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Green walking networks for climate change adaptation

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ABSTRACT

Climate change (CC) potentially affects people travel behaviour, due to extreme weather conditions. This is particularly true for pedestrians, that are more exposed to weather conditions. Introducing the effect of this change in transport modelling allows to analyse and plan walking networks taking into consideration the climatic variable. The aim of this work is to develop a tool that can support planning and design of walking networks, by assessing the effects of actions oriented to increase resilience with respect to extreme weather conditions (CC adaptation).

An integrated approach is used, thus combining transport and land-use planning concepts with elements of outdoor thermal comfort and network accessibility. Walking networks are analysed through centrality indexes, including thermal comfort aspects into a general cost function of links and weighted nodes. The method has been applied to the walking network inside the Campus of the University of Catania (Italy), which includes different functions and where pedestrian paths are barely used by people. Results confirm that this tool is sensitive to the variables representing weather conditions and it can measure the influence of CC adaptation measures (e.g. vegetation) on walking attitude and on the performance of the walking network.

Introduction

Most of the current literature focuses on the relationship between climate change (CC) and transport-related greenhouse gases (GHG) emissions. Mitigation of climate change has been the mainstream research and planning practice in the last decades, mainly oriented to reduce GHG emissions. Fewer contributions can be found on adaptation to the impacts of extreme weather conditions deriving from CC.

A great number of studies recommend new approaches to urban and transport planning as solutions to climate change mitigation. Examples include Smart Growth (ICMA, 2002), Transit Oriented Development (Calthorpe, 1993) and Transport Demand Management (Ignaccolo et al., 2006a). All of them advocate for development of high mixed-use densities and walkable communities in areas close to public transport nodes. These are arguably the most effective development strategies for increasing the number of trips at a walkable distance and favouring the access to transit stops and stations. Besides, promoting the shift towards more sustainable transport modes (mainly walking and cycling) is one of the best ways for limiting the increase in motorisation. Therefore it should be a priority for local authorities, especially in emerging countries.

However, CC adaptation requires space for green and blue infrastructure within and around built areas, because too high densities can exacerbate the urban heat island effect and increase the likelihood of urban flooding. This conflict is an example

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of how mitigation actions could compromise adaptation objectives. It suggests that climate change must be tackled by integrating mitigation measures, such as limiting the production of GHG emissions, with adaptation measures, in order to prepare our cities to its inevitable impacts.

An urban green infrastructure network (Inturri and Ignaccolo, 2011) is seen as a good solution, both for CC mitigation and adaptation. It can favour people walking from residential areas across public open spaces and natural green corridors, to urban activities even under extreme weather conditions. Green infrastructure networks have both the potential to support a modal shift from road to walking, thus reducing GHG emissions, and to increase the resilience providing greater human comfort.

There are guidelines to build effective green walking networks (Martincigh, 2002, 2005) and some studies show that street trees have the greatest per-unit-area potential for cooling and the greatest potential to alter the albedo of urban surfaces compared with other vegetation (NYC Regional Heat Island Initiative, 2006; Ali-Toudert et al., 2005; Ali-Toudert and Mayer, 2007).

In this paper a method is presented, which establishes a functional link between climate issues and 'walkability' aspects. The aim of the research is to understand how climatic conditions and adaptation measures can affect the performance of a walking network, in order to assist the decision-making process in urban planning and design.

Thermal comfort and travel behaviour

The relationship between climate change and transport behaviour is quite an unexplored area. Many studies focus on the impact of climate change on transport and refer to increase in travel times, congestions and infrastructure disruptions (Koetse and Rietveld, 2009; Tsapakis et al., 2013). Nevertheless, there are few attempts to effectively link climate-related variables and thermal comfort issues with travel behaviour and modal shift (Saneinejad et al., 2012).

Sabir et al. (2008) used a multinomial logit mode choice model and found that people switch from car to bicycle as temperature increases. However, if temperatures reach levels higher than 25 °C, people switch back from bicycle to car and public transport. Aaheim and Hauge (2005) carried out a survey in Bergen (Norway) regarding travel attitude and climatic data, showing that climate change would take to an increase in public transport, in walking and cycling. Clearly these results are significant for the specific case study: while in Bergen high temperatures lead to better walking conditions, evidence shows that, when temperature rises in hot and dry climate cities, people switch to air-conditioned cars and the attitude to walk and cycle decreases. By the way, this leads to enhanced energy requirement and further exacerbates climate change.

There is a wide literature about reproducing pedestrian behaviour at the very fine scale in closed and open environments (e.g. by means of agent-based models: Bruse, 2007; Camillen et al., 2009). Nevertheless, the quantitative relationship among thermal comfort of pedestrians, microclimate variables and walking attitude at the scale of the street network is still an unexplored issue.

Thermal comfort is defined by ASHRAE (1966) as 'that condition of mind which expresses satisfaction with the thermal environment'. The substantial difference between indoor and outdoor comfort lays in solar radiation and wind chill. One of the most important parameters which governs the human energy balance is the mean radiant temperature, defined as 'uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure' (ASHRAE, 2001). The proposed method uses the 'Universal Thermal Climate Index' or UTCI (Jendritzky et al., 2007; Błażejczyk et al., 2010) as a comprehensive indicator of the temperature perceived by pedestrians linked with the thermal sensation, which takes into consideration solar radiation through the mean radiant temperature. It is considered a suitable index in order to incorporate the climate variable into the attributes influencing walking attitude.

Methodology

The methodology proposed is based on the analysis of walking networks through node centrality indexes taken from a revision of the Multiple Centrality Assessment method (Porta et al., 2008). The concepts of node accessibility, equivalent walking distance (Wibowo and Olszewski, 2005) and thermal comfort are integrated using a general cost function of links and weighted nodes.

Walking-specific attributes and a thermal comfort measure are introduced into the model, since they can contribute significantly to the best path choice by pedestrians.

The procedure consists of the following elements:

(1) a 'network model' including the representation of origin and destination (OD) sites (zones), walking segments and their properties (links), intersections of segments (nodes);
(2) a 'cost function' that links climatic attributes and walking-specific issues (slope, stairs, etc.) and the 'walkability' (the cost) of each segment of the network;
(3) 'centrality indexes' used here as accessibility measures, both global (at the level of the whole network) and local (at the zone level), in order to carry out evaluations and comparisons for different situations.

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