life, property, and the function of services/systems due to disasters. Designing to resist any hazard(s) should always begin with comprehensive hazard/threat and risk assessments. This process includes identification of the hazards present in the location and an assessment of their potential impacts and effects on the built environment based on existing or anticipated vulnerabilities and potential losses.

It is common for different organisations to use varying nomenclature to refer to the components of risk assessment. For example, terrorism and foreign military power are referred to as ‘threats’ by the intelligence community, while hurricanes and floods are referred to as ‘hazards’ by emergency managers, even though both are fundamentally forces that have the potential to cause damage, death, injury and loss of functionality in the built environment. Regardless of who is conducting the risk assessment, the fundamental process of identifying what can happen at a given location, how it could affect the built environment, and what the potential losses might be, remains essentially the same from one scenario to the next. Only after the overall risk is fully understood should potential mitigation measures be identified, prioritised, and implemented.

The research

A state of the art literature review; including academic papers, governmental and non-governmental reports, UK legislation and regulations, governmental, institutional and industrial guidelines and policy documentation was undertaken. The EM-DAT database (EM-DAT 2008) of global emergency events was searched and the data was analysed to assess the most prevalent and high impact (regarding financial costs and the loss of human life) disasters in the UK. Between July 2007 and March 2008, 50 questionnaire surveys were also completed by a selective range of experts involved with construction, risk and emergency management, local and national government and urban planning. These questionnaires were designed to elicit perspectives and opinions about hazard and threat awareness and knowledge of available governmental and non-governmental guidance for hazard mitigation and emergency preparedness. This data were augmented by 20 semi-structured in-depth interviews with experts from the construction sector, engineering, emergency planning, and urban planning. Two charrette workshops were then undertaken to help the research team to develop and validate the decision support tools. The key findings from the research were as follows.

- The greatest threats to the built environment in the UK are from flooding (riverine, pluvial and coastal) and severe windstorms.
- While there is an ever growing range of information that is available, there is a lack of suitable guidance that is focused specifically on proactive mitigation measures for the construction sector.
- The pre-construction phase of a building's life cycle is the most critical phase when DRM measures (such as hazard mitigation) should be considered by architects/designers, structural and civil engineers, urban planners, specialist contractors and emergency/risk managers.

In light of these findings, Bosher *et al.* (2007) have established the need for a framework that can assist construction and non-construction stakeholders to address hazards during the early planning and design stages and that this can be achieved through the creation of decision support tools.

THE TOOLKIT

The PRE-EMPT toolkit is a project-focused tool (there is an organisational component this is still currently under development) that can help key decision makers in the UK to systematically embed hazard mitigation and resilience considerations into new and existing developments. The web-based decision support tool has been made open-access via a devoted website (www.pre-empt.org.uk) and is composed of three sections, namely: 1) Hazard and threat identification; 2) Implications of the hazards (vulnerabilities); and 3) The 'To Do' list which will finally lead to a project focused 'Action Plan'. The web-based tool will provide a relatively simple checklist for key decision makers that will enable them to ensure that hazard mitigation considerations are addressed (if required) at the earliest possible stage of a project. This tool has been developed to encourage more joined-up thinking in relation to how the built environment is delivered and will therefore complement broader frameworks such as ISO14001 (International Environmental Management Standard), ISO2600 (Social Responsibility), BS8900:2006 (Guide for managing sustainable development) and BS 25999-1:2006 (Business continuity management: Code of practice). However, it has been developed to represent a contingent tool which can be appropriated and applied to a variety of different situations and contexts. The details of the process will now be explained.

Hazard and threat identification

The first step in a risk management is hazard and threat identification. A hazard and threat assessment considers the full spectrum of threats for a given facility/location. The types of threats that a user may wish to consider are listed in Table 1, which also shows (a selected list) of whether mitigating for certain hazards is a key consideration in the professional practice of engineers, architects and construction managers in the UK (after Bosher *et al.* 2007). The findings, which are based on the questionnaire surveys, suggest that these hazards need to be considered more effectively during the professional practice of construction managers (ConMan) in particular, but also architects and engineers.

It is therefore important that a hazard/threat assessment should be undertaken that examines supporting information to evaluate the likelihood and potential scale of each threat. Of course, if no hazards are identified during this process then there is no requirement to proceed with the rest of the assessment. Nonetheless, it is important to recognise that even by simply undertaking the 'hazard and threat identification'

process the user has addressed an important component of DRM that is too often neglected.

Table 1: Disciplinary perspectives of key UK specific hazards (after Bosher et al.2007)

Perspectives of whether the hazard is a key consideration in professional practice			
Hazard/Threat	Engineers	Architects	ConMan
Riverine flooding	Yes	Yes	Yes
Pluvial flooding (localised heavy rain)	No	No	No
Coastal erosion and flooding	No	No	No
Windstorms	Yes	Yes	No
Terrorist attacks	No	No	No
Extreme temperatures	Yes	Yes	No

For natural threats, historical data concerning frequency of occurrence certain hazards such as floods, windstorms, or earthquakes can be used to determine the credibility of the given threat. Lead government agencies can provide advice on the extent to which certain hazards/threats might affect a project (details of these agencies are provided at www.pre-empt.org.uk). Regarding terrorist threats, it is possible to gain an insight into the potential impact of a terrorist attack by using historical data. However, it is important to realise that such data cannot be used to understand the level of threat from a terrorist attack, therefore it is essential that up to date intelligence about such threats is sought from key government agencies. This sensitive information can be obtained from Counter-Terrorism Security Advisors (CTSAs) that are located within the intelligence services (typically known as Special Branch) of regional police constabularies. CTSAs can also provide construction professionals with advice on whether counter-terrorism measures should be adopted and what types of measures could be used (for more on this topic, see Harre-Young *et al.* 2009).

Implications of the hazards (vulnerabilities)

Once the credible hazards are identified, a vulnerability assessment should be performed. The vulnerability assessment can be a relatively simple process that considers the potential impact of specific hazards as well as the vulnerability of the facility/location. Impact of loss is the degree to which the operation of the business/facility is impaired by the impact of a given threat. A key component of the vulnerability assessment is properly defining the ratings for impact of loss and vulnerability. These definitions may vary greatly from facility to facility. For example, the amount of time for which capability is impaired is an important part of impact of loss. If the facility being assessed is a major component of critical infrastructure, a downtime of a few minutes may be a serious impact of loss, while for a Social Security office a downtime of a few minutes would be quite minor. A sample set of generic definitions have been listed below.

- **Devastating:** The facility is damaged/contaminated beyond habitable use. Most items/assets are lost, destroyed, or damaged beyond repair/restoration.
- **Severe:** The facility is partially damaged/contaminated. Examples include partial structure breach or some items/assets in the facility are damaged beyond repair, but the facility remains mostly intact. The entire facility may be closed for a period of up to two weeks and a portion of the facility may be

closed for an extended period of time (more than one month). Some assets (such as IT equipment) may need to be moved to remote locations to protect them from further damage.

- **Noticeable:** The facility is temporarily closed or unable to operate, but can continue without an interruption of more than one day. A limited number of assets may be damaged, but the majority of the facility is not affected.
- **Minor:** The facility experiences no significant impact on operations (downtime is less than four hours) and there is no loss of major assets.

Vulnerability is defined to be a combination of the exposure of the facility to hazards and the level of deterrence and/or defence provided by the existing countermeasures. In the context of flooding, the exposure of the asset or facility to flooding events is determined by a number of factors, such as the likelihood of flooding and the extent to which the asset of facility is protected from flood events. Sample definitions for vulnerability ratings in the context of flood hazards are as follows (after Environment Agency, 2009).

- **Very High:** This is a facility that has high exposure to floods, and the level of deterrence and/or defence provided by the existing countermeasures are inadequate. The chance of flooding each year is greater than 1.3% (1:75 years).
- **High:** This is a facility that has high exposure to floods and/or the level of deterrence and/or defence provided by the existing countermeasures are only adequate. The chance of flooding each year is greater than 1.3% (1:75 years).
- **Moderate:** This is a facility that has moderate exposure to floods and/or the level of deterrence and/or defence provided by the existing countermeasures are marginally adequate. The chance of flooding is 1.3% (1:75 years) or less, but greater than 0.5% (1 in 200 years).
- **Low:** This is a facility that has low exposure to floods and/or the level of deterrence and/or defence provided by the existing countermeasures are more than adequate. The chance of flooding is 0.5% (1:200 years) or less.

Risk Analysis

Once an assessment has been made, a combination of the impact of loss rating and the vulnerability rating (in consultation with leading agencies and stakeholders) can be used to evaluate the potential risk to the facility from a given threat. An example of a risk matrix is depicted in Table 2.

Table 2: Example of matrix used to identify levels of risk

Impact of loss	Level of vulnerability			
	Very high	High	Moderate	Low
Devastating	H	H	H	M
Severe	H	H	M	L
Noticeable	H	M	M	L
Minor	M	M	L	L

The risk ratings illustrated in Table 2 can be interpreted as follows.

H - These risks are high. Countermeasures recommended to mitigate these risks are essential to the long term sustainability of the development and should be implemented as soon as possible.

M - These risks are moderate. Countermeasure implementation is important to the long-term sustainability of the development and should be undertaken.

L - These risks are low. Countermeasure implementation may enhance security and contribute towards 'future proofing'.

If a 'high' or 'moderate' risk has been identified it is advisable to consult with the lead Government agencies that would be responsible for dealing with the specific hazard (details of these agencies are provided at www.pre-empt.org.uk). Users would need to consider the implications of the hazards in a number of ways (see Table 3) because hazards can have far reaching impacts upon the operations of construction companies, the structural and materials requirements, associated infrastructure and the project's neighbours and the local community.

Table 3: The implications of the hazards: Key issues to consider

Key issues	For instance?
Operational	How might the hazards impinge upon your ability to deliver the project? What can you do to address any associated problems in the delivery of the project?
Structural	What structural changes will be required to mitigate the hazard?
Materials	What types of resilient materials will you need to use? At what cost?
Infrastructure	Will the critical services (water, sewerage, power, transport etc.) to your development be affected? Can you protect them?
Neighbours	Do the neighbouring developments have a detrimental impact upon the safety and security of your development/project?
Local community	To what extent does your project impact upon local resilience? How does the local socio-economic context influence the resilience of your project?
The business case	How might the hazards affect the rental/sale value of the development? If required, could your adaptations increase the value of the development?

The 'To Do' list

Upgrade Options/Recommendations

Based on the findings from the risk analysis, the next step in the process is to identify countermeasures that can lower the various levels of risk. If minimum standard countermeasures for a given facility level are not currently present, these countermeasures should automatically be included in the upgrade recommendations. Additional countermeasure upgrades above the minimum standards should be recommended as necessary to address the specific threats identified for the facility (see Table 4 for examples of countermeasures related to flood risk). The estimated installation and operating costs for the recommended countermeasures will need to be considered but also the possible long-term benefits of using such measures.

Studies on the cost effectiveness and return ratios of investments related to mitigating crime and natural hazards have been carried out and can offer an insight into the long-term benefits of proactively addressing mitigating for hazards (also see Harre-Young *et al.* 2009). For example, Armitage (2000) showed that in regard to mitigating crime in residential properties, designing in and retrofitting measures cost 26% and 36% respectively of the average cost of a burglary in the UK. With regard to the study of natural hazards, research into Federal Emergency Management Agency grants by the Multihazard Mitigation Council (2005) showed that for every dollar that was spent on mitigation, society saved \$4 in the event of a disaster or a hazard causing damage.

Table 4: Some key considerations when addressing flood risk in England and Wales?

Key considerations	Options (indicative)
Who can you turn to for specialist advice?	Contact the Environment Agency, Local Authorities, plus a range of engineering and flood risk management consultants.
What measures can eliminate the hazard?	Consider the locational planning (away from sources of flood risk) and landscape design (such as bunds and embankments) of the development
What measures can reduce or resist the impact of the hazard?	Consider the use of Sustainable Urban Drainage Systems, non-return valves on sewerage outlets, use of water resistant construction materials, location of essential services and use of removable flood barriers.
What might the costs be to mitigate for the hazard?	It is important to consider whether any additional costs will be required because it could be argued that early measures during the concept and design may not have to incur any extra costs.
Could extra costs be recouped in the short-term?	If extra costs are required it is possible that these could be minimal and possibly be recouped in the short-term through increased resale prices or in the long-term through increased rental revenues associated with the 'spin-off' benefits of marketing a 'resilient' development.
Could extra costs be recouped in the long-term?	If you will be operating/managing the development the benefits could include reduced insurance premiums, reduced maintenance costs and reduced service disruptions during localised flooding events.

Re-Evaluation of Risks

The implementation of the recommended security, design and/or structural upgrades should have a positive effect on the impact of loss and/or the vulnerability ratings for each threat. The final step in the process is to re-evaluate these two ratings for each threat in light of the recommended upgrades. Using a riverine flood as an example, the installation of flood protection/resilience measures (i.e. lime plaster on walls and raised electrical points) will not prevent the flood from occurring, but would reduce the damage caused by the flood waters. Therefore, the impact of loss rating for a flooding event would improve, but the vulnerability rating would stay the same.

The action plan

The final component of the toolkit is the 'PRE-EMPT Action plan'. The 'Action Plan' is a project-specific report that can be used clients or other interested parties to demonstrate that all the options have been considered (even if it is merely demonstrating that a range of hazards have been assessed but did not pose a threat). This will be a brief, printed outline of the key actions and issues that should be considered prior to, and during, the construction project. This action plan should ideally be reviewed at each stage of the design, construction and operation process (such as detailed in the Royal Institute of British Architects 'Plan of Work') and upon completion of the project the 'Action Plan' can be included in the project's legacy archive.

Current status of the toolkit

The on-line version of the PRE-EMPT toolkit is in the early stages of being validated by a range of construction stakeholders. Once this process has been completed the toolkit will be revised (if necessary) and launched nationally in October 2009. The toolkit will be free to use, merely requiring the users to register their details, and will provide the user with a simple interface to guide them in their decision making.

Additional guidance documentation and internet links to supporting information will also be key components of the toolkit.

CONCLUSIONS

Research has revealed that the greatest threats to the built environment in the UK are from flooding (riverine, pluvial and coastal) and severe windstorms. However, while there is an ever increasing range of guidance, information and legislation for stakeholders in the construction sector, there is a lack of suitable guidance that is specifically focused on proactive mitigation measures (as espoused by the principles of DRM) that are targeted for use by key stakeholders in the construction sector. Even when suitable guidance is available, awareness of when to best use such guidance by key construction related decision makers is poor. The PRE-EMPT toolkit that has been developed during this project has therefore been designed to enable construction stakeholders, such as civil and structural engineers and architects, to make informed decisions regarding the proactive integration of mitigation measures during the design, planning, construction, operation and maintenance of existing and future construction projects. This is achieved by providing ways of integrating the knowledge necessary to mainstream hazard mitigation into built environment processes in a flexible non-prescriptive way. It is hoped that this will complement existing processes and additionally will offer a point of departure for enabling both natural and human induced threats to be better accounted for in design and construction processes.

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