FRAMEWORK FOR OPTIMIZING SUSTAINABLE INFRASTRUCTURE BRIDGE PROJECTS

By

AHMED NOUH AHMED MESHREF

A Thesis Submitted to
The Faculty of Engineering at Cairo University
in Partial Fulfillment of the Requirements
for the Degree of

DOCTOR OF PHILOSOPHY
in
STRUCTURAL ENGINEERING

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Under Supervision of

Prof. Dr.
Moheeb El-Said Ibrahim

Professor of Construction Engineering
and Management
Structural Engineering Department
Faculty of Engineering
Cairo University

Prof. Dr.
Mohamed Mahdy Marzouk

Professor of Construction Engineering
and Management
Structural Engineering Department
Faculty of Engineering
Cairo University

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Approved by Examining Committee:

Prof. Moheeb Elsaid Ibrahim ----------
Professor of Construction Engineering and Management - Structural Engineering Department - Cairo University - **Thesis Main Advisor**

Prof. Mohamed Mahdy Marzouk----------
Professor of Construction Engineering and Management - Structural Engineering Department - Cairo University

Prof. Adel Ibrahim El-Dosouky ----------
Professor of Construction Project Management - Structural Engineering Department - Tanta University

Prof. Mohamed Abd El Latif Bakry ----------
Manager of Strategic Management Department - Social Development Fund

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
September-2014

Engineer's Name: Ahmed Nouh Ahmed Meshref
Date of Birth: 16/04/1980
Nationality: Egyptian
E-mail: ahmednouh80@yahoo.com
Phone: …….
Address: …….

Registration Date: 17/06/2008
Awarding Date: …./…./……..
Degree: Philosophy of Doctoral
Department: Structure Engineering Department

Supervisors:

Prof. Prof. Moheeb Elsaid Ibrahim
Prof. Mohamed Mahdy Marzouk

Examiners:

Prof. Prof. Moheeb Elsaid Ibrahim
Prof. Mohamed Mahdy Marzouk
Prof. Adel Ibrahim El-Dosouky
Prof. Mohamed Abd El Latif Bakry

Title of Thesis: FRAMEWORK FOR OPTIMIZING SUSTAINABLE INFRASTRUCTURE BRIDGE PROJECTS

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Summary:

Proper development and operation of infrastructure projects, such as bridges and highways, can contribute significantly to the mission of sustainable development. This thesis introduces a key-list of gathered important criteria that affect the sustainability of bridge projects. The initial list of criteria has been identified by unstructured interviews. Then, structured interviews and questionnaire survey have been conducted to identify the final list that is deemed important in rating green bridges. Final criteria results from this thesis are used to develop a green bridge rating system to achieve sustainable development. Degree of importance and weights of these criteria are determined using Simo's procedure. Five classes of bridges are proposed to judge their status with respect to sustainability. This research proposes a conceptual instrument that measures the user-based assessment of material sustainability and validates decision-maker's perceptions in order to evaluate the contribution of characteristics in materials selection. The contribution of this research is the development of a framework that consists of two modules for selecting appropriate building materials in order to help decision-makers with the appropriate selection of conventional or green bridges materials. The modules of the framework are; materials sustainability score (MSS) module and multi-objective optimization (MOO) module. The proposed framework helps to pursue sustainable environmentally friendly practices when selecting of bridges materials based on the proposed rating system in this thesis regarding actual costs. A case study is presented to demonstrate the use of the proposed framework.

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NOMENCLATURE

AASHTO	American Association of State Highway and Transportation Officials
ACEC	American Council of Engineering Companies
ACPA	American Concrete Pavement Association
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
BEST	Building Environmentally and Economically Sustainable Transportation
CARB	California Air Resources Board
DOT	Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GDOT	Georgia Department of Transportation
GDP	Gross Domestic Product
GHP	Green Highways Partnership
GSHC	T&DI/ASCE 1st Green Streets and Highways Conference

IDOT	Illinois Department of Transportation
I-LAST	Illinois Livable and Sustainable Transportation
IRTBA	Illinois Road and Transportation Builders Association
LCA	Life Cycle Assessment
LCCA	Life-Cycle Cost Analysis
LEED	Leadership in Energy and Environmental Design
MTO	Ministry of Transportation (Canada)
OMR	Office of Materials and Research (specifically)
PI	Principal Investigator
ppm	parts per million (air pollution unit
SIPRS	Sustainable Infrastructure Project Rating System
STEED	Sustainable Transportation Environmental Engineering and Design
SWMs	Solid Waste Materials
T&DI	Transportation and Development Institute
TRIS	Transportation Research Information Service

USGBC	Leadership in Energy and Environmental Design Reference Guide for New Building Construction
CH2M Hill	University of Washington
SESC	Soil Erosion and Sedimentation Control Measures
SWMP	Storm-water Management Plan
NPDES	National Pollutant Discharge Elimination System
MDEQ	Michigan Department of Environmental Quality
BMP’s	Approved Best Management Practices
SCM	Supplemental Cementitious Materials
NCHRP	National Cooperative Highway Research Program

ABSTRACT

Sustainable development principles have been implemented in various sectors including construction. Proper development and operation of infrastructure projects, such as bridges and highways, can contribute significantly to the mission of sustainable development. In this respect, there is little existing work on appropriate methods to assess the sustainability performance of bridges projects. This thesis introduces a key-list of gathered important criteria that affect the sustainability of bridge projects. Various construction industry standards have been reviewed in order to decide the criteria that influence sustainability of bridges' projects. The initial list of criteria has been identified by unstructured interviews. Then, structured interviews surveys have been conducted to identify the final list that is deemed important in rating green bridges. Various construction industry standards have been reviewed to decide on the criteria that influence sustainability of bridges' projects. Final criteria results from this thesis are used to develop a green bridge rating system to achieve sustainable development. Degree of importance and weights of these criteria are determined using Simo's procedure. Five classes of bridges are proposed to judge their status with respect to sustainability, with these being Non-Green, Certified, Green, total Green, and Evergreen. Material selection has been identified as an area where designers and contractors can have a significant impact on the sustainable performance of a bridge. Objective criteria such as design considerations and cost constraints can play a role in the selection of materials. However, there may be subjective criteria that could also impact the selection of materials. As such, an optimization model is developed to help decision makers to select materials. The research proposes a conceptual instrument that measures the user-based assessment of material sustainability and validates decision-maker's perceptions in order to evaluate the contribution of characteristics in materials selection. Interviews surveys of design and construction experts in sustainability and green practitioners were carried out. The results of the survey reveal that attention should be paid when taking the decision of which material should be used. This decision bears significant environmental, economic, financial, and social influences. Selecting inappropriate materials can be expensive, but more importantly, it may preclude the achievement of the desired environmental goals. The contribution of this research is the development of a framework that consists of two modules for selecting appropriate building materials in order to help decision-makers with the appropriate