Adaptation Strategies for Climate Change in the Urban Environment (ASCCUE)

Narrative report for GR/S19233/01 (PI – Professor John Handley, School of Environment and Development, University of Manchester)

Background/Context

This consortium project is part of the EPSRC/UKCIP Building Knowledge for a Changing Climate (BKCC) programme, looking at how climate change will affect different aspects of the built environment (www.k4cc.org/bkcc). ASCCUE focused on the urban environment with a view to assessing climate change impacts and developing and testing appropriate adaptation responses through spatial planning and urban design.

The biophysical properties of the urban environment are distinctive with a large building mass (350kg.m^{-2} in dense residential areas) and associated heat storage capacity, reduced greenspace cover (with its evaporative cooling and rainwater interception and infiltration functions) and extensive surface sealing (around 70% in high density settlement and city centres) which promotes rapid runoff of precipitation. Climate change amplifies this distinctive behaviour by strengthening the urban heat island and increasing surface run-off (Gill et al, 2004). People and property may be put at risk from these and other impacts. In the UK the Construction Research Innovation Strategy Panel (CRISP) emphasised the need to identify the most vulnerable sectors and geographical areas, and highlighted 3 key issues for the built environment: coastal and riverine flooding; subsidence, wind and storm damage; and impacts of warm summers on thermal comfort.

However, whilst research priorities had been identified, little progress had been made in quantifying climate change impacts on the urban environment and developing an integrated response. ASCCUE sought to remedy this deficiency and assembled a multi-disciplinary research team from four universities that was well equipped to meet the challenge. We recognised that climate change may bring some benefits to city living but that it poses a significant threat to building integrity and human welfare. Urban greenspace may also be at risk, but our principal interest here is in the adaptation potential provided by the 'green infrastructure' in moderating climate change impacts. All aspects of the CRISP agenda were tackled except wind damage, where there is still a great deal of uncertainty in the climate modelling.

Key advances and supporting methodology

The project therefore sought to develop an improved understanding of climate change impacts in urban areas (focusing on building integrity, human comfort and urban greenspace) and on how these, and neighbourhoods within them can best be adapted. We wished to explore solutions in stakeholder workshops with a view to developing practical guidance for climate conscious planning and urban design.

We aimed to produce generic research findings that would be widely applicable. However, to provide a realistic test-bed for methodological development, our work was concentrated in two case study locations at opposite ends of the SE/NW climate gradient.

- Greater Manchester – a representative case; a large conurbation (population 2.5 million) with a full range of building types, varied topography and soils.
- Lewes – an extreme case; a small coastal town in Sussex (population 15,000) which lies astride a tidal river and which has already experienced severe flooding (most recently October 12th, 2000).

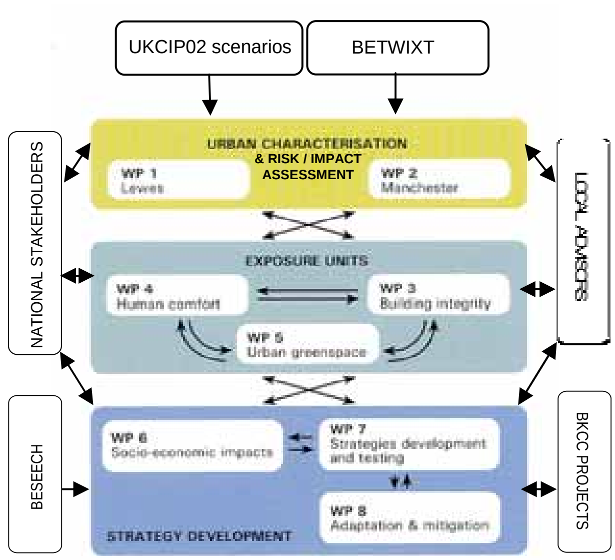

Fig. 1. ASCCUE research framework

This integrated assessment methodology (Fig. 1) initially involved impact assessment at the conurbation or catchment level (WP1 & 2) and then more detailed assessment of selected exposure units at the neighbourhood level (WP3, 4, & 5). Assessment of socio-economic impacts (WP6) informed both the earlier work and strategy development (WP7), whilst a scoping exercise looked for potential synergies or conflicts between adaptation and mitigation (WP8). National stakeholders provided overall guidance through a Steering Group led by the Town and Country Planning Association (TCPA) and local advisors were engaged in both case study locations, with a formal Advisory Group in Greater Manchester. Whilst this integrated approach was itself pioneering in this context, key advances were also made in each work package area.

Urban characterisation (Work Packages 2 and 5)

The new Spatial Planning paradigm in the UK calls for analysis at a variety of scales, from the city-region to the local neighbourhood. A robust and repeatable methodology was devised for mapping urban areas and their surroundings from digital ortho-rectified aerial photographs into distinctive Urban Morphology Types (13 major categories, 29 sub-categories). The maps (Fig. 2) were verified by Local Authority partners and updated as new imagery became available, so permitting assessment of land use change. Working on advice from our national steering group the classification was made fully compatible with the National Land Use Database.

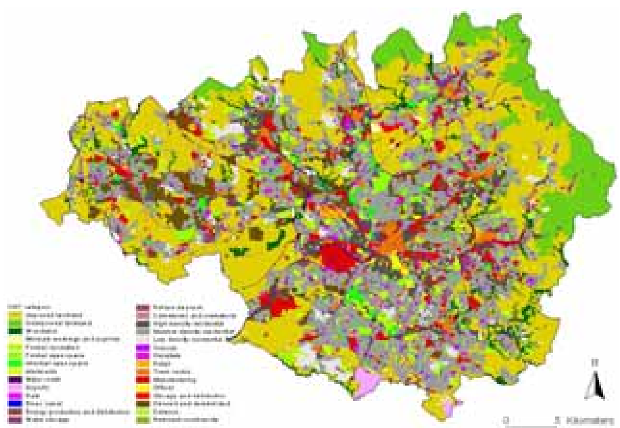

Fig.2. UMT map of Greater Manchester

The next task (carried out within WP5) was to characterise surface cover by stratified random sampling using nine surface cover categories (e.g. building, other impervious, mown grass etc). This allowed us to visualise the distribution of built and evapotranspiring surfaces at the conurbation (Greater Manchester) or catchment (Lewes) scale. The urban characterisation methodology is readily transferable and provides a firm basis for risk assessment and modelling of climate change impacts (Handley et al, in press). The UMT maps have been made freely available to the Local Authorities under licence and are being used by them to inform both emergency and spatial planning.

Risk Assessment (Work Packages 1 and 2)

The research team, following Crichton, adopted a common risk management framework and a consistent approach to risk assessment:

$$\text{Risk} = f\ \{\text{Hazard, Exposure, Vulnerability}\}$$

Where *hazard* is the extent, severity and probability of a climate related hazard; *exposure* is the extent and value of elements that would be affected were the hazard to be realised; and *vulnerability* is the susceptibility of the elements to the hazard (Gwilliam et al, 2006).

The advantage of using this approach for climate related risk assessment is that complementary adaptation strategies can be devised which reduce risk by either reducing exposure (e.g. preventing a flood reaching the area in question) or reducing vulnerability (e.g. measures to increase the resilience of the building stock).

In **Greater Manchester**, priority themes for risk assessment were identified at a workshop with local stakeholders:

Exposure unit	Hazard	Elements at risk
Built environment	Flooding, geohazards (e.g. landslides, shrink-swell clays)	Built environment, key infrastructure and services
Urban greenspace	Drought (available water content), runoff, temperature	Key greenspace infrastructure including parks, gardens and trees
Human comfort	Temperature (day and night maxima), precipitation	Receptive environments e.g. for shoppers and commuters
Human health	Temperature (day and night maxima)	Population density and characteristics

The risk assessment itself was carried out in a GIS environment with the UMT map often providing the ‘elements at risk’ layer. Even simple overlays were informative (e.g. in Greater Manchester 12 out of 27 electricity substations are potentially exposed to high flood hazard levels (EA Flood Zone 3), and by the 2080s High 159 schools experience a surface temperature regime that at present is associated with town centres, compared to 49 currently). However, more sophisticated approaches were possible, for example work on heat stress in vulnerable populations, which combined climate scenario (BETWIXT) data with likely changes in the socio-economic mix (BESEECH) (Lindley et al, 2006). Here, as in other examples, there is a strong coincidence between vulnerability and exposure, with communities with limited adaptive capacity often bearing the brunt of climate change impacts.

This conurbation scale risk assessment proved to be an effective way of scoping out climate change impacts and identifying areas at risk for closer study. Within ASCCUE it helped to identify suitable neighbourhoods for the adaptation strategy workshop (WP7), and is now contributing to the development of a City Region Spatial Strategy for Greater Manchester.

Probability and process models need to be used at the next level of inquiry. **Lewes**, a flood prone town, lies on a tidal river where rainfall (and therefore river flow) interact with tide to increase flood risk frequency, a situation that will be further aggravated by sea level rise. The traditional approach to calculating flood risk in this situation is from combined probability analyses treating the variables as either totally independent or dependent of each other. Fluvial discharge and tidal surge however are not mutually independent as extreme events are both partially related to low atmospheric pressure systems. Extreme joint probability statistics have now been adopted as the best practice for predicting extreme water levels for coastal defence design from tide and wave height data. The approach adopted in this study was to integrate this methodology with astronomical tide heights, surge levels and upstream fluvial flow data with one-dimensional hydraulic modelling to predict the frequency of potential flood events at Lewes. The approach was validated using recorded (historic) gauge data and compared with estimates derived from the more conventional approaches. The methodology produced a more reliable estimate of flood frequency than the conventional approaches, even before the effects of climate change are factored in. This approach significantly increases the predicted frequency of potential flood events; climate change exacerbates the problem (White, forthcoming). In this instance hydraulic modelling also showed that an engineered off-stream tidal surge water storage area on the floodplain below Lewes would be capable of mitigating flooding in Lewes up to 2080. However, here as elsewhere in the UK adaptive responses could be compromised by pressure for development within the floodplain and more widely by continuing urbanisation in the upper catchment.

The Exposure Units

Three work packages (WP3, 4 & 5) explored the consequences of climate change for building integrity, human comfort and urban greenspace. Here the scale of inquiry was at the neighbourhood level which involved surveys of individual buildings (WP3) and people (WP4).

WP3 (**Building Integrity**) aimed to develop a new approach for assessing, at a neighbourhood scale, the risk to buildings from natural hazards caused by climate change. To be of most use to adaptation policy, a methodology is needed which can integrate several hazards caused by climate change into a single measure of risk. The research aimed to develop a framework for the methodology such that it could be tested in principle using data relating to flood and geological hazard from Lewes.

In this research risk is expressed in terms of the cost of damage over a period. A starting point for the research was a method devised by Blong (2003) of evaluating historical damage to any type of building caused by any hazard. It measures damage as the cost of reinstatement:

$$\text{Damage} = \text{Replacement Ratio (RR)} \times \text{Damage Value (DV)}$$

where RR is a measure of the value of the building in multiples of the value of an average family house (measured in “house equivalents”) and DV is the function of the building cost lost in the hazardous event, measured across six “damage classes” from 0 (no damage, full resilience) to 1 (total collapse, complete vulnerability). By reinterpreting RR and DV in the light of the ASCCUE definition of risk (see above), Blong’s measure could be redefined to include vulnerability. As RR is the value of the building at risk, it was interpreted as a measure of exposure. As DV is the proportion of the building damaged by the hazard, it could be interpreted for any particular hazard in the following “damage function”:

$$\text{Damage Value} = f\,\{\text{Hazard severity, Building vulnerability}\}$$

Through the assessment of exposure, hazard and vulnerability and their application within this function the damage likely to individual buildings could be assessed in terms of periodic reinstatement cost, measured in housing equivalents. The methodology was field tested in Lewes where its practicality and effectiveness were demonstrated (Fedeski and Gwilliam, in press). Through addition of damage values, damage estimation can be achieved for larger sectors such as postcodes or WP2’s Urban Morphology Units. A key publication (Gwilliam et al, 2006) shows how the conurbation scale screening methodology (WP2) can be dovetailed with a more detailed assessment of the vulnerability of the building stock (WP3) to provide a nested approach to risk assessment of climate related hazard in urban areas.

Climate change will bring significantly higher temperatures with important consequences for **human comfort**. Findings from WP2, which mapped the risk to sensitive receptors in summer for the High emissions scenario up to the 2080s, showed that city centre populations might be particularly exposed to these higher temperatures (Lindley et al, 2006). Moreover, the BKCC CRANIUM study has provided probabilistic scenarios which show that even under a Medium-High scenario for Ringway (Manchester Airport), the number of hot days (i.e. maximum temperature > 24.5ºC) in summer will increase from around 5 days in the reference period 1961-1990 to about 45 days in the 2080s.

WP4 has broken new ground in linking external thermal comfort surveys with climate change models (BETWIXT) and socio-economic scenarios (BESEECH). Under these changed conditions, WP4 concluded that the demand for open space will increase for a number of reasons: to enjoy the warmer conditions over a longer season and a longer day into evening; to have access to open air, wind and shade from uncomfortably hot, poorly ventilated offices, shops and public buildings during the day, or from over-cooled buildings; and to have access to the open-air for cooling from uncomfortably warm, naturally-ventilated residential properties in the evening or at night.

Because most studies have concerned the interior of buildings, rather less is known about human comfort in the external environment. WP4 sought to improve our understanding of this by carrying out field work on human comfort and microclimate in all seasons and all weathers at town centre locations in Greater Manchester and Lewes. A questionnaire was designed to establish people's perceptions of comfort and their local environment; a portable weather station was constructed to measure ground-based meteorological conditions at the location and time of the interviews. The survey methodology drew on that of the EU-funded RUROS (Rediscovering the Urban Realm and Open Spaces) project (http://alpha.cres.gr/ruros/), which surveyed seven cities in five countries. This helped to ensure a wider application and to allow the ASCCUE results to be generalised through comparison with the RUROS database.

The field work confirmed that, as expected, people outdoors respond to the season and to weather. While there is considerable adaptation to different conditions and temperatures, such as changes in clothing, activity and location, the adaptation is incomplete. Climate change will increase the mismatch unless urban designers and city centre managers anticipate these changes and plan accordingly. The key to comfort in outdoor spaces is the adaptive opportunity offered by the spaces to the people in them, allowing them to choose between micro-climates to suit themselves. Such opportunities in Manchester and Lewes town centres were found to be severely limited at present and the extent to which towns and cities can be adapted will be influenced by the social and cultural context. The BESEECH socio-economic scenarios suggest significantly different story-lines for the provision of and access to public open spaces in urban centres and the adaptive response (Wilson et al, submitted).

One response, which came through strongly from the public surveys, is to provide "more greenery". Fortunately, whilst the rate of turnover in the building stock and therefore the scope for adaptation is limited, there is much greater scope for changing the quantity and quality of the vegetation cover - the 'green infrastructure'. However, whilst such an approach is often strongly advocated, the climate-related benefits of urban greenspace are rarely quantified. WP5 (**Urban Greenspace**) sought to remedy this by applying two established models for energy exchange (and hence surface temperature) and surface runoff and linking them for the first time to the UKCIP02 climate scenarios.

This modelling work was undertaken for Greater Manchester and used the UMTs as its spatial basis and the surface cover analysis as a key input, representing the 'current form' of the urban environment. Model runs were completed for the baseline and future climate using UKCIP02 scenarios and outputs from the BETWIXT daily weather generator. In addition, model runs included a series of 'development scenarios' where greenspace was added to explore adaptation strategies or removed to represent current development trends (Gill, 2006).

The way that climate change intensifies surface temperature is shown in Fig. 3.

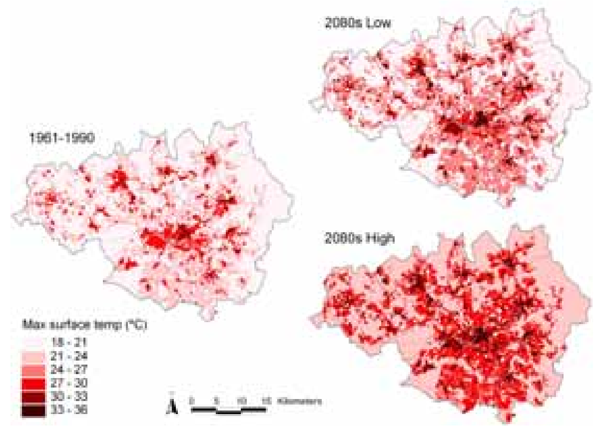

Fig. 3. Modelled maximum surface temperature in Greater Manchester for the 98th percentile summer day

Surface temperature is important because it is a key factor in human comfort. Greenspace can be used to moderate this effect. Our research has concluded that adding 10% green cover keeps maximum surface temperatures in high density residential areas and town centres at or below the 1961-1990 case up until the 2080s High. Greening roofs also moderates surface temperatures. A caveat is during droughts when plants experience water stress, the cooling effect of evapotranspiration is reduced. WP5 found that drought conditions for grassland increase both spatially and temporally with climate change. In such conditions, water bodies will be important for evaporative cooling and mature trees for their shade, whilst irrigation will be required to maintain functionality (Gill et al, in press).

Urbanisation accelerates surface run-off and this effect will be amplified by climate change. By the 2080s High, the 99th percentile winter precipitation event has 56% more rain than in 1961-1990, resulting in an 82% increase in runoff from Greater Manchester. Surface sealing, through urban intensification, increases run-off and the risk of sewer surcharging. We explored the way surface sealing reduces climate headroom with our sister project AUDACIOUS (Duckworth, 2005). Whilst adding green cover can reduce runoff locally, this effect is not enough to counter the extra precipitation from extreme events. The use of storage in combination with green surfaces will be required, and could be used to irrigate greenspace in order to maintain its functionality in times of drought.

Strategy Development

Strategy development involved a sharing of knowledge and experience between the research team and stakeholders in a series of interactive workshops. In Greater Manchester we explored impacts and responses in the following contexts: city centre, densifying suburb and a restructuring urban area. New development was explored in a joint workshop with the Defra cross-regional project on ‘sustainable communities’ (LUC et al, 2006). Contributions from other BKCC projects (BETWIXT, BESEECH, AUDACIOUS) helped to inform these workshops. Climate change impacts are cross cutting and unavoidable, they demand a multilevel policy response (national, regional, local), the engagement of a variety of delivery mechanisms and effective regulatory oversight. The research has emphasised the importance of risk assessment and strategy development at a variety of scales but work at the conurbation scale is critical (Lindley et al, in press). It is also important to ensure that adaptation complements, rather than undermines, efforts to reduce greenhouse gas emissions (McEvoy et al, 2006a). The functionality of the ‘green infrastructure’ needs to be protected and enhanced (Gill et al, in press) and measures taken to improve resilience during the development and redevelopment process. It has to be remembered that climate change brings opportunities as well as problems, especially in the public realm.

Project Plan Review

The research team worked in an integrated way, exchanging data, supporting each other during field work and coming together regularly for research management meetings and workshops. Specific responsibility for the leadership of each work package was as follows: Tanton, Southampton WP1; Lindley, Manchester WP2; Fedeski/ Gwilliam, Cardiff WP3; Wilson/ Nicol, Oxford Brookes WP4; Pauleit/ Ennos/ Handley, Manchester WP5; and McEvoy/ Handley, Manchester, supported by all team members WP6-8. The overall project was led by Handley and managed by McEvoy from Manchester with support from Lawson and latterly Griffiths.

The ASCCUE project team, working with UKCIP, also played a wider role in communicating research findings across all BKCC projects (McEvoy). Data acquisition is a major challenge in climate impacts research. ASCCUE (Lindley) led the BKCC Data Management Group which facilitated cost effective data acquisition, promoted data management and developed a number of metadatabases (see http://www.k4cc.org) of research outputs. As a result of this work, metadata records for all BKCC research outputs are hosted via the central UK metadata repository (http://www.gigateway.org.uk/).

The work proceeded broadly in line with the project plan except that the end date was extended, by agreement with EPSRC, from mid-April to mid-October, 2006 to coincide with the completion of Gill’s PhD studentship at Manchester (Gill, 2006). A PhD studentship was also attached to WP1 at Southampton University.

Explanation of Expenditure

The project out-turn was broadly in line with the project budget, except for a small increase in project management costs associated with the project extension. There was minor virement between budget heads to reflect actual expenditure.

Research Impact and Benefits to Society

The development of an integrated assessment framework for climate change impacts on the urban system, with strong stakeholder engagement and informed by climate change and socio-economic scenarios represents a major advance and provides a transferable model within and beyond the UK. There were significant methodological advances and new, policy relevant insights on climate adaptation in all work packages.

The ASCCUE Steering Group, comprising government departments and agencies, professional bodies, and allied researchers from industry, developed a communication strategy which encouraged strong stakeholder involvement and active dissemination. The final report to the Steering Group is available (Handley and Carter, 2006).

From the outset the ASCCUE project and website attracted international and national attention from both the research and policy communities (e.g. Provost, 2006). There have been many project related presentations, including Brussels, Copenhagen, Paris, Duluth (USA) and Hangzhou (China). McEvoy was selected as a UK delegate to the international workshop of young climate researchers in Havana, Cuba (Feb 06) and similarly Nanayakkara (WP4) to Estonia (Jan 06).

Key presentations to policy makers include the Royal Commission on Environmental Pollution, the Board of the Forestry Commission with the Minister of State for the Environment, the Commission for Architecture and the Built Environment, in Brussels during consultation on the EU Green Paper on climate adaptation, and a TCPA conference involving the Minister for Planning and Local Government. With support from ASCCUE and others, the TCPA is producing a design guide (Climate Adaptation by Design) which will be published alongside the BKCC National Dissemination Conference in March, 2007. ASCCUE research informed the Foresight project ‘Future Flooding’ and we responded to consultations by the Three Regions Climate Change Group (TRCCG, 2005) on a checklist for development and DEFRA (Making Space for Water). Our work was presented and discussed internally at DCLG during preparation of the draft Planning Policy Statement ‘Planning and Climate Change’ and incorporated in a review paper (Green and Handley, 2007) commissioned through the Planning Research Network.

The potential for urban greenspace to moderate climate change impacts has attracted particular attention. Our initial publication (Gill et al, in press) won the Planning Research Network prize paper competition for 2006. The Forestry Commission is now reviewing its role in urban forestry and CABE Space is preparing a national initiative on climate change adaptation.

At the regional level ASCCUE assisted the Environment Agency in their response to the North West Regional Spatial Strategy and the emergent City Region Spatial Strategy is proving to be an excellent test bed for the ASCCUE adaptation methodology. Susannah Gill has been appointed to the Mersey Forest Green Infrastructure Unit where she is taking forward a practical demonstration project. In the South East, Wilson was part of the LUC led project team for the recently published good practice guide for Sustainable Communities (LUC et al, 2006). ASCCUE held a joint workshop with this project in March, 2006 and our work on city centres informed the Defra project on Climate Change and the Visitor Economy (McEvoy et al, 2006b).

Future Research

The role of climate change as a driver in regional planning is being explored by Handley and Pauleit in PLUREL, an FP6 project led by KVL Copenhagen. Lindley and Handley are co-investigators on a recently awarded EPSRC project (SCORCHIO) which is building on ASCCUE by exploring the heat island phenomenon in Greater Manchester and its implications for building design and management. Handley and Lindley are both involved in EPSRC's successor project to BKCC (Sustaining Knowledge for Climate Change), which seeks to sustain the adaptation research community, disseminate the findings of BKCC, address research challenges in advanced workshops and assist EPSRC and UKCIP in developing the future research agenda.

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