Collaboration for Environmental Evidence

Systematic Review No. 91

WORKING TITLE: *WHAT IS THE IMPACT OF CHANGING WIND PATTERNS DUE TO CLIMATE CHANGE ON BUILDING DESIGN AND OPERATIONS?*

Draft Review Protocol

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Cover Sheet

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1. Background

The UK is one of the windiest countries in Europe. The strongest winds in the UK are due to depressions, the majority of which are from the Atlantic Ocean driven by the prevailing westerlies. Depressions are most frequent during the winter, and it is in this season that the strongest winds occur. For example, the Burns' Night Storm occurred in January 1990 resulting in severe gales, with west Wales and Cornwall having gusts of up to 108 mph (Eden 1995). During this storm an estimated three million trees were felled and forty-seven deaths were attributed to the storm (Lamb 1991). As well as winds from depressions, the UK experiences tornadoes, downbursts due to thunderstorms, and topographic winds. Windstorms are "the most important natural hazard of recent decades, in terms of the frequency of loss events, the total expanse of the areas affected and, above all, the scale of the damage caused" (Rauch 2008).

The impacts of wind on the design and operations of structures are many. Wind loading on buildings effects cladding and the structure itself, and can result in cladding failure, roof tiles being displaced or roof sheeting being blown off, the collapse of chimneys, and the failure of walls. In the UK, the cost of the damage done to buildings due to windstorms is typically around £200m a year, but can exceed £2bn (Mootoosamy and Baker 1998). High winds also lead to traffic restrictions on bridges, for example, a suspension bridge may be closed to high sided vehicles, thus affecting the operations of the structure. Additionally, mean wind speeds and gusts have comfort and safety implications for pedestrians. Windy conditions can result in pedestrians avoiding a particular location, for example, a retail area or an outdoor seating area of a café. Air flow also affects the dispersion of exhausts from buildings such as hospitals and factories; therefore, a change in wind speed and flow direction could result in the re-entrainment of pollutants. Wind induced natural ventilation is affected by both mean wind speeds and gusts, therefore, as with pollution dispersion, a change in the wind could lead to changes in how a building is ventilated. Furthermore, changes in wind patterns will also affect the penetration of wind-driven rain and thereby affect the weather resistance of building facades.

The UK Climate Projections report of 2009 (UKCP09) presents data showing the historic trends and future projections of the climate within the UK, with wind being one of the climate variables considered, including wind speed, storm frequency and storm tracks. UKCP09 (Murphy, Sexton et al. 2009) reports that Alexander, Tett et al. (2005) shows that the frequency of severe storms has increased significantly in the UK since the 1950s (when looking at the time period of 1957 – 2003) during January, February and March, but that this may be part of long-term variability. UKCP09 also reports on the work presented in Allan, Tett et al. (2009) which extends the work of Alexander, Tett et al. (2005) to look at the period 1920 – 2004. This also shows that during January, February and March the storm frequency was greatest in the 1990s. During October, November and December, the greatest number of storms occurred in the 1920s, with a secondary peak in the 1990s. UKCP09 comments that possible trends in severe UK wind storms are "difficult to identify due to low numbers of such storms, their decadal variability, and by the unreliability and lack of representativity of direct wind speed observations." Regarding future changes in UK wind patterns, UKCP09 states that very different projected changes in storms occur with the different climate models, and concludes that "there is uncertainty about future changes in wind speed and direction and we have little confidence about the regional

changes in average or extreme wind speeds". The HadCM3 17-member perturbed physics ensemble projects that there will only be small changes in the strength of mid-latitude depressions and that these changes are generally a reduction in strength. However, a multi-model ensemble of twenty other climate models shows a general increase in storm strength. The HadCM3 ensemble projects a southerly shift in the track of mid-latitude depressions by up to 7° latitude, whereas the multi-model ensemble of twenty other climate models shows little shift in the track. The projections relating to wind are contradictory and uncertain; however, this is subsidiary question. For the current work, it is taken that wind patterns may change in the future, and the impact of any such changes on building design and operations is investigated.

2. Objective of the Review

2.1 Primary question

The objective of the systematic review is to identify literature which will answer the following question:

What is the impact of changing wind patterns due to climate change on building design and operations?

The elements, i.e. subject, intervention, comparator and outcome, of the systematic review question are given in Table 1.

Table 1. Elements of the systematic review question.

Subject	Intervention	Comparators	Outcomes
Buildings	Changing wind patterns due to climate change	Current design and operations of buildings in areas which experience different wind patterns	Impact on design and operations

An example of the comparator would be a study examining the differences between current design and operations of buildings in the relatively calm south east of England and those in the windier north west of England and Scotland. International data will be used only if they are directly comparable to the UK situation, e.g. in terms of building and weather. The impact of design and operations will be identified through changes to design and operations that would be made to deal with changing wind patterns, e.g. roof design altered to withstand more frequent gales. The changes to design will relate to both new-built and retrofit.

3. Methods

3.1 Search strategy

The following databases will be used to obtain relevant literature:

- ISI Web of Science with Conference Proceedings
- Engineering Village
- Index to Theses in Great Britain and Ireland
- Bielefeld Academic Search Engine

- Scirus
- ScienceDirect

Additionally, searches will be made on the following websites:

- Munich Re
- ClimateWise
- National Institute of Building Sciences – Whole Building Design Guide
- Institution of Civil Engineers – Virtual Library
- FacilitiesNet.com
- CRC Net BASE

A general internet search will be undertaken using:

- Google (including Google Scholar)

The first 100 results will be considered for inclusion in the review if relevant.

The search string that will be used in the searches is as follows:

"climate change" AND (building* OR structur* OR "built environment") AND (design* OR operation* OR code* OR standard*)

A Boolean search will be used for all databases, some (i.e. Web of Science, Engineering Village, Bielefeld, Scirus and ScienceDirect) are set up for such a search automatically, whereas the Index to Theses has a number of search options, one of which is Boolean. Web of Science allows the search to be undertaken by topic, title, author, publication or address. The search will be undertaken by topic. The search can be undertaken by keyword, author or title in Engineering Village, the keyword option will be used. Bielefeld Academic Search Engine searches the entire document, author, title, subject headings, publisher or (part of) URL. Both subject headings and the entire document will be searched. In Scirus, the search options are complete document, article title, journal title, author(s) name, author(s) affiliation, keyword(s), ISSN or (part of) URL. The search will be undertaken in the complete document and by the keywords. In ScienceDirect, the options are abstract and title and keywords, author, specific author, source title, title, keywords, abstract, references, ISSN, ISBN, affiliation and full text. The search in ScienceDirect will be undertaken using the abstract and title and keywords option. Searches in the Index to Theses in Great Britain and Ireland can be limited by title, author, university, class, degree or year. As these will be too limiting for the requirements of the search, none of these fields will be utilised.

In addition to the literature found directly with the search string, references within the literature will be followed up.

3.1.1 Scoping Review

During the scoping review various search strings were tested in ISI Web of Science. Table 2 gives the number of 'hits', and the number and percentage of relevant literature found within the 'hits' when using the search found to be appropriate.

Table 2. Results of the scoping review for the search string found to be appropriate.

Search string	Number of hits	Number and percentage of relevant hits
"climate change" AND (building* OR structur* OR "built environment") AND (design* OR operation* OR code* OR standard*)	665	10 (2%)

3.2 Study inclusion criteria

For the database search, literature will initially be included if both the title and abstract identify it to contain relevant information. Although a comparator is shown in Table 1 and below, it is deemed unnecessary to include this element in the search string.

- **Relevant subject(s):**
  Buildings, structures and the built environment.
- **Types of intervention:**
  Changing wind (including storm) patterns and climate change.
- **Types of comparator:**
  Current design and operations of UK buildings in areas which experience different wind patterns.
- **Types of outcome:**
  The impacts on the design and operations of buildings and structures.
- **Types of study:**
  Experimental data (full-scale and model-scale), including those taken over a period of time, tested under future predicted conditions, and in areas with different wind patterns; mathematical models and simulations; case studies and assessments of how predictions of wind could affect codes/regulations/practices.

3.3 Potential effect modifiers and reasons for heterogeneity:

As discussed in Section 1, there is little confidence in the projections of future wind patterns, therefore, the literature found in the review may assume different changes in future wind patterns depending on which climate model is referred to. Furthermore, there is likely to be bias in the literature, due to the nature of the original question. If, due to the uncertainty of the projections of future wind patterns, it is decided that wind impacts cannot be gauged, then literature on the impacts of changing wind patterns will not be written. Such literature can only be written with some acceptance that changes may occur. There will be no literature relating to impacts if the wind patterns are taken to remain the same, and it is unlikely that there will be literature if wind speeds are taken to reduce in intensity. Heterogeneity could also occur due to the likelihood that impacts on buildings will be different depending upon the type and age of the structure.

3.4 Study quality assessment

Material found during the search will be categorised as being peer-reviewed literature, e.g. journal articles and theses, or non-peer reviewed literature, e.g. books, reports. A higher quality rating will be given to case studies and experimental work that are qualitative and have a control (e.g. a before and after scenario). Where appropriate to

the built environment, the hierarchy of quality of evidence as given in Pullin and Knight (2003) will be used.

3.5 Data extraction strategy

Spreadsheets will be produced for the relevant literature found during the search. Along with identifying the material and the document type, these will also identify the type of building/structure considered (the subject), the assumptions made regarding changes in wind patterns (intervention), and the impacts of such changes including the direct effects of wind on building design and operation and possible strategies to deal with the effects (outcome).

3.6 Data synthesis and presentation

The relevant qualitative and, if possible, quantitative, information from all sources (e.g. academia, industry) will be brought together and presented in the review. Summary tables will be included if appropriate.

4. Potential Conflicts of Interest and Sources of Support

None anticipated.

5. References

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