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Research article

Defining a quantitative framework for evaluation and optimisation of the environmental impacts of mega-event projects

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ABSTRACT

This paper presents a novel quantitative methodology for the evaluation and optimisation of the environmental impacts of the whole life cycle of a mega-event project: construction and staging the event and post-event site redevelopment and operation. Within the proposed framework, a mathematical model has been developed that takes into account greenhouse gas (GHG) emissions resulting from use of transportation fuel, energy, water and construction materials used at all stages of the mega-event project.

The model is applied to a case study - the London Olympic Park. Three potential post-event site design scenarios of the Park have been developed: Business as Usual (BAU), Commercial World (CW) and High Rise High Density (HRHD). A quantitative summary of results demonstrates that the highest GHG emissions associated with the actual event are almost negligible compared to those associated with the legacy phase. The highest share of emissions in the legacy phase is attributed to embodied emissions from construction materials (almost 50% for the BAU and HRHD scenarios) and emissions resulting from the transportation of residents, visitors and employees to/from the site (almost 60% for the CW scenario). The BAU scenario is the one with the lowest GHG emissions compared to the other scenarios. The results also demonstrate how post-event site design scenarios can be optimised to minimise the GHG emissions. The overall outcomes illustrate how the proposed framework can be used to support decision making process for mega-event projects planning.

1. Introduction

Mega-events can be defined as the large-scale cultural, commercial or sport events that involve substantial capital investment and different stakeholder groups, enhance urban regeneration, political and economic status of the host city and attract global media attention (Roche, 2000; Getz, 2008; Lee et al., 2014). The most well-known mega-events are the Olympic Games, FIFA World Cup and a World Fair such as the Expo events. Mega-events normally result in numerous economic and social benefits for the host city such as the increased number of tourists, major investment in infrastructure projects, creation of new jobs, sport education, etc. Mega-events are also associated with various environmental impacts due to the vast amounts of construction materials, energy and resource use, waste generation, air and noise pollution during the construction of the event site, staging the event and post-event site redevelopment and operation. Therefore, a mega-event as an overall project can be described as a long-term multi-billion dollar project comprised of multiple phases of different duration which involves complex planning process and a vast array of different stakeholders.

Environmental strategies for the mega-events have recently become a fundamental part of the overall events' sustainability management plans. Typically, they specify the actions that are going to be implemented in order to minimise negative environmental impacts resulting from the preparation and staging of the event. In the last few decades, the range of such actions has expanded significantly from merely planting new trees to complex energy recycling schemes and innovative sustainable venue designs and materials. Nowadays, the event organisers also publish the post-event reports where they specify the progress against the initial targets such as the London 2012 Post-Games Sustainability Report 'A legacy of change' (LOCOG, 2012).

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A number of sustainability and environmental guidelines and standards have recently been developed which assist event organisers with implementation of sustainability measures during the preparation and staging of the event. Some guidelines are universal for all types of organisations such as ISO 14001-14006 ‘Environmental Management Systems’ (ISO, 2014a) or ISO26000 ‘Social Responsibility’ (ISO, 2014b). Others, such as BS8901′ Specification for a Sustainability Management System for Events' (BSI, 2014) or ISO 20121 ‘Event Sustainability Management Systems’ (ISO, 2012) were developed specifically for the events management. Although the standards provide some useful recommendations for the event organisers, they do not specify any quantitative targets or define a set of indicators or tools that should be used to measure the performance progress. Moreover, they generally address the preparation or the event phase without considering the post-event legacy phase.

From the host city's perspective, the legacy is by far the most important phase of a mega-event project. The actual event only lasts a few weeks and the duration of the legacy phase is decades. Since the 1990s, the significance of securing a positive lasting legacy created by a mega-event has been widely recognised (IOC, 2007). It is now emphasised that the candidate cities should be evaluated on the environmental consequences of their plans, and sustainability assessment should focus on the long-lasting legacy (Gold and Gold, 2011). Therefore, sustainable planning of mega-event projects should shift from focusing on the construction and event stages only to a holistic assessment of the whole project's life cycle including the post-event legacy phase. This is because the major use of the infrastructure built for the event from a host city's perspective is the legacy phase. The legacy is by far the longest phase of a mega-event project and this is where most of the environmental impacts will occur (GIZ AgenZ, 2013).

A number of studies have recently been published that attempt to evaluate different types of mega-event legacies. Some authors propose frameworks for measuring socio-economic legacies (e.g., Minnaert, 2012; Lamberti et al., 2011; Prayag et al., 2013); others focus on the evaluation of economic impacts and utilisation of the built infrastructure in the post-event period (e.g., Hiller, 2006; Li et al., 2013). A number of conceptual frameworks for measuring legacies of mega-events have been recently proposed. Most of them, however, focus on the evaluation of potential tourism legacy such as the theoretical framework proposed by Li and McCabe (2013). Therefore, a critical review of the latest studies on sustainability assessment of mega-event projects reveals that a quantitative environmental assessment of mega-events mainly includes the impacts associated with the actual event or the construction of the event venues. Hence, there is no a common standard or a uniform methodology that could be applied for a holistic quantitative assessment and comparison of the environmental impacts of mega-event projects, as also observed by other authors (e.g. Collins et al., 2009).

This paper presents a novel quantitative framework that can be used during the planning process for mega-event projects in order to assist decision makers with the evaluation and optimisation of the environmental impacts of the proposed site design scenarios. The framework and a case study are described in Section 2. Section 3 provides a mathematical formulation of the optimisation model developed within the proposed framework. Section 4 presents the outcomes and analysis of the computational results. The final section outlines the overall conclusions and future work.

2. Methodology and a case study

2.1. Mega-event project as a complex system

As defined earlier, a mega-event project is a long-term large-scale project with multiple sub-projects of different scope and duration. Fig. 1 provides a holistic representation of a mega-event as a complex system with numerous inputs such as materials, labour and energy, and outputs, such as infrastructure, employment and services (Parkes et al., 2012). The activities within the system also cause environmental impacts, which may be both positive and negative.

The overall system is divided into three main subsystems according to the phases of the project: construction, event and legacy. Each subsystem consists of other sub-subsystems and all of them are interconnected. Each subsystem also involves a complex interaction of economic (E), environmental (EN) and social (S) aspects that have to be addressed during a planning process. The design phase is certainly the most crucial stage because this is where the most significant aspects and various alternatives of the proposed site design scenarios are being developed and evaluated. Thus, concurrent planning of the construction of the event site and post-event site redevelopment and evaluation of the environmental impacts of the alternative design scenarios is fundamental to ensure that the project continues delivering sustainable positive impacts long after the event is over. Section 2.2 presents a novel framework for the holistic environmental assessment of mega-event projects that can be used to evaluate and optimise the emissions resulting from each stage of the project.

2.2. Summary of the proposed quantitative framework

The quantitative framework presented in this paper requires a set of proposed scenarios for the event and its legacy. It provides quantitative evidence for decisions to be made about future development by comparing optimised conditions for each scenario. It takes into account the environmental impacts of the following aspects: water supply and wastewater removal during the construction and operation of the event and post-event venues; fuel used for transportation of construction materials and demolition waste during the construction of the event site and redevelopment of the post-event site, and fuel used for transportation of visitors during the event and legacy phases; embodied emissions from construction materials; energy used during construction of event venues and infrastructure and operation of the event during the event and post-event phases (see Table 1). In this work, the environmental impacts associated with greenhouse gas (GHG) emissions are accounted for, which is mandatory for the UK companies' environmental reporting (DEFRA, 2013). The three main greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The results are expressed in kg of carbon dioxide-equivalent (kg CO_2-eq).

Environmental impacts resulting from management of municipal solid waste (MSW) is not considered in this study because of the complexities of various integrated waste management systems. The authors propose different evaluation framework for the environmental assessment of MSW management options using life cycle assessment (LCA) which is described in detail in Parkes et al. (2015).

Within the proposed framework, a mathematical model has been developed that takes into account the GHG emissions summarised in Table 1. The objective of the model is to minimise the environmental impacts of different stages of a mega-event project for each proposed scenario, subject to a number of constraints described in Section 3.

The model can be used at different stages of the project. First, it can be used at the design phase to evaluate and optimise the environmental impacts of the construction of alternative event site design scenarios. The results obtained for the specific event can also serve as a benchmark against future or previous mega-events of the