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# Application of environmental performance analysis for urban design with Computational Fluid Dynamics (CFD) and EcoTect tools: The case of Cao Fei Dian eco-city, China

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**Abstract**

This paper suggests a type of quantitative research method with the application of Computational Fluid Dynamics (CFD) and EcoTect tools for a sustainable urban design project. This paper is part of a funded research study and was completed in 2010. This study is part of the larger project for planning and development of Cao Fei Dian eco-city development in North-Eastern China; one of the first eco-city development projects in the first batch of pilot eco-cities in China. The research programme addresses the main aspects of good practice in terms of eco-design and sustainability. These aspects include wind flow analysis around buildings, insolation analysis of open spaces, pollutant dispersion in water systems and noise control on urban highways. This study aims to explore a range of research methods in order to enhance the performance of integrated design with a comprehensive planning stage. The integration in evaluation across professions and subject boundaries is emphasised to identify the key gaps between sustainability and design. The main method of this study is the application of CFD and EcoTect tools for environmental performance of a larger urban area than the common use for architectural interventions or immediate outdoor spaces of a project. This study suggests an integrated urban design model with the application of computational tools (i.e. CFD and EcoTect in here) and how these could inform, from a technical dimension, a more comprehensive approach to executing best practice in design and planning. The paper concludes by suggesting an integrated model of urban design to achieve urban sustainability.


*Keywords:* Sustainability; Urban design; CFD; Optimisation; Environmental performance

## 1. Introduction

In the past few decades, the need to responsibly tackle global warming and exhaustion of fossil fuel has increased the importance of sustainability in the fields of built environment and architectural design. This field of study has been explored in various ways in both practice and academia. The purpose of this study is also to explore methods

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of environmental performance evaluation models and their application into a design thinking model for the sole enhancement of urban sustainability. In this research paper, the intention is to also link research outputs with contemporary urban design practices; one of which is the environmental performance analysis and how it affects the process of design development in practice. In the later sections, this study describes a design-led project which was hugely benefitted from such method of design thinking; a method that is precisely described as an 'Integrated Design Approach (IDA)'. This includes a thorough development of an integrated design proposal, taking into account key aspects of transportation, environmental performance, mixed-used development and pollutant dispersion, which are all interlocked in the whole design process. In order to relate this approach into a design-led method and achieving a sustainable urban model, computer prediction models and assessment tools are used to predict, test and evaluate the environmental performance of the proposal. Later on, such techniques can be applied for the purpose of modification and necessary adjustments of the design proposal. This study primarily focuses on two factors of the wind environment analysis (based on CFD simulations) and solar performance (based on EcoTect analysis) in the urban context. These are mainly considered for the optimisation of the proposed built environment and to suggest for design enhancement solutions. The proposed model is derived from the overall concept of urban sustainability agenda, in order to be holistic in nature and applicable in practice.

Urban sustainability is no longer a new norm in the field of built environment, yet it has a variation of applications in practice. It is seen as a multi-perspective understanding and evaluation of cities, which initially included the environmental, economic and social aspects of the built environment. It is also very much dependant on the context in which the new development is proposed for construction and operation. The contextual aspect is precisely important, as it can play a major role in defining and refining the concept of urban sustainability. This is particularly importance as the fourth pillar of governance may adapt, change or differ from one context to another. The multi-scalar and multi-dimensional nature of urban sustainability provides us with a range of opportunities to undertake various approaches in achieving it in research and practice. Recent studies include various factors and recognition of urban sustainability in practice, some of which include the management perspective (Madu et al., 2017), multi-scalar city analysis (Dor and Kissinger, 2017), associated with sustainability indicators (Dawodu et al., 2017; Pupphachai and Zuidema, 2017) and modelling of the built environment (Cheshmehzangi, 2016). The latter is what we consider for this particular study, as an approach to realisation of various available tools and programmes that can be utilised in the built environment practice. In a later section of this paper, this factor is discussed as part of the Integrated Design Approach (IDA) or purely the integrated thinking in design development and modelling of the built environment.

When it comes to the context of urban sustainability (i.e. as an approach in urbanism), architects and urban designers have a larger share of responsibility for the world's consumption of fossil fuel, global warming and gas production than any other professional groups (Edwards, 1999). Yet, exploring and optimising buildings alone cannot provide significant impact on developing sustainable urban forms, microclimatic design and efficient urban patterns that are by far more effective than building-level solutions. This reflects on the fact regarding the growing demand and increase usage of urban energy, considering the built environment as a major $CO_2$ producer (i.e. more than 35% of the whole energy consumption globally). Different studies indicator various figures for the total amount of energy consumption by the built environment, but we can certainly argue that the built environment has become a major driver of change for environmental degradation, global warming as well as the increase of $CO_2$ emissions and energy consumption in the past few decades. This factor alone indicates a lack of concern from the sector of the built environment at a larger scale which has resulted in major issues of Urban Heat Island Effect (UHIE) and urban over-densification in many cities around the world. Some of the global scenarios have significant impacts on energy planning from policy and polity dimensions, as well as the increase of urban density and infill development that have altered the discourse of harmonious living in the urban environments. In fact, some of these major issues that are we are currently facing are not necessarily new. For instance, UHIE was discussed and analysed as early as 1818, when Luke Howard introduced the phenomenon that was causing climate change in the City of London, UK. The only major difference is the extent in which we have now urbanised or expanded our city environments, which are now causing severe effects globally. Particularly in the global south, this is now a major concern as the approach or concept of urban sustainability is yet to become a major factor in their development agenda. Therefore, suggestions on urban sustainability models are very effective in the field of research and are important for potential policy development and best practice examples.

In the built environment, sustainability aims to pioneer directions to meet economic, environmental, social and governance dimensions of the city/community development. This factor certainly feeds into the concept of sustainable city or sustainable design that clearly indicates a design or plan of a city with comprehensive consideration of environmental impact in the urban development of any kind; a description that more or else shaped the idea of sustainable urbanism when it was first argued by Richard Register (1987) and was later implemented in later global agendas (e.g. Agenda 21) and other key global initiatives that address the concept of urban sustainability in both policy and practice. As a result of these, the