

# Framework for developing construction sustainability items: the example of highway design

Calista Y. Tsai\*, Andrew S. Chang<sup>1</sup>

Dept. of Civil Engineering, National Cheng Kung University of Taiwan, No.1 University Road, Tainan 701, Taiwan, ROC

## ARTICLE INFO

### Article history:

Received 28 September 2010  
Received in revised form  
13 June 2011  
Accepted 11 August 2011  
Available online 19 August 2011

### Keywords:

Sustainability  
Highway design  
Construction projects  
LEED  
GRI

## ABSTRACT

Sustainable issues have been widely discussed in the construction industry in recent years. Although some studies have examined sustainability, it is still difficult for engineering designers to incorporate sustainable concepts into their work. The design stage is key in the life cycle to integrating sustainability into construction projects. Therefore, practical methods and tools are needed to facilitate sustainability in design work.

This study proposed a framework for developing sustainable items for highway design. Highway-related sustainable items were identified from a literature review of sustainable requirements and highway project practices. Next, specific sustainable items were selected through interviews with practitioners including designers, constructors, and maintenance owners. A checklist consisting of 60 technique and material sustainable items was created. Finally, the checklist was tested on four highway design projects to check the applicability of the sustainable items.

The results show that over 52% of the 60 developed sustainable items were considered and 50% incorporated into design. Designers can use the checklist as a tool to mark considered items, record man-hours devoted to sustainability, and calculate the percentage of items incorporated. The framework can narrow the gap between theoretical requirements and current design practices, thus leading construction projects toward sustainability.

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## 1. Introduction

Sustainable development in the construction industry has become an important issue (Holton et al., 2010), but it seems to be lagging behind other sectors. Myers (2005) reviewed the annual reports of 42 construction companies in the UK and found little information related to sustainability was disclosed, and relatively few large companies changed their business paradigm. Chong et al. (2009) surveyed over 200 civil engineers in the US, and nearly all respondents regarded sustainability as important, but actual application and implementation by their organizations was extremely low. Because of sustainability issues, Glass et al. (2008) indicated that major changes related to materials, techniques, skills, and innovation and management are needed in the construction industry.

The green building evaluation system such as the LEED (Leadership in Energy and Environmental Design) is an initiative for

sustainability in the construction industry. It provides a project checklist of prerequisites and credits required to evaluate the environmental performance of a building (USGBC, 2005). The AASHTO (American Association of State Highway and Transportation Officials) developed a compendium of practices, procedures, and policies for integrating environmental stewardship into highway construction and maintenance activities for Departments of Transportation (DOT) in many states (TRB, 2004). It indicated the need for standards and improvements in environmental processes, practices, and significant environmental items.

The design stage is a key to adding sustainable concepts to construction projects (NRC, 1991). Engineering consultants provide planning and design services in the initial stages of the life cycle of infrastructure. The energy and materials needed for, and waste produced by, infrastructure in the sequential stages of construction and operation have a great impact on the environment. Great potential reductions in operations' sustainable impacts could be made if sustainability is considered early in planning and design (McLellan et al., 2009; Cerdan et al., 2009; Spangenberg et al., 2010). Moreover, the design stage is the most comprehensively addressed portion of the life cycle in most green building guidelines and evaluation methods (Bunz et al., 2006).

\* Corresponding author. Tel.: +886 912012104; fax: +886 62677575.

E-mail addresses: [calista0523@yahoo.com.tw](mailto:calista0523@yahoo.com.tw) (C.Y. Tsai), [anschang@mail.ncku.edu.tw](mailto:anschang@mail.ncku.edu.tw) (A.S. Chang).

<sup>1</sup> Tel./fax: +886 6 2757575 63153.

Theories and requirements are mentioned frequently in sustainability related research. Nevertheless, the requisite tools and techniques for achieving sustainability in construction projects are lacking (Chong et al., 2009). There is a gap between theoretical methods and practices such as in energy management in production and environment impact assessment (Bunse et al., 2011; Lee, 2006). Practitioners experienced difficulties assessing environment impacts also because of the differences between methods and tools. There is a need to build a framework to facilitate the standardization of corporate sustainability management approaches (Azapagic, 2003).

This study proposed a framework for developing sustainable items for highway design. It intended to narrow the gap between theoretical sustainable requirements and current design practices. One purpose was to propose a framework of developing sustainable design items by incorporating practice. The other was to develop the sustainable items and their checklist that can be easily used by designers.

The infrastructure is valued at over 13 trillion in the US and the construction industry has an annual turnover in excess of £ 100 billion in the UK (Hughes, 2007; Holton et al., 2010). Sustainable transportation is one of the major categories to be further researched in construction and highway is a major part of transportation (Hughes, 2007). The framework for developing sustainable items for highway design can be referenced by other types of construction projects to move toward sustainability.

## 2. Research method

The research purposes were met by undertaking the case study method and a series of interviews. Case studies are recognized as a suitable research method for the type of exploratory studies such as this research in describing and analyzing the context of sustainable items (Yin, 2008). This method has been adopted by many sustainability studies (Palme and Tillman, 2008; Holton et al., 2010; Borchardt et al., 2011). Multi-stakeholder interviews including brainstorming, focus groups and expert suggestions are also often used to develop sustainable items or measures (AccountAbility, 2008).

This study adopted the similar methodology to develop highway-related sustainable items in addition to reviewing

sustainability requirements and sustainable construction projects. The framework or research process is shown in Fig. 1.

First, sustainability requirements, such as the LEED green building system, the Global Reporting Initiative (GRI) sustainability reporting guidelines, and relevant studies, were reviewed to understand their evaluation principles, credits, and environmental indicators as well as look for possible sustainable items. Next, construction design practices were reviewed from the bottom-up by analyzing the compendium from AASHTO as well as roadway projects in Japan and Taiwan, based on what they achieved for sustainability, to find ways to add sustainability into highway designs. Subsequently, about 45 highway-related sustainable items were identified from sustainable requirements and construction design practices. Further, these items were evaluated as to whether they were applicable through ten interviews with 24 practitioners including designers, constructors, and maintenance owners with more than 20 years of highway-related experiences. Applicable sustainable items were then developed after clarifying the sustainability issues involved in designing highways.

A group of eight designers had interview meetings for four times to discuss the 45 identified items one by one about their feasibility and difficulty when used in design. Interviews with the designers were emphasized because they understand well the current design practices and contextualization of sustainable items (Lundberg et al., 2009). The designers were from different disciplines of highway design work, such as pavement, drainage, bridges, etc. of a large consulting company with extensive techniques and experiences in transportation. Six constructors and ten government owners in total were then interviewed two times and three times, respectively, to confirm the items that could be used in the construction and maintenance stages. Then 60 sustainable items were developed after the identified items were accepted, integrated or removed through the last interview with the designers once again. The developed items were compared with the credits and indicators in the LEED and GRI. Finally, a checklist consisting of the 60 developed sustainable items was created, and tested on four projects provided by the company to validate their applicability to highway design.

The stakeholders interviewed in this study included only major participants of the construction projects such as designers, owners

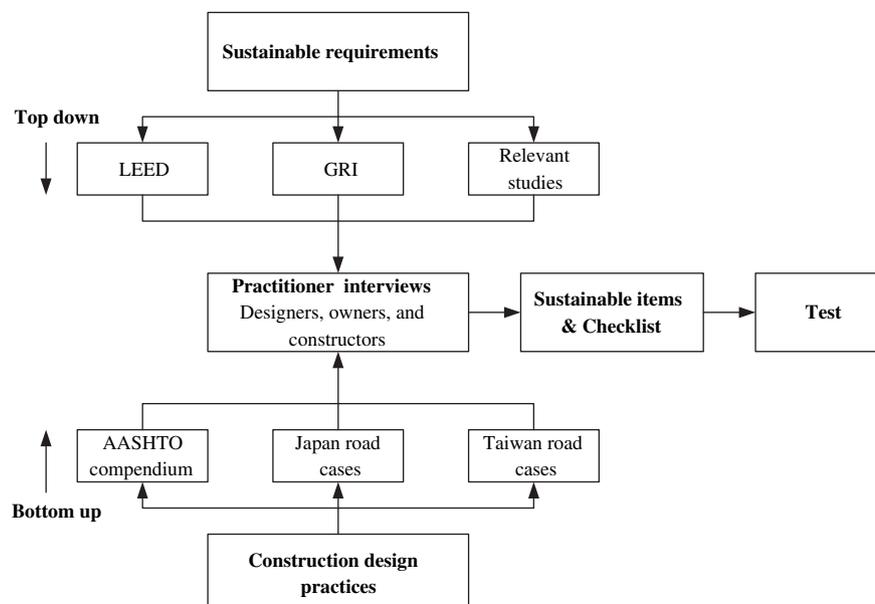


Fig. 1. Framework for developing sustainable items.

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