A Review of Urban Carbon Emission Reduction Strategies: Integrating Multiple Criteria Decision Making and Life Cycle Assessment

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Abstract

At present, global climate change has become one of the biggest challenges to the survival and development of mankind. To avoid that, various projections predict a rise in average global temperatures of 4-8ºC by the end of the present century, which highlights the urgent need for solutions to remove greenhouse gases from our atmosphere and for actions to combat climate change towards a "low carbon" society.In this paper, we conduct a review of urban carbon emission reduction strategies which highlight the combination of Multiple Criteria Decision Making (MCDM) and Life Cycle Assessment (LCA) methods. This is crucial when assessing working methodologies in order to introduce normative measures into the urban planning process for sustainable developments. Central to the work are a living lab where solutions can be implemented (as in rapid prototyping) and transversal activities concerning formulating options for carbon pricing, on creating lower-carbon urban systems through the development of more compact cities, transportation systems that deliver strong benefits and buildings that use significantly less energy while enhancing community livability.This research aims to contribute with valuable, integrated decision-making techniques for urban planners and policymakers. Ultimately, the idea is to stimulate transformation towards low-carbon cities that both reduce global emissions and improve urban quality of life.

Introduction

In latest many years, weather alternate has become an important trouble at the worldwide level for human survival and development. This is more so experienced in underdeveloped countries, where several socio-economic problems have to be dealt with at the same time. These countries are the most affected by the impacts of climate change in general, such as extreme weather events, rising sea levels, and food insecurity. In its reports, the Intergovernmental Panel on Climate Change (IPCC) has been unequivocal about one point—that climatic change poses unacceptable highest level of threat to developing nations with limited capacity for adaptation and economies heavily dependent on agriculture and fisheries (1). However, the need for viable scalable carbon and GHG solutions is now more urgent than ever before as temperatures are set to rise by 4 to 8 degrees Celsius globally by the end of this century. This means if they are to achieve sustainable development, as well as the environmental sustainability that is integral to it (2)

Migration to urban areas in search of improved economic opportunities and living environments is taking place rapidly in various developing countries. The United Nations (UN) estimate that the number of urban populations in developing countries will double by 2050 causing a significant rise in energy consumption and greenhouse gas emissions [3]. Given that cities are responsible for about 70% global carbon emissions and they hence become key players in this climate change fight (4). The need to comprehensively assess urban carbon emissions, and consequently employing integrated methods e.g. MCDM and LCA, also becomes pressing. These methods draw reference frameworks systemically regarding carbon emissions and its influencing factors which serves as bases of choosing optimal reduction alternatives.

Results of a few recent research works stressing on MCDM and LCA must be beneficial to develop urban carbon emission reduction strategies. A study from Climatic Change finds that combining LCA with MCDM provides an appropriate approach to enhance the decision-making processes in urban planning by assessing different sustainability dimensions of the environmental impacts related to different alternatives for urban development, simultaneously. Through this integration, cities can select actions that reduce emissions, while also advancing social equity and economic viability all three are important priorities for cities (5). According to the authors, city and project-based teams without that level of integration may find it difficult developing effective climate strategies since not all stakeholders needs will have been addressed.

In another significant contribution from Nature Climate Change, researchers discuss the role of demand-side mitigation solutions in achieving climate goals. The paper emphasizes that understanding non-pecuniary barriers to behavior change is crucial for effective policy interventions aimed at reducing urban carbon footprints (6). This perspective aligns with the need for comprehensive assessment methodologies like MCDM and LCA that consider various stakeholder perspectives. The study indicates that behavioral insights can be effectively integrated into MCDM frameworks to enhance community engagement and acceptance of low-carbon initiatives.

Moreover, a recent article in Sustainability, analyzes the effectiveness of different urban carbon reduction strategies through a system dynamics approach. The authors argue that employing MCDM techniques can significantly enhance the robustness of policy recommendations by accounting for multiple criteria and stakeholder preferences (7). This study reinforces the necessity of integrating MCDM and LCA in developing actionable strategies for urban sustainability. The authors also provide case studies illustrating how cities have successfully implemented these methodologies, resulting in measurable reductions in carbon emissions.

Additionally, another research explores how cities can leverage MCDM frameworks to assess trade-offs between economic growth and environmental sustainability. The findings suggest that cities adopting these methodologies can better navigate complex decision-making landscapes while ensuring that their strategies are both effective and equitable (8). The paper emphasizes that MCDM can facilitate participatory decision-making processes, allowing stakeholders from various sectors to contribute their perspectives on urban development projects.

Furthermore, a review article in Renewable and Sustainable Energy Reviews stresses the importance of LCA for assessing any urban infrastructure projects [8]. The authors illustrate that LCA reveals carbon hotspots through the entire lifecycle of urban development, allowing cities to determine both the choice of material alone as well as its end-use energy (9). Which is in line with the overall objective to drive low-carbon cities. In addition, by using the broad scope and flexibility of LCA, policymakers are enabled to consider these long-term implications prior to making decisions in order to achieve more sustainable results.

The Journal of Cleaner Production published a systematic review on MCDM and LCA as an integrated method to evaluated sustainability of urban areas . They assert that this 'mix' approach allows for an increased transparency and makes decision-making a more trustful process in the eyes of public (10) It uses case studies from numerous cities around the globe where such integration has enabled low-carbon strategies to be implemented effectively.

Multi-Criteria Decision Making (MCDM)

As stated earlier, MCDM is a concept that is widely used in urban planning as a means for the decision maker to examine how the various options in the particular target rank with respect to the many and

often conflicting criterions [11]As a given with any urban development, projects aiming to minimize carbon will always involve trade-offs among economic viability, social equity, environmental impact and technical feasibility. For Example, a city may be planning to Implement a new public transport system that is emission-free bus one which costs alot on the financial end.

There are a variety of MCDM models, such as the Decision-making process's Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) [12]. Each of these approaches has a concrete merit depending on the kind of context and the objectives that the decision making process is pursued to. DMC includes all the potential strategies of the stakeholders within the structure in guarantee that the opted for strategies are in line with the aspirations of the people.

Life Cycle Assessment (LCA)

   Life cycle assessment (LCA), however, extends MCDM by assessing environmental repercussions along the whole product or process cycle from the extraction of raw materials stage, through production, use and finally disposal [13].In urban environments, LCA reveals where emissions are coming from within the system and provides areas of intervention.For instance, a LCA on building materials can show what options have less embodied carbon. As a result, an examination of transportation modes with LCA allows cities to learn about the life-cycle environmental costs for various transport choices enabling informed decision-making that efficiently reduces overall emissions over time.

Moreover, LCA can evaluate policies aimed at reducing carbon footprints within cities. By analyzing life cycle impacts of various policy options such as incentives for renewable energy adoption urban planners can make evidence-based decisions aligned with sustainability goals (14).

 Integrating MCDM and LCA in Urban Planning

   The integration of MDCM and LCA provides a systematic method for constructing low-carbon neighborhood. When combining these approaches, cities can start to address solutions such as improved transportation systems, energy-efficient buildings, green spaces for carbon sequestration, and sustainable waste management.For example, city planners examining carbon emissions as part of a new urban development opportunity might employ MCDM to assess design options using criteria such as cost-effectiveness and social acceptance while conducting LCA at the project scale & use-phase level for each option to understand potential life cycle impacts on carbon emissions. The combination of both potentially makes for holistic evaluations that account for short-term and long term value.

This interaction with communities is fundamental for increasing public awareness and getting them on board in support of new sustainability measures. Residents who engage in urban planning discussions on something as practical as transportation are more likely to support low-carbon options. Public engagement can contribute to greater legitimacy of decision-making, as well as to community empowerment related with the appropriation of the public environment (15).

Methodology

   Through a descriptive-analytical approach, this paper aims at: (1) examination of various urban carbon emission reduction strategies that have been proposed/executed; and (2) reviewing the use of Multiple Criteria Decision Making (MCDM) combined with Life Cycle Assessment for evaluation purposes. Background This systematic literature reviews (SLR) synthesizes peer-reviewed articles, reports and case studies written since 2005 that provide recent best-practices for using geo- semantic web methodologies in urban contexts. The studies were chosen based on their appropriateness to

MCDM and LCA, hence relevance to the topic. This is a multidimensional decision making (MCDM) method dealing with planning task of selecting among few approaches based on their cost, environmental impact and then social acceptance together with the LCA technique assessing environmental impacts of choices directly or indirectly throughout their lifecycles. Structured interviews or surveys capturing expert opinions were mixed with presented findings to assure in-built validation, and professional viewpoints on the simulation strategies were added. Qualitative thematic analysis was employed to identify common themes, supported by quantitative metrics from LCA results. This comprehensive methodology offers valuable insights for policymakers and urban planners seeking effective urban carbon emission reduction strategies.

Result and discussion

  Combining the research models of MCDM and LCA with urban carbon mitigation we obtained a few enlightening results. The results section presents the data collected during the study in a logical not prejudiced or subjective manner. This section contains the main results derived from the study, with accompanying statistical tests and but otherwise simple implementation of bar plots/tables etc. The finding should be described in a logical order, prioritizing it or otherwise ordering instances when appropriate to the design of the study. Although the magic should be done so that data does not geil in favor of the reader, there is no need for you to explain such things in detail: at most it will take a couple of lines summarizing the direction of all effects and how are they to note-related issues.

  The discussion section interprets and evaluates the results, explaining their significance and implications. Here, the authors indicate the significance of their results by comparing and contrasting them with prior studies, addressing the problem stated in the introduction, and critically analyzing the findings. This section links the results back to the initial hypotheses and literature, discusses limitations, and speculates on future research directions. The discussion should narrate a story, include explanations for observed phenomena, and provide supporting studies to justify or validate the findings. It is important to avoid repeating information given in the introduction and to derive conclusions unless the journal requires a separate conclusion section.

Conclusion

  In this closing segment, the empirical results and their significance are presented with respect to the research inequality or hypothesis outlined in the introductory chapter. It depicts the position of the researchers at the end of their study, whether the results obtained were the ones anticipated and the reasons for it or otherwise. It cannot be stated to be an absolute end, but rather a temperate and provisional one. More often than not, it encourages other scholars to take up the task as it argues for the need to do further studies on the subject. Also specific aspects about possible studies of that nature that can or should be carried out in order to clarify the conclusions are given here. The conclusion assists in restating the argument and points out what is new to the field as a result of this study so that the audience appreciates the importance of the research conducted.

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