W117 Journal for the Advancement of

Performance Information and Value

Vol. 13, Issue 1

CIB W117.org

August 2021

cib

Copyright © 2021 by Kashiwagi Solution Model, Inc (KSM Inc). All rights reserved. Printed in the United States of America. No portion of this publication may be reproduced in any manner without the written permission of the author(s) and/or publishing house (KSM Inc).

Journal for the Advancement of Performance Information and Value
ISSN 2169-0464 (Online)
ISSN 1941-191X (Print)
Copyright 2021 by KSM Inc.

Edited and reviewed by Nguyen Le
Cover Art designed by Kyle Hartwick

Published and distributed by:

Kashiwagi Solution Model Inc.
2251 N 32nd St #5
Mesa, AZ 85213

For information, please email W117 staff at JournalW117@gmail.com.

The views expressed in this report are based solely on the independent research performed by the author(s). This publication does not necessarily represent the views of CIB.

Editorial Board

Editor
Dean T. Kashiwagi, PhD, P.E., IFMA
Fellow, Fulbright Scholar
Co-Chair, W117 Performance Measurement in Construction
Director, Performance Based Studies Research Group
Adjunct Professor, SKEMA Business School
United States of America

Co-editor
Jacob Kashiwagi, PhD
Research Director, Performance Based Studies Research Group
United States of America

Journal Coordinator
Nguyen Le, PhD
Project Engineer
MWH Constructors
United States of America

Academic Researchers

A. Lee, PhD
Professor
University of Huddersfield School of Art, Design and Architecture
United Kingdom

A. Robinson Fayek, PhD
Professor
Hole School of Construction Engineering, Department of Civil and Environmental Engineering
Canada

Aderemi Adeyemi, PhD
Associate Professor
University of Botswana
Botswana

Ahmad Hadavi, PhD, MBA
Associate Director, Clinical Professor
Northwestern University
United States of America

Ahmed A. Alofi, PhD
Vice Dean
Yanbu, Taibah University – Eng College
Saudi Arabia

Ashok Kumar
Project Assistant
CSIR- Central Building Research Institute
India

Avi Wiezel, PhD
Assistant Dean for Facilities
Arizona State University
United States of America

B. Gledson, PhD, MCIOB, MAPM, SFHEA
Senior Lecturer, Programme Leader
Northumbria University
United Kingdom

B. Kameswara Rao, PhD
Professor
CBRI - Central Building Research Institute
Structural Engineering Division
India

Baabak Ashuri, PhD, DBIA, CCP, DRMP
Director of Economics of the Sustainable Built Environment Lab
Georgia Institute of Technology
United States of America

Bon-Gang Hwang, PhD
Assistant Professor
National University of Singapore - School of Design and Environment
Singapore

Chia Fah Choy
Associate Professor, Head of Programme
Universiti Tunku Abdul Rahman
Malaysia

Daniel Castro-Lacouture, PhD PE
Georgia Tech School of Building Construction
United States of America

David J. Greenwood, PhD
Professor
Northumbria University - Faculty of Engineering and Environment
United Kingdom

Dhaval Gajjar, PhD
Associate Professor
Clemson University
United States of America

Dimitrios Loukas
Researcher
SKEMA Business School
The United Arab Emirates

E. Chinyio
Course Leader
University of Wolverhampton

E. Witt, PhD
Associate Professor
TUT - Tallinn University of Technology - Department of Civil Engineering and Architecture - School of Engineering
Estonia

H. Visser
Senior Lecturer
University of South Africa - Graduate School of Business Leadership (Unisa SBL)
South-Africa

I. Zavrski, PhD, MSc. Eng.
Professor
University of Zagreb - Faculty of Civil Engineering
Croatia

Ir. Z. Hamid, PhD
Chief Executive Officer of CREAM Certification Services (CCS)
Construction Research Institute of Malaysia
Malaysia

Ir.Dr. R. Hassan
Professor / Specialist Consultant
Construction Research Institute of Malaysia
Malaysia

Ivica Zavrski, PhD
Professor
University of Zagreb
Croatia

J. Mbachu
Associate Professor
Massey University

Jackson Harare, MS
Researcher
SKEMA Business School
Canada

John Gelder
University of South Australia - School of Natural & Built Environments
Australia

Joseph Kashiwagi, MS
Researcher
SKEMA Business School
United States of America

Kinglsey Okenyi
Researcher
SKEMA Business School
Nigeria

L. Thomas JD, PdD
Director of Construction Management Program at Stevens Institute of Technology
Academic Unit Head
James Madison University
United States of America

Luis Otavio Cocito de Araujo, PhD
Associate Professor
Universidade Federal do Rio de Janeiro
Brazil

Majed Alzara, PhD
Vice Dean
Al Jouf University - Engineering College
Saudi Arabia

Malik Khalfan
Associate Professor
RMIT University
Australia

Mohammed Algahtany, PhD
Assistant Professor, Engineering College
Northern Border University
Saudi Arabia
N.H. Bertelsen
Senior Researcher
SBi - Danish Building Research Institute
Denmark

N.M. Almeida
Lecturer
IST–ID
Portugal

Niels Bertelsen
Senior Researcher
Danish Building Research Institute

Olga Wilhelmsen
Researcher
University of Agder
Norway

Oswald Chong, PhD, P.E.
Associate Professor
Arizona State University
United States of America

P-C. Liao, PhD
Associate Professor
Tsinghua University - School of Civil Engineering - Institute of International
China - PR

Pascal Evertz
Researcher
SKEMA Business School
Netherlands

Ruveyda Komurlu, PhD
Associate Professor
Kocaeli University
Turkey

Saud Almutairi, PhD
Vice Dean of Uinzah Engineering
Qassim University
Saudi Arabia

Shiviah Raviraj
Professor
S.J. College of Engineering
India

Sunil Kumar
Assistant Professor
S.J. College of Engineering
India

T. Fei Deng
PhD Student
University College London
London

T. Häkkinen, PhD
Senior Principal Research Scientist
Finland

T. Maqsood, PhD
Associate Professor
RMIT University - School of Property, Construction & Project Management
Australia

Tarja Häkkinen
Senior Principal Research Scientist
VTT Technical Research Centre of Finland
Finland

Teresa Harvey
Researcher
SKEMA Business School
United States of America

Tsunemi Watanabe
Professor
Kochi University of Technology
Japan

Vincent Cotoron, MSc
Researcher
Polytechnic University of the Philippines
Philippines

William Badger, PhD
Professor Emeritus, School of Engineering
Arizona State University
United States of America

William Verdini
Emeritus College Dean
Arizona State University
United States of America

Y. Sandanayake, PhD
Head of Department
University of Moratuwa - Department of Building Economics
Sri-Lanka

Yasir Alhammadi, PhD, FMP
Head of Civil Engineering Department, Vice Dean of Enginnering College
Prince Sattam bin Abdulaziz University
Saudi Arabia

Zuhairi Bin Abd Hamid
Construction Research Institute of Malaysia (CREAM)
Malaysia

Industry Professionals

A. Fung
Deputy Director of Housing
Hong Kong Housing Authority
China - Hong Kong

Alfredo O. Rivera, PhD
Director
Leadership Society of Arizona
United States of America

Andrew Bills, MS
Project Engineer
Hensel Phelps Construction
United States of America

Babak Memarian, PhD
Director
Exposure Control Technologies Research at CPWR
United States of America

Charles Zulanas, MS
Vice President
Loveland Logistics
United States of America

D.A. Couse
Secondary Liason CIB General Secretariat
NRC - National Research Council
Canada

Denise DiGruccio
Corporate Accounts Manager (Retired)
Neogard
United States of America

Eduardo Rubio
Maintenance Planning Leader
HEINEKEN Company
Mexico

Erik Brown
Manager consulting and Sourcing
Green Planet 21
United States of America

Erik Mars
Best Value Expert
Mars Inkoopadvies
Netherlands

Isaac Kashiwagi, PhD
Project Manager
Kashiwagi Solution Model Inc
United States of America

Ir. W.J.P. Bakens, PhD
Associate Coordinator
Sustainable Built Environment
Netherlands

Jake Gunnoe, PhD
Director
Leadership Society of Arizona
United States of America

Jacob Charries
Procurement Officer
Oklahoma District Attorney Council
United States of America

Jacob Williams
Head, Program Management Office
MIT Lincoln Laboratory
United States of America

Jeffory Meyer
Sr. Planning Architect | Design & Construction Division
General Services Administration
United States of America

Jim Butler
Director Global Sourcing
Corporation of the Presiding Bishop
United States of America

John Morrison
Pre-Construction Services
CMSWillowbrook
United States of America

Jolanda Lempers
Best Value Expert
Best Value Verkoop
Netherlands

Kevin Goheen
International Council for Research and Innovation in Building and Construction
Canada

Len Gambla
Director of Business Operations
Neom
United States of America

Matt Thornley
Regional Sales Director
Staples
United States of America

Nathan Chong
Consultant
M&R Facility Concepts, Inc.
United States of America

Neha Malhotra
Project Manager at CBRE
Google
United States of America

Nuno Gonçalo Almeida
IST–ID
Consector Section
Portugal

Pawel Zejer
Senior Project Manager
URS Corporation, an AECOM Company
Poland

Ruslan Hassan
Professor/Specialist Consultant
Construction Research Institute of Malaysia (CREAM)
Malaysia

Stephanie Lindner
Contracting Officer
Federal Emergency Management Agency
United States of America

Steve Hagar
Procurement/Facilities Administrator
Oklahoma Housing Finance Agency
United States of America

Steven Mayle
President
Custom Seal
United States of America

Teena Ziegler
Chief Procurement Officer
Arizona Department of Environmental Quality
United States of America

Yutian Chen, PhD
Educator
Leadership Society of Arizona
United States of America

Table of Contents

© K S M , I n c

Using the Best Value Approach to Improve Project Performance in the Vietnam Construction Industry

Nguyen Le, PhD
MWH Constructors
Arizona, USA

Oswald Chong, PhD, P.E.
Arizona State University
Arizona, USA

Dean Kashiwagi, PhD, P.E.
Kashiwagi Solution Model, Inc.
Arizona, USA

Received: 01 February 2021; Revised: 21 April 2021; Accepted: 27 April 2021

The Vietnam Construction Industry (VCI) has been facing risks that cause delays, budget overrun, and low customer satisfaction that required continuous research efforts on solutions. This paper focuses on how the Best Value Approach (BVA), a procurement and project management philosophy, could be utilized in VCI projects to improve overall performance. Analysis from six industry experts determined how current VCI conditions, namely risk and success factors, are related to the BVA. Sixteen BVA success principles were identified and ranked based on their perceived impact to project performance by an industry survey with 98 VCI practitioners. The results show high agreement rate with all sixteen BVA principles. Spearman's rank-order correlation test determined relatively high agreement between owners and contractors, and lower agreement between owners and consultants on the ranking. The majority of participants agreed that the BVA would improve project performance and were interested in learning more about the BVA. The results encourage further BVA testing and education in the VCI. This approach is not limited to the VCI but could be followed by other developing nations.

Keywords: Best Value Approach, Procurement, Risk Management, Project Management, Performance Information, Developing Countries, Relative Importance Index, Vietnam

Introduction

Nowadays, Vietnam has been emerging as the latest East Asian growth engine which attracts the attention of global investors. Today, Vietnam is currently among the countries with the highest gross domestic product (GDP) growth rates. In 2002, GDP growth in Vietnam hit 7% (high) and recorded the fastest economic growth in Southeast Asia. In 2007, the GDP kept growing to 8.5%, marking the third consecutive year above the 8% benchmark for this small country (Ling & Bui, 2010; Long et al., 2004). The construction sectors account for significant economic growth in Vietnam. The Vietnam Construction Industry (VCI) has been growing at 15% annually in the past 10 years. In 2002, VCI comprised 39% of the GDP growth rate. In 2011, VCI increased its contribution to 41.1%. However, despite large growth and increasing demand for construction, multiple research efforts in the past 15 years, with the most recent one conducted by Le et al. (2020a), have identified that there are still risks in the VCI that cause disastrous results such as schedule delays, budget overruns, and low customer satisfaction. It is therefore imperative to develop and conduct research on potential solutions to improve the VCI project performance.

Objectives of the Study

The objective of this paper is to explore the potential of the Best Value Approach (BVA) and its project delivery process, Performance Information Procurement System (PIPS or BVA PIPS), in construction project applications in the VCI to improve overall performance. Although the research targets the VCI, the methodology presented can be used in other construction industries. Hence, the results would be useful, not only for VCI practitioners but also for those in other developing countries.

Literature Review

Characteristics of the VCI

Dominant risk factors causing non-performance in construction projects in developing countries have been studied and critically reviewed in many scientific journals and reports in the last 20 years. In this context, project performance is defined using one of the most popular definitions of success which is "on time, on budget, and with high customer satisfaction" (Sanvido et al., 1992). In 2020, Le et al. collected over 90 risk factors pertaining to construction project performance from major studies conducted in twelve developing countries. Similar risk factors were grouped under one risk factor and eventually yielded 23 common risk factors. Those risk factors were incorporated in a survey which included 103 VCI practitioners to determine each risk factor's frequency of occurrence, severity, and relative importance in the context of construction projects in Vietnam. The results are as following:

1. Top 5 frequent risks: Bureaucratic administrative system, slow payment of completed works, ineffective designs and frequent design changes, corruption / collusion, and lack of experience in complex projects.
2. Top 5 severe risks: Financial difficulties of owner, poor contractor performance, financial difficulties of contractor, corruption / collusion, and lack of experience in complex projects.
3. Top 5 relatively important risks: Bureaucratic administrative system, financial difficulties of owner, slow payment of completed works, poor contractor performance, and financial difficulties of contractor.

Further analysis examined the interrelationships among those 23 risk factors and grouped them into four main components: 'Lack of Site and Legal Information', 'Lack of Capable Managers', 'Poor Deliverables Quality', and 'Owner's Financial Incapability'.

Le et al. (2020b) conducted a subsequent study pertaining to Critical Success Factors (CSFs) for the VCI. CSFs are certain conditions when achieved would lead to project success, defined by Rockart (1982) as: "…those few key areas of activity in which favorable results are absolutely necessary for a manager to reach his/her goals." This study identified 23 CSFs directly addressing common risk factors in the VCI. The most impactful CSFs as revealed by rankings from 101 VCI practitioners included:

- All project parties clearly understand their responsibilities.

- More serious consideration during contractor selection stage.
- Test contractors' experience and competency through successful projects in the past.
- Project team members need to be well matched to particular projects.
- Promote pre-qualification of tenders and selective bidding.

Those 23 CSFs were further analyzed using factor analysis to examine the principal success factor groupings and resulted into four components: 'Improving Management Capability', 'Adequate Pre-Planning', 'Stakeholders' Management', and 'Performance-based Procurement'.

The studies above provide an understanding of current conditions of the VCI in terms of causes of non-performance and requirements to achieve success. They also created a foundation for future efforts and research to develop management strategies or employ innovative ideas to leverage education and trainings in the VCI.

Best Value Approach

The Best Value Approach (BVA), a procurement and project management philosophy, was first developed at Arizona State University in 1991 (Rivera, 2014). Throughout BVA's development, this method had undergone multiple names including: Performance Information Procurement System (PIPS), Performance Information Risk Management System (PIRMS), and Best Value Procurement (BVP) (Rivera, 2014). BVA uses the Construction Industry Structure chart (Figure 1) to describe the difference between the traditional procurement / project delivery practices and BVA methodology (Kashiwagi et al., 2005).

The environment of traditional procurement / project delivery practices is called price-based environment (Figure 1, Quadrant I). In the price-based environment, the owner directs project by developing the technical requirements, selecting contractor based on technical information, writing the contract, controlling and making decisions. Such practices do not differentiate contractors' capability as all contractors are required to bid on the same "hard" scope. In essence, contractors are to bid on the owner's requirement as directed, regardless of the correctness of the directions. They do not receive credits towards the award for proposing higher quality solutions. As a result, price becomes the dominant selecting criterion, profits become the contractor's sole objectives, and low bid prevails. High-quality contractors have to sacrifice quality and high performance to meet the minimum standards to compete which increase risks to the project as illustrated in Figure 2. Other symptoms of the price-based environment include contractors sending inexperienced personnel, poor performance, higher overall costs, inefficiency, use of relationships to solve problems, and non-transparency (Kashiwagi & Kashiwagi, 2015). The price-based environment characteristics are similar to the conditions in the VCI, as observed in previous studies (Long et al., 2004; Le-Hoai et al., 2008).

The BVA resolves the risks of price-based environment by creating the BVA environment (Figure 1, Quadrant II). The major difference between BVA environment and price-based environment is the replacement of owner's decision making and management, direction, and control (MDC) with the utilization of expertise. In addition to cost, the contractor is hired for his expertise. In the BVA environment, the owner utilizes the contractor to develop technical requirements for a project.

Technical information is only shared with the owner when a contractor is selected. The selected contractor develops the contract for the project and has total control of the project, and the owner only approves the actions. The BVA owner outsources the project to the contractor and thus requires the contractor to be accountable for the project, send their high-performance team to minimize risks, and perform quality control. By observation, the BVA promotes high-performance and minimizes risks that originated from the price-based environment (Kashiwagi et al., 2005, Kashiwagi & Kashiwagi, 2015).

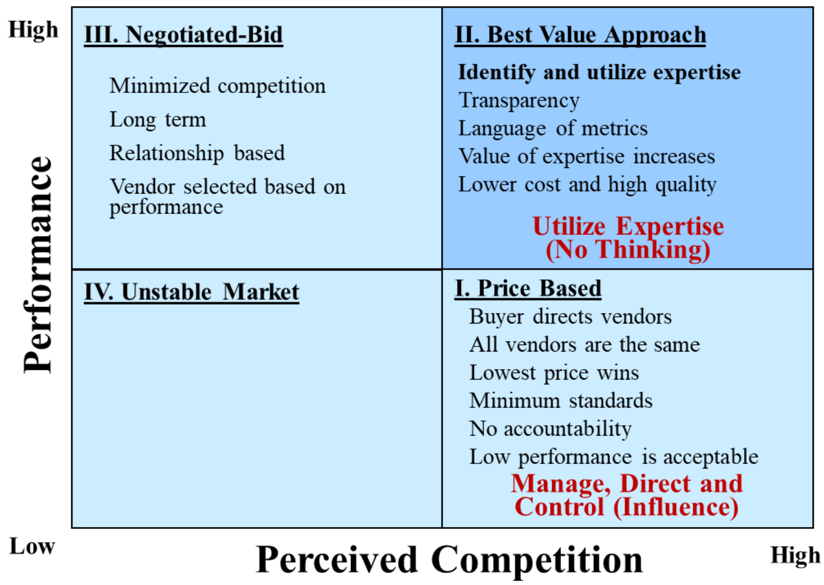


Figure 1: Industry Structure

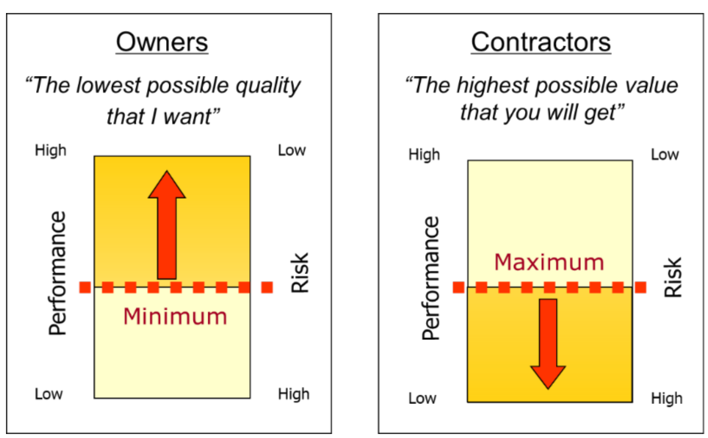


Figure 2: Minimum Standards and Risk

In practice, the BVA is implemented into a four-phase delivery process called Performance Information Procurement System (PIPS or BVA PIPS) (Figure 3) (Kashiwagi, 2019):

- Phase 1 – Preparation: In this case, the owner identifies their project team and develops the Request for Proposal (RFP) which includes their requirements and BVA price controls.

Contractors who are interested in bidding will be educated in the BVA process and how they will be evaluated.

- Phase 2 – Selection: The contractors are ranked in this phase based on their level of expertise specific to the subject project. All contractors compete and set themselves apart using non-technical performance metrics pertaining to their capability to meet the owner's requirements. In this phase, contractors are prioritized solely based on expertise and competitive pricing, not by the offered technical scope as often seen in traditional procurement. However, this does not mean that the bidding contractors should not prepare a scope because their price should be based on a scope that they would be proposing if selected to proceed to the next phase.
- Phase 3 – Clarification: The top-rated contractor in Selection Phase is invited to the Clarification Phase. This contractor will present their scope of work and plan including detailed schedule, milestone schedule, cost, risk management plan, performance metrics to be kept through the project, and the Weekly Risk Report (WRR). The WRR is a BVA template that the selected contractor fills out during Clarification phase and submits to all stakeholders weekly throughout the project. The main functions of the WRR are to track progress and deviation of the contractor's plan; record change orders, project performance metrics, risk management plan; and allow stakeholders to follow and know the status of the project. The owner reviews, discusses, and approves the contractor's proposal before awarding the contract.
- Phase 4 – Execution: The awarded contractor executes their approved proposal. During project development, the contractor is responsible to perform quality control and risk management. All project actions are accomplished and recorded in the WRR.

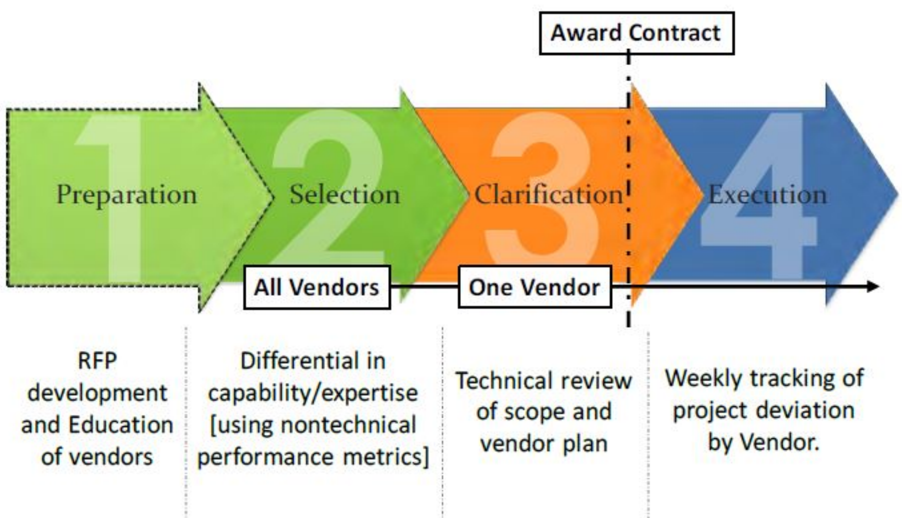


Figure 3: Performance Information Procurement System Process

The BVA and its application, PIPS, are continuously tested to deliver services, mainly in IT and construction industries. To date, BVA has been used in over 2,000 projects with total value of $6.6 billion in 32 US states and many countries with dominant results as shown in Table 1 (Kashiwagi, 2019; Alzara, 2016b). A review of BVA literature indicates that BVA has potential to improve the construction projects' performance in Vietnam. However, an evaluation of BVA application in the VCI has yet to be performed.

Table 1: Examples of BVA Case Studies

Criteria	United Airlines	State of Utah	University of Hawaii	State of Minnesota
Duration	1996 - 1998	1999 - 2011	2000 - 2005	2005 - present
Number of projects	32	4	11	247
Awarded Cost	$13 million	$64.4 million	$1.7 million	$97.2 million
Satisfaction	100%	N/A	92%	100%
On time	98%	100%	100%	100%
Within budget	100%	100%	100%	100%
No change orders	100%	100%	N/A	100%

Research Methodology

Phase 1 – Qualitative Analysis

The purpose of this phase is to identify significant BVA characteristics that are applicable to the context of VCI. The context of VCI is based on previous recent studies on common risk factors (Le et al., 2020a), and success factors (Le et al., 2020b). Brainstorming sessions and unstructured interviews were conducted with a group of six experts consisting of a civil engineering/construction engineering professor, a practicing contractor, two owner representatives from the VCI, and two BVA certified trainers to identify the BVA characteristics related to the context of VCI. These experts each had at least 15 years of experience in their fields at the time of this study. The experts studied and determined the relationships between the VCI current conditions and the BVA PIPS, as illustrated in Figure 4. The relationships revealed how those risk factors could be resolved by success factors, which in turn could be achieved by certain phases in the BVA PIPS process. For example, 'Lack of Site and Legal Information' could be resolved by 'Adequate Pre-Planning' and 'Stakeholders Management' that would be achieved by the 'Clarification' and 'Execution' phases in the BVA PIPS process.

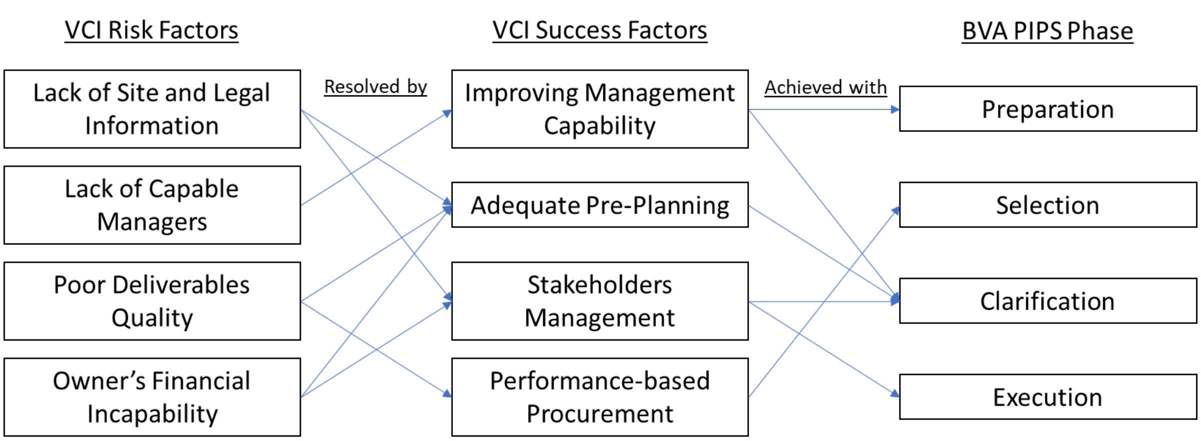


Figure 4: Relationships between VCI Conditions and BVA PIPS Process

Each phase in the BVA PIPS process have unique characteristics. The applicable BVA PIPS characteristics are adopted from two studies from Saudi Arabia (Alzara, 2016a; Algahtany et al., 2016) that yielded a total of 19 BVA principles indicating BVA characteristics that could improve project performance. The experts filtered out 3 unrelated BVA principles and proposed 16 BVA principles pertaining to success in the VCI that were then incorporated in an industry survey to evaluate their relative importance.

Phase 2 – Industry Survey and Quantitative Analysis

This research uses a field survey as its key research method to collect data pertaining to the research objectives. The survey collects data from various VCI practitioners pertaining to their perspectives on the pre-established 16 BVA principles. The survey aims to identify the relative impacts that those BVA principles had on project performance in the VCI. The survey also asks the respondents on whether the presented 16 BVA principles would improve project performance, and if they are interested in learning more about BVA. The five-point Likert scale of 1 to 5 measured the respondents' agreement on each BVA principle. The numerical values assigned for the Likert Scale are as follow: '0 – Strongly Disagree, 1 – Disagree, 2 – Neutral, 3 – Agree, 4 – Strongly Agree'.

The survey was validated before it was distributed. The same group of experts in Phase 1 were utilized to participate in the validation exercises. The experts were requested to critically review the structure and content of the questionnaire, and recommended changes to the originals. Their recommendations are incorporated into the final questionnaire, which was then sent to the survey participants in Vietnam. The participants are divided into "Owners", "Contractors" and "Consultants", and they were either sent an email with a link connected to the survey or physical mail to their offices. The online survey was developed using Google Survey and printed copies of the survey forms were mailed out with return envelopes enclosed. Completed surveys were compiled online and physically from the returned mails. The surveys were returned within a month after they were mailed out.

The collected survey was quantitatively analyzed using IBM SPSS Statistics v25. The research team conducted the following analysis:

1. Cronbach's alpha coefficients to test internal consistency of the results.
2. Relative Importance Indexing to rank the BVA principles based on response ratings data.
3. Spearman's rank-order correlation coefficient to determine the degree of agreement of rankings between each responded group.

Data Collection

The survey was sent to over 300 construction professionals from the three construction stakeholder groups only in Vietnam. Contacts of survey participants had been previously obtained from public database and private networks. These professionals were selected from construction companies involved in sectors such as Commercial / Residential, Infrastructure / Heavy Civil, and Industrial. These sectors consist of large and complex projects which are often exposed to multiple risk factors that result in delays, over-budget, and low stakeholder satisfaction issues (Adafin, et al., 2019; Arief & Latief, 2021; Wu et al., 2018; Rana & Pitroda, 2021; Marmaya & Mahbub, 2018).

Nearly half of the surveys were returned (140 surveys were returned). Of the 140 surveys that were returned, incomplete surveys were eliminated from the responses. As a result, 42 surveys were removed from the analysis. A total of 98 completed surveys remained for further analysis (described in Table 2). While the total response rate was around 47%, a total of 32.7% of the invited survey were used for the analysis.

Table 2: Characteristics of Questionnaire Respondents

Demographic Characteristics	Responses	%
Groups		
Owners	44	44.9%
Contractors	34	34.7%
Consultants	20	20.4%
Industry Experience		
0 - 5 years	18	18.4%
6 - 10 years	18	18.4%
11 - 20 years	37	37.8%
Over 20 years	25	25.5%
Project Types		
Commercial / Residential	59	60.4%
Infrastructure / Heavy Civil	22	22.3%
Industrial	17	17.3%
Project Sizes		
< $1M	16	16.3%
$1M - 5M	41	41.8%
> $5M	41	41.8%

Among the 98 returned questionnaires, 44 respondents worked for owners (44.9% of the responses), 34 for contractors (34.7%), and 20 for designers and/or consultants (20.4%). The majority of participants held high-level managerial positions, such as project managers, directors, or associate directors. The respondents' mean years of relevant experience in the construction industry is around 16 years. Such highly experienced profile and the management roles of the respondents would likely translate into highly reliable results and thus enhance the quality of the findings.

Data Analysis

The research team conducted the following analysis:

1. Cronbach's alpha coefficients to test internal consistency of the results,
2. Relative Importance Indexing to rank the BVA principles based on response ratings data,
3. Spearman's rank-order correlation coefficient to determine the degree of agreement of rankings between each responded group.

Cronbach's Alpha Coefficients

The Cronbach's Alpha Coefficients of the internal consistency reliability tests for impact ratings of the survey results are 0.955. Litwin & Fink (1995) suggested that consistency is high when Cronbach's alpha is above 0.7. This confirmed that there is high internal consistency among the answers.

Relative Importance Indexing

The survey results were analyzed using Relative Importance Index that were previously employed in several studies (Kaming et al. (1997); Le-Hoai (2008); Doloi, et al. (2012). This index measures the degree of agreement on each BVA principle. It is computed with the following formula:

$$RII = \frac{\sum_{0}^{4} a_i n_i}{4N}$$

in which a = the weight assigned to each response (as in this research, a range of 0 for "Strongly Disagree" to 4 for "Strongly Agree"), n = frequency of occurrence for each response, and N = total number of responses.

Ranking of BVA Principles

The calculations of RII and the ranking of the 16 BVA principles identified in the questionnaire are presented in Table 3. All 16 BVA principles have overall RII values between 0.8 and 0.6 (with 1.0 indicates absolute agreement and 0.0 indicates absolute disagreement). High RII values indicate that the respondents generally agreed with BVA principles. Six BVA principles namely, 'selection of contractors based on performance with price should be supported', 'existence of expert project manager with the contractor is essential', 'project milestone schedule should include all risks and activities of client and other stakeholders', 'interviewing the selected contractor's project manager performing the work is necessary', 'being transparent by updating all stakeholders weekly about all upcoming activities would help and motivate them to be accountable for their own activities', and 'contractors should be required to submit verifiable performance information' are highly ranked by all respondent groups. These BVA principles ranking would help to establish their relative impact on project performance and attention should be given to them during project development in the VCI. VCI practitioners could also choose to adopt certain BVA principles to their management strategies to improve and monitor project performance.

Table 3: Relative Importance Index and Rankings

Phase	BVA Principles	Overall		Owners		Contractors		Consultants	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
(S)	Selection of contractors based on performance with price should be supported	0.791	1	0.801	1	0.824	1	0.713	1
All	Existence of expert project manager with the contractor is essential	0.755	2	0.767	2	0.809	2	0.638	9
(C)	Project milestone schedule should include all risks and activities of client and other stakeholders	0.745	3	0.761	3	0.779	5	0.650	5
(S)	Interviewing the selected contractor's project manager performing the work is necessary	0.740	4	0.750	4	0.779	5	0.650	5
(E)	Being transparent by updating all stakeholders weekly about all upcoming activities would help and motivate them to be accountable for their own activities	0.735	5	0.722	8	0.779	5	0.688	3
(S)	Contractors should be required to submit verifiable performance information	0.735	5	0.744	6	0.787	4	0.625	10
(E)	The contractor is the best party that can prepare project weekly reports; owner and consultants should review them	0.727	7	0.699	10	0.794	3	0.675	4
(S)	Contractors should be required to submit foreseeable risks on the project and how they will manage them	0.724	8	0.750	4	0.735	11	0.650	5
(E)	Tracking schedule and cost deviations and their responsible parties would help in measuring all parties' performance	0.719	9	0.705	9	0.743	10	0.713	1
(E)	Reminding stakeholders about what, when, and how to manage their risks and activities would help them increase their performance	0.709	10	0.699	10	0.779	5	0.613	12
(C)	Adding the requirement for contractor to plan the project from beginning to end, including scope of work, technical and milestone schedule, risks not in their control, and how they will measure their performance would improve the quality of procurement process	0.704	11	0.733	7	0.735	11	0.588	14
(E)	Weekly update of all stakeholders' performance would motivate them to be accountable for their tasks	0.696	12	0.665	13	0.765	9	0.650	5
(S)	The government documents and posts projects and contractors performance for comparison would be beneficial	0.678	13	0.688	12	0.721	14	0.579	15
(C)	The contractor identifies and assists stakeholders in managing their own risks would reduce those risk impacts	0.676	14	0.665	13	0.721	14	0.625	10
(C)	Disputes would be minimized if the contractor includes all activities and risks out of their control in the plan and measures all parties' performance during the project	0.661	15	0.665	13	0.691	16	0.600	13
(C)	Project performance would increase if the contractor includes all stakeholders' risks and activities in milestone schedule and measure their performance during project development	0.658	16	0.648	16	0.728	13	0.563	16

*PIPS Phases: Selection (S), Clarification (C), Execution (E)

Spearman's Rank-Order Correlation

The Spearman's Rank-Order Correlation (SRC) measures the implied degree of agreement on the ranking among groups of respondents. The value correlation coefficient ranges between +1 and -1, where +1 indicates absolute positive relationship (agreement), while -1 indicates absolute negative relationship (disagreement) (Tikote et al., 2017). It is computed with the following formula:

$$\rho = 1 - \frac{6 \times \sum d^2}{n(n^2 - 1)}$$

in which ρ = level of consensus between two groups ($0 \leq \rho \leq 1$); d = the difference in ranking of a risk factor, and n = number of ranking places.

Table 4 shows the results of Spearman's Rank-Order Correlation and significance level calculations among the respondents. The results show that there is generally good agreement between owners and contractors (69%). However, designers / consultants did not share similar views as Table 4 indicates. The survey shows that the consultants did not generally agree with the owners and contractors. Owners and contractors commonly share more similar project goals (i.e. on-time, on-budget) and their perception on project quality is mostly similar (quality generally means focusing on visible quality). The goals of designers and consultants focus are mainly on the technical aspects of projects, such as structural design, aesthetics and functional performances. The designers/consultants are also involved at the design and planning phases of the projects, rather than the actual construction process.

Table 4: Spearman's Rank-Order Correlation Among Responding Groups

Groups	SRC	Sig. level
Owners - Contractors	0.688	0.003
Contractors - Consultants	0.582	0.018
Owners - Consultants	0.489	0.055

Final Impressions and Interests

The respondents were asked about whether the presented 16 BVA principles would improve project performance, and if they are interested in learning more about BVA. As a result, 69.3% of the respondents agreed that the presented BVA principles would improve project performance, while 31.6% were neutral, and 6.1% disagreed. Last but not least, 64.3% of the respondents were interested in learning more about BVA, while 31.6% were neutral, and 4.1% were not interested (Table 5).

Table 5: Impressions and Interests about BVA

Claims	Responses	%
BVA would improve project performance		
Agree & Strongly Agree	68	69.4%
Neutral	24	24.5%
Disagree & Strongly Disagree	6	6.1%
To learn more about BVA		
Interested	63	64.3%
Neutral	31	31.6%
Not Interested	4	4.1%

Conclusions

As a developing country, the economy in Vietnam has been growing fast and steady with significant contribution from construction activities. However, multiple studies in the past 15 years identify that there are still risks existing in the Vietnam Construction Industry (VCI)'s projects that cause schedule delays, budget overruns, and low customer satisfaction. Therefore, it is necessary to continuously develop research on solutions to manage risks and improve the VCI performance. The main results of this paper are as follows:

- Reviewing current VCI conditions in terms of common risk factors and success factors pertaining to project performance. Project performance is defined as on-time, on-budget, and with high customer satisfaction.
- Introduction of the Best Value Approach (BVA) and its project delivery process, Performance Information Procurement System (PIPS), to analyze BVA's potential to be applied in construction projects in the VCI and improve overall performance.
- Sixteen BVA principles were identified as a result of a qualitative analysis of six experts and survey ratings by 98 construction practitioners in Vietnam. The BVA principles were ranked to help establish their relative impact on project performance and attention should be given to them during project development.
- VCI practitioners indicated that they agreed with the BVA principles and that BVA would improve project performance in the industry. The majority of survey respondents were interested in learning more about BVA.

Further efforts are recommended to strengthen this research. Pilot tests using BVA on actual construction projects in Vietnam are necessary to accurately determine BVA's utility to the industry. Education of BVA is also important as it is a change from the traditional approach of the industry. Current students, owners, contractors, and consultants who have interests in performance information, performance procurement, project management, and risk management should seek opportunities to be educated in BVA. University environment is ideal to proliferate BVA education in terms of graduate degree program, research initiatives, workshops, and guest lectures. The approach in this research is general that it may be followed by researchers from other developing countries.

References

Adafin, Johnson, et al. "An assessment of risk factors impacting budget variability in New Zealand commercial construction projects." (2019).

Algahtany, M., Alhammadi, Y., & Kashiwagi, D. (2016). Introducing a New Risk Management Model to the Saudi Arabian Construction Industry. Procedia Engineering, 145, 940–947. https://doi.org/10.1016/J.PROENG.2016.04.122

Alzara, M. A. (2016). Measuring the Construction Performance in Saudi Arabia and Proposing New Procurement Model Based on BV PIPS (A University Case Study). Retrieved from https://repository.asu.edu/items/41230

Alzara, M., Kashiwagi, J., Kashiwagi, D., & Al-Tassand, A. (2016). Using PIPS to minimize causes of delay in Saudi Arabian construction projects: university case study. In: International Conference on Sustainable Design, Engineering and Construction. In International Conference on Sustainable Design, Engineering and Construction (pp. 932 – 939). Retrieved from https://www.sciencedirect.com/science/article/pii/S1877705816301278

Arief, M., and Y. Latief. "Project planning system improvement in residential development project: A risk analysis." IOP Conference Series: Materials Science and Engineering. Vol. 1098. No. 2. IOP Publishing, 2021.

Doloi, H., Sawhney, A., & Iyer, K. C. (2012). Structural equation model for investigating factors affecting delay in Indian construction projects. Construction Management and Economics, 30(10), 869–884. https://doi.org/10.1080/01446193.2012.717705

John F. Rockart. (1982). The Changing Role of the Information Systems Executive: A Critical Success Factors Perspective. Sloan Management Review, 3–13. Retrieved from http://www.sims.monash.edu.au/subjects/ims5042/stuff/readings/rockart_1982.pdf

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., & Harris, F. C. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia. Construction Management and Economics, 15(1), 83–94. https://doi.org/10.1080/014461997373132

Kashiwagi, D. (2019). How to Know Everything Without Knowing Anything Volume 3. (I. Kashiwagi, J. Kashiwagi, & J. Kashiwagi, Eds.). Mesa: Kashiwagi Solution Model Inc.

Kashiwagi, D., Sullivan, K. T., Greenwood, D., Kovell, J., & Egbu, C. (2005). Source of Construction Industry Instability and Performance Problems. In Construction Research Congress 2005 (pp. 1–10). Reston, VA: American Society of Civil Engineers. https://doi.org/10.1061/40754(183)79

Kashiwagi, I., & Kashiwagi, D. (2015). The Cause of Collusion in the IT and Construction Industries, 7(1), 1–16. Retrieved from https://www.researchgate.net/publication/295854271

Le, N., Chong, O., & Sullivan, K. (2020a). Construction Risks in Developing Countries: A Vietnam Case Study. Journal for the Advancement of Performance Information and Value, 12(1), 30 - 49. https://doi.org/10.37265/japiv.v12i1.41

Le, N., Chong, O., & Kashiwagi, D. (2020b). Success Factors for Project Risk Management in Construction Projects: A Vietnam Case Study. Journal for the Advancement of Performance Information and Value, 12(2), 63. https://doi.org/10.37265/japiv.v12i2.126

Ling, F. Y. Y., & Bui, T. T. D. (2010). Factors affecting construction project outcomes: case study of Vietnam. Journal of Professional Issues in Engineering Education and Practice, 136(3), 148–155. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000013

Litwin, M. (1995). How to Measure Survey Reliability and Validity. SAGE Publications. https://doi.org/10.4135/9781483348957

Long, N. D., Ogunlana, S., Quang, T., & Lam, K. C. (2004). Large construction projects in developing countries: A case study from Vietnam. International Journal of Project Management, 22(7), 553–561. https://doi.org/10.1016/j.ijproman.2004.03.004

Marmaya, Ezyana Anyzah, and Rohana Mahbub. "Evaluation of Environmental Impact and Risk Assessment Methods of Industrial Buildings in Malaysia." Asian Journal of Quality of Life (AjQoL) 3.13 (2018): 39-47.

Rana, Jyotin Shaileshbhai, and J. R. Pitroda. "Risk Analysis and Mitigation Technique in Indian Transportation Industries: A Review." Reliability: Theory & Applications SI 1 (60) (2021).

Rivera, A. (2014). Impact of a Non-Traditional Research Approach: Case Study on the Performance Based Studies Research Group (PBSRG). Retrieved from https://repository.asu.edu/attachments/143378/content/Rivera_asu_0010N_14488.pdf

Sanvido, V., Grobler, F., Parfitt, K., Guvenis, M., & Coyle, M. (1992). Critical Success Factors for Construction Projects. Journal of Construction Engineering and Management, 118(1), 94–111. https://doi.org/10.1061/(ASCE)0733-9364(1992)118:1(94)

Tikote, R. H., Magdum, M. M., & Khandare, M. A. (2017). Delay Analysis in Industrial Projects by using Relative Importance Index Method. Retrieved from https://www.semanticscholar.org/paper/Delay-Analysis-in-Industrial-Projects-by-using-Tikote-Magdum/87974ebc032c34fa4c69f3e6d97b435ef7854bda

Wu, Yunna, et al. "Risk management of public-private partnership charging infrastructure projects in China based on a three-dimension framework." Energy 165 (2018): 1089-1101.

Synthesis of Practices and Tools for Cost Estimation and Cost Management for Transportation Projects

Minsoo Baek, Ph.D.
Kennesaw State University
Marietta, Georgia, United States

Baabak Ashuri, Ph.D.
Georgia Institute of Technology
Atlanta, Georgia, United States

Received: 11 February 2021; Revised: 13 April 2021; Accepted: 26 April 2021

Cost escalation during project development is inevitable on transportation projects. The lack of a systematic process for establishing a baseline budget with the consideration of potential issues (risks) that negatively impact project cost throughout project development presents a major challenge for State Departments of Transportation (DOTs). The overarching objective of this paper is to identify best practices for cost estimation and management that can aid project managers and engineers throughout the project development process (PDP). To achieve the objective, this paper conducted a systematic literature review, comprehensive content analysis of cost estimation and cost management processes in other State DOTs, and interviews with transportation cost professionals. A systematic literature review identified four key areas for cost estimation and cost management, including: (1) risk analysis and contingency; (2) identification of cost escalation factors; (3) accuracy of preliminary cost estimate; (4) and constructability review. Cost estimation and control processes in Minnesota, California, Texas, Ohio, and Washington State DOTs are provided as examples of best practices for establishing reliable baseline cost estimates. This paper represents a current synthesis of state DOTs' practices on cost estimation and cost management in the U.S.

Keywords: Baseline Cost Estimate, Cost Control, Cost Estimation, Cost Management, Risk Management.

Introduction

Cost growth during project development is a major concern for State highway agencies (SHAs) that lack funds and resources. According to a study conducted by Anderson et al. (2008), half of the large transportation projects in the United States have exceeded their initial budgets. Also, the Government Accountability Office (GAO) proposed that 77% of highway projects in the United States experience cost escalation (GAO, 1997). Considerable research effort has been devoted to establishing accurate cost estimates early in the project development process (PDP) and controlling established budgets throughout the PDP. For instance, National Cooperative Highway Research Program (NCHRP) Report 574 developed guidance for cost estimation management and cost estimation practices to aid SHAs in developing consistent and accurate project estimates. This research report provided several global strategies to manage cost escalation factors (Anderson et al., 2007). NCHRP Report 826 provided transportation agencies with guidance on estimating preconstruction services costs and managing those costs throughout the PDP. This report suggested that data-driven methodologies (i.e., a top-down and a bottom-up approach) are required to promote consistency and accuracy of the preconstruction services costs and also address a project cost escalation issue (Gransberg et al., 2016).

© K S M , I n c

Another NCHRP Report conducted by Anderson et al. (2008) addressed the cost escalation problem by identifying issues inherent to right-of-way cost estimation and providing SHAs with a structured right-of-way cost management process during the PDP. In follow-up research (Biehler et al., 2010), a systematic process for risk analysis and management was proposed to assist SHAs in controlling project cost escalation. The guidebook provides several risk analysis tools and management practices for risk identification, assessment, analysis, mitigation, allocation, and monitoring and control, which can be facilitated by SHAs.

Furthermore, the American Association of State Highway and Transportation Officials (AASHTO) (AASHTO, 2013) provided practical guidance to help SHAs develop accurate cost estimates and manage the estimating process. This guidance asserted that cost estimating should be conducted simultaneously during preconstruction phases of project development. Previous research on a cost escalation problem disclosed that allocating efficient time and resources for cost estimation is important, establishing baseline cost estimates early in the PDP is critical, conducting a risk management process during PDP is essential, and performing a review process for the cost estimates during the PDP is important for controlling cost growth. However, managing cost escalation during the project development becomes more difficult because of the increase of complexity and uncertainty of highway projects and the number of participants involved in the project development, the constraints in legal or regulatory, and the interventions of the public on the projects.

Several studies have pointed that SHAs have a difficulty in mitigating cost escalation during project development because of several failures. For example, SHAs fail to establish a feasible and reliable project budget because of the incomplete or uncertain information of a project early in the project development. Moreover, SHAs have limited capability to control the established budget throughout the project development process because of uncertainty in scope, design, cost, and schedule. A failure of developing a feasible and reliable project budget and controlling the established budget often leads to significant changes in project scope and schedule. According to a study conducted by Molenaar and Wilson (2009), inconsistent and inaccurate cost estimates place significant burdens on SHAs in delivering their project by causing negative impacts such as scope changes, performance shortfalls, misallocation of funds, and a loss in benefits to the public.

Preconstruction activities conducted as parts of the PDP have profound impacts on the final project cost and schedule. The ability of the agencies to influence project cost and schedule is reduced as the project moves along through the PDP (Chou, 2009).Critical decisions made in the design development process have direct impacts on the final project cost. Therefore, it is important to establish and create a proper baseline budget model as early as possible during the initial phases of the PDP. Anderson et al. (2007) claimed that the cost control process should be monitored and documented as the project advances for assisting project managers and estimators in managing cost escalation that occurred with scope changes or risks. Moreover, if the project development process is not properly managed, there is a good chance that the owner experiences cost overrun and schedule delay for the project. The major root causes of cost overrun and schedule delay include an unreliable baseline cost estimate, a failure to be aware of uncertainty early in the project development, and lack of appropriate risk-related management practices and analysis tools for managing and controlling the established budget and schedule (Shane et al., 2009; Molenaar et al., 2010).

Although the past studies provided a list of strategies, methods, and tools for cost estimation and cost management during the PDP, few have provided best practices with major benefits for developing and controlling cost estimates during project development.

Research Methodology

The research methodology consists of a systematic literature review, comprehensive content analysis, and interviews with transportation cost professionals. The following steps are followed in the research methodology:

1. Systematic literature review on major issues during the PDP studied in construction management journals.
2. Comprehensive content analysis on the state of practice in budget-based design in State Departments of Transportation (DOTs).
3. Result validation with transportation cost professionals in other State DOTs.

In this review, this study reviewed papers that studied major issues during the project development process in highway projects. Papers published in the construction management journals such as *Journal of Construction Engineering and Management*, *Journal of Management in Engineering*, *Transportation Research Board*, and *International Journal of Project Management* are reviewed for identifying the current state of research in cost control during project development.

This paper conducted a comprehensive content analysis to explore the current state of practice in cost control in the highway industry by analyzing the content of the project development documents of other State DOTs. This paper performed follow-up interviews with the selected transportation cost professionals to identify practical solutions for controlling project costs during the PDP.

Results

Key Areas of Cost Estimation and Management

Through a systematic literature review, this study identified key areas for cost estimation and management during the project development as follows:

- Risk analysis and Contingency- Molenaar (2005); Molenaar and Wilson (2009); Teye Buertey et al. (2012); Diab (2013); and Diab et al. (2017).
- Identification of Cost Escalation Factors- Akinci and Martin (1998); and Shane et al. (2009).
- Accuracy of Preliminary Cost Estimate- Chou et al. (2006); Chou (2009); Asmar et al. (2011); Harper et al. (2014); and Gardner et al. (2016).

- Constructability Review- Anderson et al. (1999); Fisher et al. (2000); Goodrum et al. (2004).

1. Research into Risk Analysis and Contingency

A well-structured procedure integrated with risk analysis tools is essential for developing more accurate cost estimates and controlling cost escalation during the project development process. Also, effective risk analysis enables one to estimate contingency for highway projects. Several studies have focused on risk analysis and the contingency estimating process. Molenaar (2005) presented a programmatic approach to cost-risk analysis for cost estimation for highway megaprojects. The author insisted that cost estimation practices need to improve because many projects are often cut in scope or canceled altogether due to other projects exceeding their budgets. The author believed that utilizing stochastic methods (range cost estimates) for estimating project costs can be more applicable in the conceptual phase of PDP because of the uncertain nature of project costs. The author concluded that the process of the programmatic cost-risk analysis enables one to have greater transparency of project cost and uncertainty to both program management and stakeholders and better understanding and communication of the risks involved in large transportation projects.

Moreover, Molenaar and Wilson (2009) proposed a three-tier approach for risk analysis and contingency estimation. The authors classified the complexities of highway projects in three levels (i.e., most complex projects, moderately complex projects, and non-complex projects) and summarized risk identification, risk analysis, and contingency estimating tools for a three-tier approach. The authors proposed that consistent application of risk management and better estimates for contingency can mitigate cost escalation problems.

Teye Buertey et al. (2012) investigated the cost contingency estimating process and proposed a framework to improve upon the practice. The authors urged that the contingency amount varies according to the completeness of design, predicted design variation, and certainty of the construction technology. The authors proposed an integration process of design, cost estimation, and risk modeling. Furthermore, the authors believed that collaborative team effort by the project team can enhance the project risk identification and successive management.
Diab (2013) studied cost and schedule growth of highway projects with risk assessment in the planning phase. The author identified several factors that impact project costs, including utility conflicts, increase toxics exposure with construction materials and methods, increased congestion and delays for motorists, etc. The author concluded that integrating risk assessment should be included in the planning phase of PDP for the effective construction engineering and management practices and the sustainability of infrastructure projects against risk drivers that cause cost growth and schedule delay.

Diab et al. (2017) assessed the impact of risk drivers on the owner's and/or contractor's contingency amounts using regression analysis. The authors insisted that the accuracy of contingency relies on the systematic assessment of project risks. They concluded that risk drivers should be taken into account in building their baseline schedule. Inadequate constructability review and design of structures are critical risk drivers in estimating the contingency amount. The major recommendations for risk analysis and contingency identified from the literature are as follows:

- Incorporate risk assessment into the project development process.
- Conduct a systematic risk analysis process for understanding and communicating project risks.
- Utilize proper and consistent risk analysis tools for more accurate estimates of contingency.
- Require a collaborative team effort for identifying project risks and performing effective risk management.

2. Research into Identification of Cost Escalation Factors

Awareness of the potential cost escalation factors has a critical impact on controlling the project costs as the design advances throughout various phases. Akinci and Martin (1998) identified factors causing cost overruns during the project development process of construction projects. The authors focused on the external factors that are not controllable by owners and contractors. The factors affecting cost estimates of projects include estimator's biases, vagueness in scope, design complexity, and project size. Then, they urged that these factors should be identified and considered during developing cost estimates in project development.

A study by Shane et al. (2009) identified cost increase factors for highway projects through an in-depth literature review and verified the identified factors with over 20 state highway agencies. The authors stated that cost estimators should properly consider the project scope, economic conditions, community interest, and the macroeconomic condition when developing cost estimates. Also, to deliver projects on budget, the agencies should have a baseline cost, an awareness of factors that can cause cost escalation, and project management discipline. Thus, the authors identified several cost escalation factors, classified internal factors (e.g., optimistic cost estimates, lack of experience with a delivery method or procurement approach, and budget constraints) and external factors (e.g., local government concerns and requirements, fluctuations in the rate of inflation, and scope change) during the planning and design stages of the project development. The author concluded that awareness of the cost escalation factors can be an initial process for mitigating cost escalations. They proposed that thorough estimate documentation approval processes during the PDP and education and communication of their parties regarding the cost and schedule impacts can improve the consistency and accuracy in cost estimates.

The major recommendations for identification of cost escalation factors identified in the literature are as follows:

- Identify potential cost escalation factors early in the project development.
- Document the identified factors and communicate them to the project team.

3. Research into Accuracy of Preliminary Cost Estimates

The inaccuracy of baseline cost estimates causes a significant challenge in delivering projects for SHAs who have limited funds. Thus, several studies put efforts into improving the accuracy of initial cost estimates during project development. For instance, Chou et al. (2006) developed an item-level cost estimating system to predict major item costs and total project costs using highway projects let in the state of Texas. The authors claimed that the accuracy of cost estimates highly relies on the extent of information available at the time the estimate is developed. They showed that there is a strong relationship between the item quantities and the parameters (e.g., project length, project width, and project location). Thus, the authors incorporated the quantity predicting models into an item-level cost estimating system. In the following study, Chou (2009) developed a case-based reasoning model to estimate the preliminary project costs for highway pavement projects. The author claimed that the accuracy of preliminary cost estimates is affected by several factors such as roadway configuration (e.g., roadway area, lane width, and project length), engineering planning (e.g., work schedule and traffic volume), and site condition (e.g., terrain and project location).

Asmar et al. (2011) provided the statistical approach for developing a reliable conceptual cost estimate. The authors proposed a technique similar to the program evaluation and review technique (PERT) for conceptual cost estimating and the analysis of cost data. The authors insisted that the proposed approach helps the state highway agency rely on historical cost data, instead of judgment, to identify the minimum, maximum, and most probable values and provides confidence levels for cost estimates at different project phases. The authors concluded that the introduced approach that assigns a confidence level to the cost estimate can enhance the accuracy of the cost estimates at the conceptual design stage.

Harper et al. (2014) provided a comprehensive list of valid performance measures for cost estimating for highway projects. The authors believed that performance measures can help state highway agencies evaluate cost estimates at different phases during the PDP and improve the estimate accuracy by tracking the cost estimates. The authors concluded that monitoring the cost estimates and the contingency amount has a significant impact on the accuracy of the cost estimates throughout the PDP. Through utilizing the questionnaire and interviews, the authors defined five important performance measures for monitoring cost estimates as the following: (1) bidding accuracy; (2) estimating accuracy; (3) competition effects; (4) estimating process; and (5) contingency amount. The authors also claimed that monitoring the cost estimate and contingency amount is critical for controlling cost escalation and avoiding design scope creep.

Gardner et al. (2016) conducted a quantitative analysis to evaluate the effort expended for data-driven conceptual cost estimating to enhance the accuracy of the estimates for highway projects. The authors mentioned that highway agencies need to optimize their effort in estimating construction costs at the conceptual stage for the later stages in the project development. They identified cost-influencing attributes and evaluated the efforts on these attributes through the survey. They found that data-driven conceptual cost estimating can achieve reasonable accuracy at the early stage of project development by including all project attributes.

The major recommendations for accuracy of preliminary cost estimates identified from the literature are as follows:

- Identify critical factors that impact project costs.
- Assign a confidence level to the cost estimate.
- Monitor performance of the cost estimate and contingency amount.
- Consider a data-driven approach for estimating project costs at the early stage of the PDP.

4. Research into Constructability Review

The constructability of a project has a critical impact on design development. Effective constructability reviews can support improving project document quality and minimizing the scope and schedule changes during not only the PDP but also during construction (Anderson et al., 2007). Several studies focused on the constructability reviews during highway project development. Anderson et al. (1999) identified the critical issues in implementing constructability reviews for transportation projects from the perspective of state highway agencies, design firms, and construction firms. The author presented critical issues for constructability reviews for highway projects in three categories: (1) project execution processes (e.g., lack of feedback from designers, lack of adequate coordination of design, plans, and specifications, lack of communications); (2) project planning and technical design documents (e.g., lack of need to improve plans and specification and lack of coordinated timing, phasing, and scheduling); and (3) project resources (e.g., lack of adequate time to review, lack of cost considerations, and lack of experience and knowledge).

Fisher et al. (2000) reviewed and developed constructability tools for constructability reviews. The author claimed that the proper selection of constructability tools can optimize and improve project cost-effectiveness and information quality. They identified paper-based and computer-based tools for constructability reviews, such as constructability meetings, implementation responsibility matrix, and value engineering, which can be utilized in different phases (i.e., planning, design, and construction). They also concluded that integrating constructability review tools with the formal process can help the owners/contractors have a systematic and pragmatic approach to implementing constructability review on their projects.

Goodrum et al. (2004) studied State DOTs' constructability practice for highway projects and identified barriers to implementing constructability programs for their projects. The authors provided major barriers to constructability efforts including insufficient time for constructability review programs during the PDP, a lack of personnel to staff their constructability review programs, a lack of experience for constructability programs, and reluctance on the part of contractors to participate in a constructability review program. Also, the authors identified major constructability issues, including utility, traffic control, geotechnical issues (e.g., unforeseen rock and soil conditions), right-of-way, and bridge structures, that impact cost, schedule, and quality of a project. They concluded that constructability reviews should be included in the project development process. They also insisted that State DOTs need changes in the approach of project development, such as the development of close working relations between State DOTs and utility companies, prioritizing and securing key right-of-way agreements before construction begins, and allocation of funds to support the presence of law enforcement personnel in construction work zones.

The major recommendations for constructability issues identified in the literature are as follows:

- Identify constructability issues early in the project development.
- Integrate constructability review tools into the project development.

Best Practices in Cost Control in Other State DOTs

This study reviewed the current state of practices in cost estimation and control in several State DOTs and identified best practices in cost estimation and management strategies for cost control. Table 1 provides the summary of best practices of state DOTs, including Minnesota, California, Texas, Ohio, and Washington State DOTs.

Table 1: Summary of Best Practices in State DOTs' Control Strategies

State DOTs	Best Practices	Major Purposes
Minnesota Department of Transportation (MnDOT)	Variance Reports on Cost and Schedule	• Provides an early alerting system of discrepancies between the baseline of cost and schedule and current cost estimates and schedule
California Department of Transportation (Caltrans)	Quality Assurance (QA)/Quality Control (QC) Certification Practice	• To provide a review process to evaluate the completeness and readability of the estimate documents
Texas Department of Transportation (TxDOT)	Advance Planning Risk Analysis (APRA) – A Spreadsheet-based Tool	• To quickly predict factors impacting project risk
	Design Summary Report (DSR) including the Design Conference	• To record significant changes in this report
Ohio Department of Transportation (ODOT)	Alternative Evaluation Report (AER)	• To encompass the alternatives with the critical elements identified in the Purpose and Need Statement
Washington State Department of Transportation (WSDOT)	Cost Risk Assessment (CRA) and Cost Estimate Validation Process (CEVP) Workshop	• To provide qualitative and quantitative risk analysis techniques

Table 2 provides the comparison of state DOTs' cost estimation practices regarding the milestones and responsible parties of cost estimation during the PDP. It showed that several state DOTs established key decision points or milestones for developing and updating cost estimates during the PDP. Furthermore, it requires different parties/disciplines to be involved in developing and updating cost estimates. For instance, MnDOT established cost estimation milestones based on the design development (e.g., 1%-15%, 10%-20%, and 30% - 90%). Caltrans established two major milestones and six sub-milestones for preparing project planning cost estimates and project design cost estimates following the development of critical information for the project development.

Table 2: Comparison of State DOTs' Cost Estimation Practices

State DOTs	Major Milestones for Cost Estimates during PDP	Responsible Parties	
MnDOT	• Planning (Conceptual Estimating) (Design Development 1% to 15%) • Scoping (Scope Estimating) (Design Development 10% to 30%) • Design (Design Estimating) (Design Development 30% to 90%) • Letting (PS&E Estimating) (Design Development 90% to100%)	**Lead:** • Project Manager • Assistant District Engineer • Central Office Estimator	**Support:** • District Engineer • State Estimation Office • Functional Groups • Etc.
Caltrans	• Project Planning Cost Estimates ○ Project Feasibility Cost Estimate ○ Project Initiation Cost Estimate ○ Draft Project Report (PR) Cost Estimate ○ Project Report (PR) Cost Estimate • Project Design Cost Estimates ○ Preliminary Engineer's Cost Estimate ○ Final Engineer's Cost Estimate	**Lead:** • Project Manager and Project Engineer	**Support:** • Headquarters Division • District Right-of-Way • District Director • External Stakeholders • Etc.
TxDOT	• Planning and Programming (Design Development 10%) • Preliminary Design (Design Development 30%) (Preliminary Schematics) • Preliminary Design (Design Development 30-50%) (Geometric Schematics) • Preliminary Design (Design Development 30-50%) (Value Engineering) • PS&E (Design Development 100%)	**Lead:** • Director of Transportation Planning and Development • Project Manager • Roadway Design Engineer	**Support:** • District Staff • Functional Groups • Etc.
ODOT	• Planning (Design Development 10%) • Preliminary Engineering (Stage 1 Design) • Environmental Engineering (Stage 2 Design) • Final Engineering/ROW (Stage 3 Detailed Design)	**Lead:** • Project Manager	**Support:** • District Staff/Engineers • Functional Groups • Design Engineers • Etc.
WSDOT	• Planning • Scoping • Design • PS&E	**Lead:** • Project Manager • Estimator • Designer	**Support:** • Region Planning Manager • Project Engineers • Specialty Groups • Etc.

Minnesota Department of Transportation (MnDOT)'s Best Practices

1. MnDOT Cost Estimation Process

The Minnesota Department of Transportation (MnDOT) uses a well-structured cost estimation system to prepare cost estimates for highway projects. As shown in Table 3, the cost estimation milestones for developing the cost estimate consist of four steps, including planning, scoping, design, and letting. Also, Table 3 includes major tasks for developing the cost estimate. In the planning phase, MnDOT defines the needs of transportation system improvement and establishes a base for documenting the estimated basis of a project. During the scoping phase, all potential issues affecting the project cost and schedule must be identified. The baseline cost estimates are developed as an output of the scoping phase. The major tasks in the design and the letting phases are to identify any changes (in scope, cost, and time), and to update and review the baseline cost estimates. Furthermore, project managers and assistant district engineers are responsible for developing and updating cost estimates through the PDP, while other parties, such as functional groups, commissioner's staff, and district engineers, provide support for establishing the basis for cost estimates (MnDOT, 2008).

Table 3: MnDOT Cost Estimation Milestones

PDP	**Planning**	**Scoping**	**Design**	**Letting**
Major Tasks	• Identify the needs and deficiencies in the transportation system. • Prepare a Project Planning Report at the end of the Planning Phase. • Design Development: 1% - 15%	• Extensively investigate all potential issues that could affect the cost and schedule of a project. • Hold a meeting to discuss the project definition. • Identify and analyze project alternatives. • Prepare a final Scoping Report. • Develop project cost estimates (baseline cost estimate). • Design Development: 10% - 30%	• Identify changes in scope, cost, time throughout the Design process. • Update the project cost estimate (update baseline cost estimate). • Design Development: 30% - 90%	• Prepare the Engineer's Estimate and evaluate contractor bids concerning the Engineer's estimated cost. • Review Construction Cost Estimates. • Design Development: 90% - 100%

2. *Cost Estimation and Cost Management System:*

The major purpose of the integrated cost estimation and cost management process is to prepare accurate, reliable, and consistent estimates throughout the project development process. This practice allows MnDOT to achieve standardization and documentation of project estimating and cost management activities and deliverables, from the planning phase through the letting phase. Cost estimation and cost management systems use a work breakdown structure for preparing an estimate basis, determining risk, estimating contingency, and reviewing and approving cost estimates at each phase of the PDP (MnDOT, 2008).

With the cost estimation and cost management system, the entire MnDOT organization (e.g., the commissioner's staff, transportation program committee, district engineer, and central office estimator) provides inputs into the cost estimation process. One of the unique features of MnDOT's cost estimation and cost management process is that the process contains risk analysis to develop the cost estimates at each phase of the project development process. The activity of "Determine risk and set contingency" allows the project team to (1) acknowledge uncertainty, risk, and associated contingencies early in the project development process; and (2) determine the extent of risk analysis based on the project's complexity, local impacts, and other considerations.

Also, the cost estimation and cost management process include review and approval procedures for the cost estimates. These processes increase the accuracy and completeness of the cost estimates by verifying the cost estimate package and data. Lastly, the activity of the "Determine estimate communication approach" enables one to establish accountability for all cost estimates and avoid miscommunications about the cost estimates between entities involved in the project.

The following are the major benefits and advantages of the MnDOT's costs estimation and cost management process:

- A standard process for estimating, managing, and controlling costs.
- Reliable and accurate estimates.
- Improved communication and credibility with external stakeholders.
- Clear accountability for cost estimating and management.

3. Variance Reports on Cost and Schedule:

Variance reports are used to capture changes in cost and schedule and provide a mechanism for budget control through tracking changes and alerting project personnel of changes. Three steps are performed in preparation of variance reports: (1) comparing a current estimate with baseline cost estimate; (2) identifying and explaining deviations from the baseline; and (3) generating variance reports at key project milestones or when significant changes in the project occur (MnDOT, 2008).

Variance reports are prepared by the project personnel, particularly the project manager, throughout all phases of project development, most importantly during the design phase. One of the unique features of a variance report is that it is a transparent notification system for alerting project personnel of deviations in project baseline costs and/or schedule. With this reporting system, the project manager can acknowledge the difference between the baseline cost estimate and the updated cost estimate and track the differences. The variation report explains the cost increase or decrease so that the project manager can efficiently allocate resources including the personnel.

The main benefits/advantages of variance reports are:

- Early identification of differences in project cost and schedule.
- Proper resource allocation.

California Department of Transportation (Caltrans)'s Best Practices

1. Caltrans Cost Estimation Process

The California Department of Transportation (Caltrans)'s cost estimates are classified into two major estimates: (1) project planning cost estimates; and (2) project design cost estimates. Since the project planning cost estimate becomes the baseline cost estimate for a project, the estimator/project team should determine the cost estimate. This cost estimate will be used for project justification, analysis of alternatives, approval, and programming during the planning phase. The following cost estimates are project design cost estimates, which are developed after project approval and with more detailed information of a project (e.g., engineering and environmental studies). As shown in Table 4, the two major cost estimates are further divided into several sub-cost estimates, which are developed as major tasks are completed at each phase of cost estimation milestones. Moreover, a project manager and project engineer hold the responsibility of preparing and updating cost estimates during the PDP. Other stakeholders, such as headquarters divisions, district right of way, district director, and external stakeholders, provide support for developing the basis of estimate.

Caltrans utilizes two major information-sharing systems, the Project Report (PR)/Project Study Report (PSR) and Basic Engineering Estimating System (BEES), to maintain, update, and approve project information, cost estimates, and changes in project scope, costs, and schedule. Caltrans prepares critical information, such as an environmental document, consideration of public comments, and the selection of a preferred alternative, in the project report. This information becomes the estimate basis in developing cost estimates (Caltrans 2007a).

Table 4: Caltrans Cost Estimation Milestones

<table>
<tr><td>1st</td><td colspan="4">Project Planning Cost Estimates</td></tr>
<tr><td>PDP</td><td>Project Feasibility Cost Estimate</td><td>Project Initiation Cost Estimate</td><td>Draft Project Report (PR) Cost Estimate</td><td>Project Report (PR) Cost Estimate</td></tr>
<tr><td>Major Tasks</td><td>• Prepare project cost information planning studies.</td><td>• Obtain Additional information (e.g., existing, and forecasted traffic volume)
• Evaluate and validate the project cost estimate and assumptions</td><td>• Calculate the cost estimate for each project alternative.
• Complete Environmental and hazardous waste studies</td><td>• Complete the public hearing process, selection of the preferred alternative, and completion of the environmental document</td></tr>
<tr><td>2nd</td><td colspan="4">Project Design Cost Estimates</td></tr>
<tr><td>PDP</td><td colspan="2">Preliminary Engineer's Cost Estimate</td><td colspan="2">Final Engineer's Cost Estimate</td></tr>
<tr><td>Major Tasks</td><td colspan="2">• Prepare cost estimates using Basic Engineering Estimating System (BEES)
• Update frequently during the design phase as the project construction details, specifications and plans are finalized into a contract document</td><td colspan="2">• Complete the final engineer's cost estimate.
• Certify that the estimate is completed and accurate, reflects the true scope of work, and accounts for current market trends</td></tr>
</table>

To have a reliable estimate basis, Caltrans encourages functional groups to provide the information that requires developing cost estimates during project development. Also, Caltrans has predefined contingency amounts for cost estimates for each cost estimation milestone.

Caltrans should certify the accuracy and completeness of the final engineer's estimate for projects greater than $5 million.

2. Quality Assurance (QA)/Quality Control (QC) Certification Practice

The main purpose of Caltrans' QA/QC certification practice is to certify that the contract cost estimate is complete and accurate while the cost estimates reflect the true scope of the work and account for the most current market trends (Caltrans 2007b). The QA/QC process helps the agency develop the best estimate possible throughout the Plan Specification and Estimate (PS&E) development phase by (1) identifying roles and responsibilities for the QA/QC process; (2) conducting major activities of the QA/QC process, such as calculating unit quantities, calculating working dates, and verifying all estimates; (3) verifying all factors used in developing the cost estimates; and (4) obtaining approval of key stakeholders such as the project engineer, the design senior, the central region estimate specialist, and the project manager.

The unique features of the QA/QC certification process allow the project to prepare complete and accurate project estimates corresponding with project scope and budget by verifying critical factors that are considered in developing cost estimates. Table 5 lists the factors with detailed information. The outcome of this process is a certification of project cost estimates.

Table 5: Critical Factors for QA/QC process

	Factors considered in developing cost estimates
Quality Control	**Assumptions:** How the assumptions about the location (e.g., terrain, distance to a construction site, etc.), the relative availability of materials, weather conditions, etc., influence the cost estimate? What other elements influence the estimate?
	Source of Unit Prices: What factors were considered to determine unit prices of major items? Provide expenditure authorizations (EAs) of projects considered, unit prices, and quantities used. Add specialty items and costs as appropriate.
	Traffic Management Plan: Identify lane closure windows and assumptions about traffic control costs and elements (e.g., number of signs, public outreach, component, night work, etc.).
	Risk Management Plan: Identify risks relating to the development and use a basic engineering estimating system (BEES).
	Escalation Factors Used: Explain forecasted variables and assumptions used. Demonstrate forward estimating method.
	Contingencies: Is 5% contingency adequate to address each risk factor? If not, why not? How much more is needed?
	DES Structure verification of Estimate and Quantities: List who prepares calculation data and verify calculation and data.
Quality Assurance	**Constructability Review:** What is the assumed construction method and what risks are associated with that method? Indicate when reviews occurred and major findings.
	DOE Cost Estimate Review: List Completion data and conclusions of the review.
	Value Analysis Performed: List completion data and any alternatives that impact the cost.
	DES Structural Liaison Review: List date and conclusion of Review and name of the reviewer
	Independent Estimate Performed: List completion data and variance if any, from Caltrans estimate. If variance, explain how resolved.
Status	**Variance from Programmed Funds (%):** Compare current program cost to PS&E BEES.
	Next Cost Estimate Update: List projected date (three weeks before the California Transportation Commission vote).

The main benefits/advantages of QA/QC certification practice are:

- Minimal cost changes by reviewing and verifying quantities and the unit costs in comparison with recent bid openings and market trends.
- The higher accuracy of the final cost estimates by verifying assumptions and contingencies.

Texas Department of Transportation (TxDOT)'s Best Practices

1. TxDOT Cost Estimation Process

The Texas Department of Transportation (TxDOT) has five phases of the cost estimation process, as shown in Table 6. In the planning and programming phase, TxDOT develops a preliminary cost estimate, which becomes the baseline cost estimate for a project. Throughout the design and PS&E developments, the preliminary cost estimate will be updated until the agency finalizes the project cost estimate. The preliminary design phase consists of three major design developments, including preliminary schematic, geometric schematic, and value engineering, for review and approval of cost estimate (TxDOT, 2014). During the planning and programming phase, the Director of Transportation Planning and Development is responsible for cost estimates with support from other stakeholders (e.g., district staff, project manager, district planner, and functional groups). However, during the rest of the PDP, a project manager and roadway design engineer hold the responsibility of developing, updating, and controlling cost estimates.

TxDOT stores all information of the estimate basis and cost estimates in the Design and Construction Information System (DCIS), an automated information system for planning, programming, and developing projects (TxDOT 2006). Through the DCIS, TxDOT updates and shares the cost estimate and the project information with all stakeholders.

Table 6: TxDOT Cost Estimation Milestones

PDP	Planning and Programming	Preliminary Design	Preliminary Design (Geometric Schematics)	Preliminary Design (Value Engineering)	PS&E
Major Tasks	• Gather preliminary information. • Use Advance Planning Risk Analysis (APRA) tool to measure project scope definition and identify potential risks. • Use AASHTO cost estimation program, Estimator. • Prepare construction and ROW cost estimate. • Prepare a preliminary estimate (baseline cost estimates) • Design Development: 10%	• Organize design concept conference & prepare design summary report. • Prepare preliminary pavement designs. • Update construction and ROW cost estimates and corresponding DCIS data • Update cost estimate • Design Development: 30%	• Prepare pavement design report. • Perform preliminary hydraulic analysis/design. • Determine ROW and access needs. • Identify potential utility conflicts. • Update project scope • Update cost estimate • Design Development: 30% - 50%	• Gather project team experts. • Consider redesign of alternatives if needed. • Conduct VE study • Make necessary design changes Document design changes. • Revise design based on VE study findings. • Update cost estimate • Design Development: 30% - 50%	• Finalize roadway design. • Finalize project design, • Review environmental studies, ROW plans, and utility relocation requirements. • Update APRA • Prepare final engineer's estimate. • Design Development: 100%

Note: ROW= Right of Way; VE= Value Engineering

As the key information for the cost estimates is obtained at the preliminary design phases (preliminary schematics, geometric schematics, and value engineering), the project manager/estimator should pay careful attention to updating baseline cost and schedule during these phases.

2. *Advance Planning Risk Analysis (APRA) – A Spreadsheet-based Tool:*

The APRA assists the project team/key stakeholders in measuring project scope definition and identifying potential risks/elements that may impact project cost and schedule. TxDOT uses the APRA as a comprehensive checklist to identify potential risks by looking at critical risk elements. The APRA has three main sections (i.e., basis of project decision, basis of design, and execution approach) that consist of 12 categories that are further broken down into 59 elements (Caldas et al. 2007). Figure 1 shows a sample of the APRA tool with a few categories and elements. The APRA provides a standardized scope definition for each element, which is useful for an inexperienced project team member.

SECTION II - BASIS OF DESIGN							
	Definition Level						Score
CATEGORY Element	0	1	2	3	4	5	
D. SITE INFORMATION							
D1. Geotechnical Characteristics							
D2. Hydrological Characteristics							
D3. Surveys & Planimetrics							
D4. Permitting Requirements							
D5. Environmental Documentation							
D6. Property Descriptions							
D7. Ownership Determinations							
D8. Right-of-Way Mapping							
D9. Constraints Mapping							
D10. Right-of-Way Site Issues							
CATEGORY D TOTAL							
E. LOCATION & GEOMETRY							
E1. Horizontal & Vertical Alignment							
E2. Control of Access							
E3. Schematic Layouts							
E4. Cross-Sectional Elements							
CATEGORY E TOTAL							
F. STRUCTURES							
F1. Bridge Structure Elements							
F2. Hydraulic Structures							
F3. Miscellaneous Design Elements							
CATEGORY F TOTAL							
G. DESIGN PARAMETERS							
G1. Provisional Maintenance Requirements							
G2. Constructability							
CATEGORY G TOTAL							

Definition Levels

0 = Not Applicable
1 = Complete Definition
2 = Minor Deficiencies
3 = Some Deficiencies
4 = Major Deficiencies
5 = Incomplete or Poor Definition

Figure 1: Sample of TxDOT's APRA Tool

All major disciplines (e.g., right-of-way, utilities, environmental, design, and planning, and programming) participate in the APRA assessment to identify the critical elements of the project scope. The APRA has several unique features for project development. For instance, the project team can use the APRA as a checklist to determine the necessary steps to follow in defining the project scope. The project team can evaluate the completeness of the project scope development and monitor the progress of scope development at various stages during the planning phase and the PDP. Besides, the APRA aids in communication and promotes alignment between owners (e.g., TxDOT), design contractors, and other stakeholders by highlighting poorly defined areas in the project scope. Lastly, the APRA can be a means through which project team participants can reconcile differences using a common basis for project evaluation.

The main benefits/advantages of the APRA are:

- The improvement of project performance in terms of both cost and schedule.
- The identification of the project requirements in all major disciplines by quantifying, rating, and assessing the level of scope development.

3. Design Summary Report (DSR) including the Design Conference

The main purpose of the DSR is to document project information and ensure that the project does not overlook potential critical issues in the project scope development (TxDOT 2014). The DSR documents the agreed-upon fundamental aspects, concepts, and design criteria of a project and serves as the definition of the project's scope. Key stakeholders need to update the design summary throughout all phases of the PDP. As the project progresses, the DSR needs to be revised, and the agency needs to obtain approval from entities and share information with them. Project manager and function groups (e.g., right-of-way, utility, and design offices) are responsible for the execution of the ARPA.

The main benefits/advantages of the DSR are:

- The DSR provides a reliable basis of estimate for design development and cost estimates based on existing conditions and design elements of a project.
- The DSR aligns key stakeholders to input design criteria and elements.
- The DSR tracks changes in critical elements (ROW, Environmental, Traffic control, etc.) for the project development.

Ohio Department of Transportation (ODOT)'s Best Practices

1. ODOT Cost Estimation Process

The Ohio Department of Transportation (ODOT) develops cost estimates along with cost estimation milestones shown in Table 7. The cost estimation milestones consist of four phases, including planning, preliminary engineering, environmental engineering, and final engineering/right-of-way (ROW). The baseline cost estimate is developed in the planning phase and updated during the rest of the PDP (ODOT, 2013). A project manager is responsible to develop, update, and control cost estimates during the PDD, and other parties, such as functional groups, district staff, and design engineers, provide support and documentation for the cost estimates.

To efficiently develop projects, ODOT classifies transportation projects into five paths to have a customized scoping process depending on project size, project complexity, and/or potential impact on the environment. These classifications allow ODOT to have the flexibility in adjusting required tasks to address project needs. The customized scoping process ensures that only necessary work is conducted and that the project is properly planned and developed (ODOT, 2013; ODOT, 2016). For example, since feasibility studies and alternative evaluation reports are not necessary for selecting the preferred alternative for a simple improvement project, ODOT can expedite in scoping process by selecting the alternative early in the PDP, at the planning phase. Table 8 describes five project paths in detail.

Table 7: ODOT Cost Estimation Milestones

PDP	Planning (10%)	Preliminary Engineering	Environmental Engineering	Final Engineering/ROW
Major Tasks	• Develop project concept and scope. • Identify environmental, ROW, utility, and design, geotechnical, engineering issues in the preliminary information package. • Conduct field review. • Prepare base cost estimate including construction, utility, and ROW. • Involve public/stakeholder	• Develop accurate cost estimates for all feasible alternatives. • Conduct feasibility study and NEPA studies. • Analyze alternatives and identify a preferred alternative(s) using the Alternatives Comparison Matrix • Conduct VE study • Establish and develop the design parameters to generate an accurate scope, schedule, and budget. • Involve public/stakeholder	• Obtain NEPA and permit approvals. • Refine the level of impacts associated with the preferred alternative. • Conduct VE study • Prepare environmental mitigation cost estimates. • Develop preliminary ROW and utility plans and refine estimates. • Update cost estimates and milestone dates • Involve public/stakeholder	• Finalize design package. • Perform ROW/Utility acquisition • Update construction, right-of-way acquisition, and utility reimbursement cost estimates • Involve public/stakeholder

Note: ROW= Right of Way; VE= Value Engineering; NEPA= National Environmental Policy Act

Table 8: ODOT Five Project Paths

Paths	Description
Path 1	Path 1 projects are defined as "simple" transportation improvements generated by traditional maintenance and preventative maintenance. They involve minor structure and roadway work with no ROW/utility impacts. These are typically NEPA exempt or CE Level 1 NEPA documents.
Path 2	Path 2 projects are also simple (similar to Path 1- the minor structure and minor roadway work), however, these jobs can involve ROW/utility impacts. These jobs are typically CE Level 1 documents.
Path 3	Path 3 projects involve a higher level of complexity than projects in Path 1 or 2. They involve projects such as moderate roadway and structure work, intersection and minor interchange upgrades, minor realignments, reconstruction, median widening, etc. They can involve utility and ROW impacts including relocations.
Path 4	Path 4 projects involve complex roadway and structure work that may add capacity such as highway widening, new alignments in suburban or rural settings, reconstruction, access management, complex bridge replacement, and/or multiple intersection/interchange alternatives. They may have high utility and/or ROW relocations/impacts. These are typically CE Level 3 or higher level NEPA documents.
Path 5	Path 5 projects have the highest complexity and involve projects like new capacity-adding alignments in complex urban centers, major highway widening, reconstructed interchange, or new interchange. These projects will have high ROW relocations/impacts, complex utility issues, multiple alternatives, and access management issues. These projects are typically higher-level NEPA documents and will require additional scoping reviews before acceptance.

Note: CE= Categorical Exclusions; NEPA=National Environmental Policy Act

2. Alternative Evaluation Report (AER)

The AER is used to document all the alternatives and their evaluation to select a preferred alternative. The Alternative Evaluation Report (AER) is applicable to complex Path 3, Path 4, and Path 5 projects as shown in Table 9 (ODOT 2016). The AER is prepared when the preferred alternative cannot be defined/chosen in a feasibility study.

Table 9: ODOT's Alternative Selection Methods

Project Milestone	**When is information prepared to define the Preferred Alternative?**					
	Path 1	**Path 2**	**Path 3**		**Path 4**	**Path 5**
			Non-complex	Complex		
Project Initiation	Project's description, method, and footprint	Project's description, method, and footprint	-	-	-	-
Feasibility Study	-	Project's method and footprint	Project's description, method, and footprint	Project's description and footprint	Project's description and footprint	Project's description and footprint
Alternative Evaluation Report	-	-	-	Project's footprint	Project's method and footprint	Project's method and footprint

Note: Description (what will my project involve and where will it be located?); Method (what design standards will apply, how will we build it, and how will traffic be maintained?); Footprint (what are the limits that should be used for environmental clearance, will there be temporary impacts?)

ODOT summarizes all the alternatives in the AER. In Table 10, major components of the AER are listed. ODOT evaluates several alternatives based on technical analysis, costs, long-term versus short-term solutions, and stakeholder involvement. To effectively evaluate several alternatives, ODOT uses an alternative comparison matrix to eliminate alternatives and select the feasible alternative among proposed multiple alternatives.

Table 10: Components of ODOT's Alternative Evaluation Report

Alternative Evaluation Report Executive Summary	Typical Alternative Evaluation Engineering Element
• Introduction/Background • Alternatives • Traffic Analysis • Roadway Assessment • Drainage Assessment • Geotechnical Assessment • Right of Way Assessment • Utility/Railroad Assessment • Environmental Analysis • Public Involvement • Alternative Comparison • Recommendation	• Field Survey and Mapping • Typical Sections including Lanes, Curbs, Sidewalks, Trees, Lawns, and Shoulder Widths • Alignments (Horizontal and Vertical) • Clearances (Horizontal and Vertical) • Field Survey Information including Topography, Bridges, Utilities, Channels, and Railroads • Geological and Soil Boring Data (Highway/Bridge Foundations) • Drainage • Conceptual Drainage Design including Preliminary Culvert Sizes • Traffic Control • Signal Warrants • Maintenance of Traffic • Conceptual Maintenance of Traffic • Utilities • Right-of-Way, Construction, and Utility Reimbursement Cost Estimates • Locate Waste and Borrow Areas • Railroad Coordination • Value Engineering

The main benefits/advantages of the AER are:

- ODOT expects to mitigate funding constraint issues by allowing project managers to choose a cost-effective alternative.
- ODOT expects to minimize scope changes or issues with the selection of an optimal alternative by considering impacts of technical, engineering, and design issues.

Washington State Department of Transportation (WSDOT)'s Best Practices

1. WSDOT Cost Estimation Process

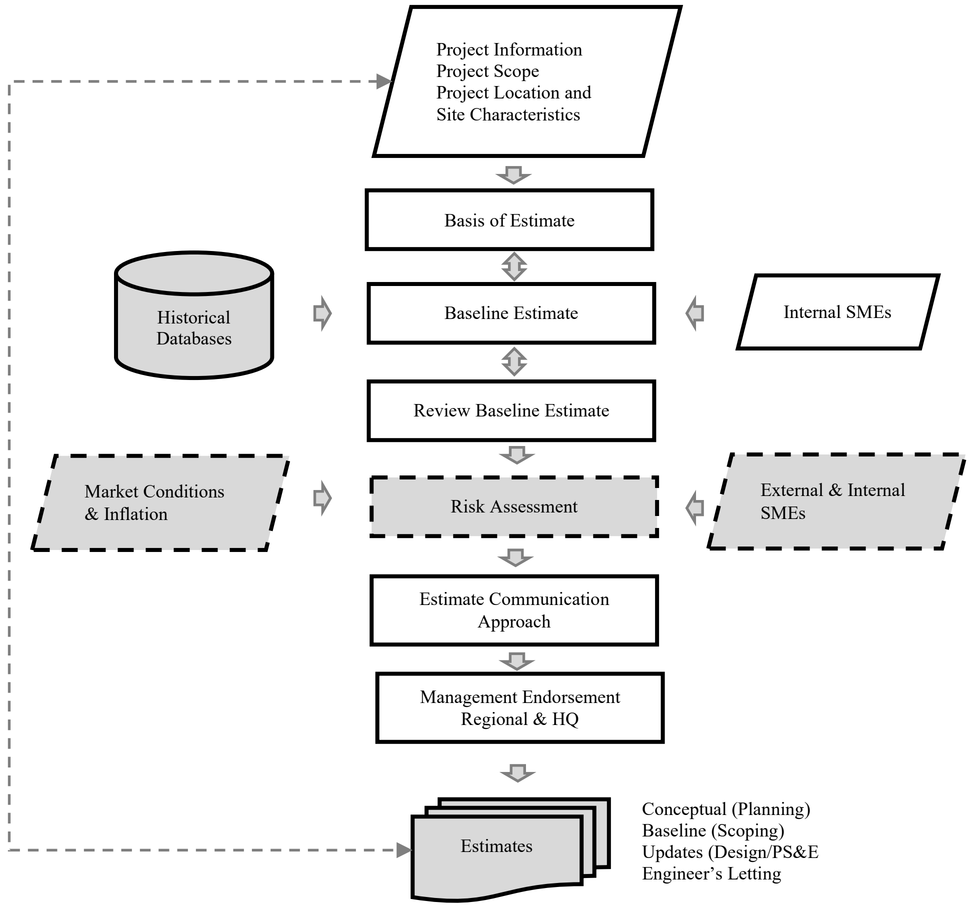
The Washington State Department of Transportation (WSDOT) develops the cost estimates along with cost estimation milestones as shown in Table 11. Although the planning phase estimate is developed with limited project information, WSDOT puts efforts into developing an accurate cost estimate by utilizing information collected from project stakeholders, historical projects, and field review. In the scoping phase, WSDOT sets the baseline cost estimates/the project budget. Throughout the design and the PS&E phases, WSDOT updates the cost estimate and refines risks, uncertainty, and assumptions that are used in preparing the cost estimate (WSDOT, 2015). During the planning and scoping phases, a project manager and estimator are responsible for developing and updating cost estimates with support from regional planning engineers, project engineers, specialty groups, etc. During the design and PS&E phases, a designer coordinates with a project manager and estimator for developing and updating cost estimates.

Table 11: WSDOT Cost Estimation Milestones

PDP	Planning	Scoping	Design	PS&E
Major Tasks	• Determine the full scope of the project. • Develop a comprehensive list of all of the components for the project. • Conduct a project field review and document potential high-cost items (costs of mitigating hazardous waste and other environmental impacts, utility relocation, etc.) • Review the unit price to reflect current trends. • Review planning estimates and assumptions	• Set the baseline cost estimates. • Document assumptions and scope definitions • Choose the correct unit costs for items in current dollars. • Justify any changes in the cost of the project. • Ensure major risks to the project. • Conduct a site visit. • Understand the current design standards and their project impact. • Identify the major items of work. • Review the project constructability. • Verify traffic control strategy	• Conduct geometric review, general plans review, and preliminary contract review. • Track changes in the estimated cost • Compare the current budget for the project cost and schedule to the new estimate. • Document each update and provide a written explanation of any significant changes. • Get a quote for materials sources. • Coordinate with the appropriate entities for the review of the cost estimates	• Conduct the final independent QA/QC checks of calculations, prices, and assumptions. • Review the basis of estimate for completeness, accuracy, and clarity. • Check quantities of major items and cost drivers. • Review special group estimates for scope and cost. • Review contract special provisions • Evaluate the potential impact of staging, materials storage, hauling of materials, location of batch plants, and other constructability related issues

Note: PS&E= Plans, Specifications, and Estimates; QA/QC= Quality Assurance/Quality Control

WSDOT has a rigorous process to develop the cost estimates for each phase of cost estimation milestones. Figure 2 depicts the steps of the cost estimating process. For developing the cost estimate, this process allows the estimators to have a reliable estimate basis by using historical databases and internal subject matter experts (SMEs).



Note: HQ= Headquarters

Figure 2: WSDOT Cost Estimating Process for Each Phase of PDP (WSDOT, 2015)

The potential benefit of this process is implementing risk assessment for each phases' cost estimate. WSDOT considers factors of market conditions and inflation for the cost estimate, as well as inputs from external and internal SMEs to capture the effect of uncertainties on project cost and schedule (WSDOT, 2015).

2. Cost Risk Assessment (CRA) and Cost Estimate Validation Process (CEVP) Workshop

The CRA and CEVP are systematic project review and risk assessment processes to identify and describe cost and schedule risks associated with the project (WSDOT, 2012). CEVP is an intense workshop in which a team of top engineers and risk managers from local and national private firms and public agencies examine a transportation project and review project details with WSDOT engineers. The CEVP can be used in all projects above $100 million. The CRA has a similar process and objective, but less intense than the CEVP. The CRA can be applicable in all projects above $25 million.

The CRA and CEVP workshop has the following unique capabilities. For example, the CRA and CEVP workshop is a systematic process for defining and reviewing or validating cost and schedule base estimates using a Lead Cost and Schedule Reviewer, Subject Matter Experts, and specialists. Moreover, this workshop aids the agency to develop concepts for responses to risks to the schedule that could impact the cost of the project and promote proactive risk management by project teams. The project team with actionable information on risk events can effectively manage the risks (threats/opportunities) on an ongoing basis, via mitigation strategies to better control project costs and schedules. Since the CRA and CEVP workshop also conducts post-mitigation analysis, the agency can ascertain the effectiveness of the planned and/or implemented risk response actions. Lastly, the CRA and CEVP methods enable the agency to identify and quantify cost escalation factors using a Monte Carlo simulation analysis, which allows modeling the collective impact of base and risk issues to produce an estimate of a reasonable range and distribution.

The main benefits/advantages of CRA and CEVP are:

- The improved communication with the public.
- The improved team communication.
- The increased ability to quantify risks and develop strategic risk management plans for the identified risk.
- The more realistic cost ranges.

Validation

This study conducted interviews with several transportation agencies with cost professionals in transportation agencies, including federal highway agency (FHWA), Missouri DOT, Colorado DOT, Utah DOT, WSDOT, to validate the effectiveness of the identified practices and tools. The interviews with transportation cost professionals indicated that the identified practices and tools were very helpful for cost estimation and cost management. Besides, the key considerations for cost control during the PDP were suggested by the transportation cost professionals as follows:

- Enough time and resources are required for clear scope development and accurate cost estimates.
- The agency should use a proper review process for cost estimates and contingency in the light of project risks.
- Risk analysis.
- The upper level of government should participate in evaluating schedule and budget changes.
- The agency should have a training tool or supporting system for inexperienced personnel.
- Project scope development should be closely tied with the cost estimating and updating process.
- A cost database is required for supporting cost estimation.

Conclusions

Changes in estimated project cost are one of the major concerns of State DOTs throughout project development from concept to completion of a project. This study identified key areas for cost estimation and cost management during project development through a comprehensive literature review. The key areas include risk analysis and contingency, identification of cost escalation factors, the accuracy of the preliminary cost estimate, and constructability review. This study also reviewed the current state of practices in cost estimation and control in several State DOTs and identified best practices in cost estimation and strategies for cost control.

Several recommendations are found out to be effective for enhancing the practice of defining and maintaining the established budget for highway projects. For instance, it is apparent that an integrated process for cost estimation and cost management is necessary to improve accurate, reliable, and consistent estimates through the PDP. Furthermore, key milestones for estimating, updating, and approving cost estimates play a critical role in tracking PDP tasks and deliverables, identifying personnel responsible for cost estimation and control, and measuring the accuracy of cost estimates throughout the project. Since potential issues (risks) may cause cost escalation during developing baseline cost estimates, risk analysis tools and inputs from key project stakeholders should be utilized to identify critical risk factors for the project. Any estimated assumptions should be captured and documented for updating and controlling the estimated project cost. Lastly, the final validation process is critical for checking if the cost estimates reflect the true scope of the work and the most current market conditions. Thus, a quality assurance/quality control (QA/QC) process is required to verify the final engineer's cost estimate before a project is advertised.

The lack of a systematic process for establishing a baseline budget with the consideration of potential issues (risks) is one of the critical barriers to developing and managing cost estimates during the PDP. This study contributes to the state of knowledge and practice by examining the literature and practice of cost estimation and cost management in SHAs. It is expected that State DOTs realize significant improvements in their cost estimation process by utilizing the identified best practices described above. The major benefits of the identified best practices are as follows:

- Uniformity and consistency of cost estimates with a well-structured cost estimation system.
- Enhancement of the project scope definition and identification of critical issues/risk areas in major components of a project.
- Maximization of information and the knowledge of a multidisciplinary team through various levels of the review process.
- A closer estimation of the contingency amount by using risk management tools that may differ by project size and complexity.
- Verification of the final engineer's cost estimate through a final quality assurance/quality control (QA/QC) process.

References

Akinci, B., and Martin, F. (1998). "FACTORS AFFECTING CONTRACTORS RISK." Journal of Management in Engineering, 14.1(February), 67–76.

Anderson, S. D., Fisher, D. J., and Rahman, S. P. (1999). "Constructibility issues for highway projects." Journal of Management in Engineering, 15(3), 60–68.

Anderson, S., Molenaar, K., and Schexnayder, C. (2007). Guidance for Cost Estimation and Management for Highway Projects During Planning, Programming, and Preconstruction. Transportation Research Board.

Anderson, S., Molenaar, K., and Schexnayder, C. (2008). "Right of Way Methods and Tools to Control Project Cost Escalation." Transportation Research Board, 49(April).

Asmar, M. El, Hanna, A. S., and Whited, G. C. (2011). "New Approach to Developing Conceptual Cost Estimates for Highway Projects." Journal of Construction Engineering and Management, 137(November), 942–949.

AASHTO (2013). "Practical Guide to Cost Estimating." American Association of State Highway and Transportation Officials, First Edition.

Biehler, A. D., Brown, L. L., Conti, E. A., Hammond, P. J., Helme, E. A. N., and Air, C. (2010). REPORT 658 Guidebook on Risk Analysis Tools and Management Practices. Transportation Research Board.

Caldas, C. H., Gibson, G. E., and Le, T. (2007). TxDOT Best Practices Model and Implementation Guide for Advance Planning Risk Analysis for Transportation Projects.

Caltrans. (2007a). CHAPTER 20 – Project Development Cost Estimates. California Department of Transportation.

Caltrans. (2007b). "Report on Quality Control / Quality Assurance (QC / QA) Activities for Project Cost Estimating." California Department of Transportation.

Chou, J.-S. (2009). "Web-based CBR system applied to early cost budgeting for a pavement maintenance project." Expert Systems with Applications, Elsevier Ltd, 36(2), 2947–2960.

Chou, J.-S., Peng, M., Persad, K., and O'Connor, J. (2006). "Quantity-based Approach to Preliminary Cost Estimates for Highway Projects." Transportation Research Record, 1946(1), 22–30.

Diab, M. F. (2013). "Integrating Risk Assessment in Planning for Sustainable Infrastructure Projects." In ICSDEC 2012: Developing the Frontier of Sustainable Design, Engineering, and Construction, 350–358.

Diab, M. F., Varma, A., and Panthi, K. (2017). "Modeling the Construction Risk Ratings to Estimate the Contingency in Highway Projects." Journal of Construction Engineering and Management, 143(8), 1–9.

Fisher, D. J., Anderson, S. D., and Suhel P. Rahman. (2000). "Integrating constructability tools into the constructability review process." Journal of Construction Engineering and Management, 126(2), 89–96.

Gardner, B. J., Gransberg, D. D., and Jeong, H. D. (2016). "Reducing Data-Collection Efforts for Conceptual Cost Estimating at a Highway Agency." Journal of Construction Engineering and Management, 142(11), 1–9.

General, U. S., and Office, A. (1997). "Managing the Costs of Large-Dollar Highway Projects." (February).

Goodrum, P. M., Hancher, D. E., and Yasin, M. (2004). "A Review of Constructibility Barriers and Issues in Highway Construction." In Construction Research Congress: Wind of Change: Integration and Innovation, 1–9.

Gransberg, D. D., Jeong, H. D., Craigie, E. K., Rueda-Benavides, J. A., and Shrestha, K. J. (2016). "Estimating Highway Preconstruction Services Costs." Transportation Research Board, Volume 1.

Harper, C. M., Molenaar, K. R., Anderson, S., and Schexnayder, C. (2014). "Synthesis of Performance Measures for Highway Cost Estimating." Journal of Construction Engineering & Management, 30.

MnDOT. (2008). "Cost Estimation and Cost Management Technical Reference Manual." Minnesota Department of Transportation.

Molenaar, K. R. (2005). "Programmatic Cost Risk Analysis for Highway Megaprojects." Journal of Construction Engineering and Management, 131(3), 343–353.

Molenaar, K. R., and Wilson, C. R. (2009). "A RISK-BASED APPROACH TO CONTINGENCY ESTIMATION IN HIGHWAY PROJECT DEVELOPMENT." CONSTRUCTION RESEARCH CONGRESS, 2009, (303), 41–50.

ODOT. (2013). "ODOT Project Development Process Manual." Ohio Department of Transportation, <http://www.dot.state.oh.us/projects/pdp/Pages/manual.aspx> (Jan. 17, 2017).

ODOT. (2016). "FEASIBILITY STUDIES AND ALTERNATIVE EVALUATION REPORTS."

Shane, J. S., Molenaar, K. R., Anderson, S., and Schexnayder, C. (2009). "Construction Project Cost Escalation Factors." Journal of Management in Engineering, 25(4), 221–229.

Teye Buertey, J. I., Abeere-Inga, E., and Adjei Kumi, T. (2012). "Project Cost Contingency Estimation in Ghana: An Integrated Approach."

TxDOT. (2006). "DCIS User Manual." Texas Department of Transportation, <http://onlinemanuals.txdot.gov/txdotmanuals/dci/dci.pdf>.

TxDOT. (2014). "Project Development Process Manual." Texas Department of Transportation, <http://onlinemanuals.txdot.gov/txdotmanuals/pdp/pdp.pdf>.

WSDOT. (2012). "WSDOT Guidelines for CRA-CEVP Workshops."

WSDOT. (2015). "Cost Estimating Manual for WSDOT Projects." Washington State Department of Transportation.

Using the Best Value Approach to Improve Construction Project Performance in the Chinese Construction Industry

Yutian Chen, PhD
Leadership Society of Arizona
Arizona, USA

Oswald Chong, PhD, P.E.
Arizona State University
Arizona, USA

Received: 01 January 2021; Revised: 15 March 2021; Accepted: 01 April 2021

The Chinese Construction Industry (CCI) is struggling with poor project performance (including cost overruns, delays, and lower satisfaction ratings). Previous research has identified that other developing countries are struggling with similar issues. According to the available economic data (GDP, growth, corruption, etc.) the CCI is very similar to construction industries in Vietnam and the Kingdom of Saudi Arabia. A literature review suggests that the CCI struggles with similar risks as these two countries. The primary difference between the CCI and other industries is the socialistic environment. Several research efforts have shown the Best Value Approach (BVA) to be a feasible solution to reconciling project performance in both Vietnam and Saudi Arabia. The research shown herein investigates whether the BVA is a feasible solution to performance issues in the CCI. Using available literature, the authors created an industry expert survey to investigate whether BVA concepts can address the performance issues in the CCI and if they can be implemented despite government policy. From 204 responses, the results suggest that most professionals are dissatisfied with the CCI performance, over 50% believe BVA concepts will improve the performance of the CCI, but only 40% believe that the BVA would be implementable in the CCI.

Keywords: China, Construction, Performance, Risk, Developing Country, Best Value Approach.

Introduction

China has the biggest construction industry in the world, however, there is minimal information available identifying the performance of its construction and related services (Chen et al., 2018). The information that is available identifies that it might be facing many issues and delivering poor performing construction services.

The authors published previous research which compared the Chinese Construction Industry (CCI) to other construction industries in developing countries (Chen et al., 2018). The study found similar industries by comparing the following criteria:

- Construction GDP
- Corruption Index
- Construction GDP growth

From the above criteria, two countries were prioritized as having construction industries most similar to the CCI, including the Vietnam Construction Industry (VCI) and the Kingdom of Saudi Arabia Construction Industry (KSACI). Le (2018) and Algahtany (2018) each conducted extensive research on the VCI and KSACI and identified the top risks causing poor performance. Le and Algahtany's studies identify that the only solution that had documented results showing that it could improve the performance of their construction industries was the Best Value Approach (BVA).

In a previous study (Chen and Chong, 2020), the top CCI risks were compared to the risks in the VCI and KSACI. The CCI experienced all of the top risks of the VCI and KSACI. However, the CCI had 50% (5) of its top 10 risks that were not found in the VCI and KSACI. Table 1 below shows the top 10 risks in CCI. The table shows whether each of these top risks were also found within the identified risks of VCI and KSACI (Table 1). Of the five dissimilar risks, four were government related issues (Legal and Contract Issues, Relationships and Guanxi, Government Control and Government Instability and Politics).

Table 1: Top CCI Risks Vs. VCI and KSACI Risks

No.	**Top 10 Risks in the China Construction Industry (CCI)**	**Top Vietnam (VCI) and Kingdom of Saudi Arabia (KSACI) construction industry risks**
1.	Legal and Contract Issues	
2.	Relationships and Guanxi	
3.	Outdated Technology	
4.	Lack of expertise in construction services	x
5.	Management Skills	x
6.	Project Financing	x
7.	Skill level of labor	x
8.	Government Control	
9.	Bureaucracy in organizations	x
10.	Government Instability and Politics	

While previous research suggests the BVA is a potential solution to performance issues in the VCI and KSACI, the CCI has unique risks that have not been investigated in the BVA research. Further analysis is needed to identify if BVA can be a potential solution for the poor performance in the CCI.

Best Value Approach Documentation

The "Best Value Approach" is licensed by Arizona State University's intellectual property (IP) licensing arm, Skysong Innovations. The BVA is the most licensed IP (60 licenses over 25 years) developed at the most innovative university in the U.S. for four years running according to U.S. News and World Report (ASU News, 2018). It has been tested over 2,000 times delivering over $6.6 billion of services in ten different countries (PBSRG, 2018).

The Best Value Approach was developed by Dean Kashiwagi at Arizona State University in 1991 for his dissertation research (Kashiwagi, 1991). Over the last 27 years, the Performance Based Studies Research Group has been testing the BVA continually and documenting its results. The testing has led to modifications in the BVA that have improved project results and have made the BVA easier to implement.

The BVA utilizes performance information to identify expertise through a competitive process, then it allows expert vendors to plan a project from the beginning to the end and create transparency by using a simplified milestone schedule to track project time and cost deviations. The entire process minimizes a professionals' thinking and decision making, allowing the expert vendors to minimize cost by 5–30%, and minimizing vendor caused time and cost deviations to under 1% (PBSRG, 2018).

The BVA was derived from the industry structure (IS) model (see Figure 1). The IS model splits the industry up into four quadrants. For our research we will focus on the quadrants with a high level of competition:

1. The Value Based quadrant that has high competition and performance.
2. The Price Based quadrant that has low competition and performance.

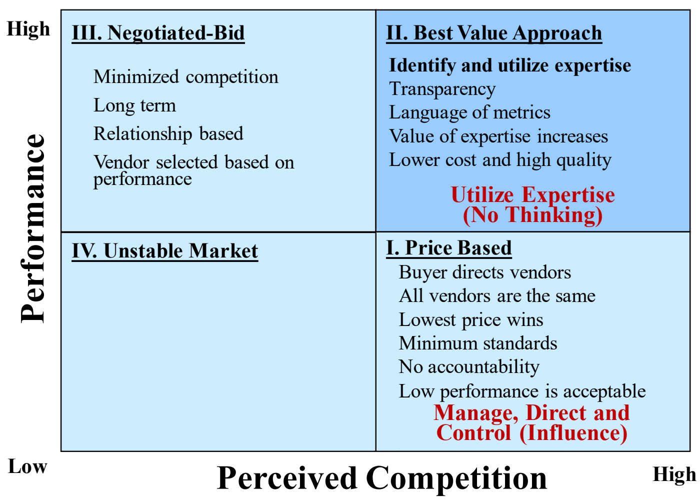


Figure 1: Industry Structure Model.

The model identifies that low performance is caused due to buyers trying to manage, direct, and control (MDC) vendors. The BVA proposes that the only way to move to the Value Based quadrant is to utilize the expertise of the vendor by moving the management of the project to the expert vendor.

The IS model identifies the following buyers' traditional activities that are used to MDC vendors (Kashiwagi, 2018; PBSRG, 2018):

- Creating technical requirements and specifications
- Partnering and developing relationships with vendors to enable the client to be involved with the management and development of the service
- Using the contract as leverage over the vendor
- Using a project manager to manage a vendor after they were awarded a contract

The IS model identifies that the following activities will enable buyers to utilize the expertise of vendors:

- Minimize the buyer's involvement in the technical details of services

- Move the buyer's activities to that of quality assurance (ensuring the vendor has created a plan and is measuring their performance through non-technical metrics) instead of quality control (ensuring the vendor is performing all their technical work correctly)
- Require vendors to tell the client what the technical specifications and requirements should be
- Utilize internal buyer personnel to help and protect the vendor

The BVA was developed to help buyers to understand and move to the Value Based quadrant and perform the activities that enable them to utilize the expertise of vendors. The BVA splits a project up into three major phases (selection, clarification, and execution) (see Figure 2):

Selection Phase

All vendors compete based on their level of expertise instead of their technical scope of work. During this phase, the vendors are not given technical requirements or specifications, but a list of expectations and an explanation of "what the client thinks they want". They are selected based on their past performance metrics, ability to identify risk, and capability of their key personnel. The highest ranked vendor moves to the clarification phase.

Clarification Phase

The clarification phase is the most important phase. In the clarification phase, the vendor with the highest level of expertise is now required to create their scope of work and technical requirements and is required to:

- Explain how they will accomplish the work efficiently and with high customer satisfaction
- Identify their plan from beginning to end, all risks that they do not control, all major milestones, how they will measure their performance, and justify their costs; and
- Respond to the client's concerns and feedback about the vendor's plan and address those concerns in their plan.

The vendors are required to resolve all concerns from the client (both technical and non-technical) using non-technical language. The contract is only signed when the client is comfortable with the vendor's plan. Otherwise, the vendor will be eliminated from clarification and the next in line vendor will be notified for clarification.

Execution Phase

Upon signing the contract, the contractor can proceed to work according to their plan. Since the vendor was the entity that developed the plan and the metrics, it has now put them in full control of the project. Performance will be tracked and posted online for each contractor through the Weekly Risk Reports (WRR) which the contractor will turn in on every Friday. In the situation that another stakeholder tries to control the expert, that incident will be reported on the WRR and the vendor identifies what the impact that incident of control will have on the project's performance.

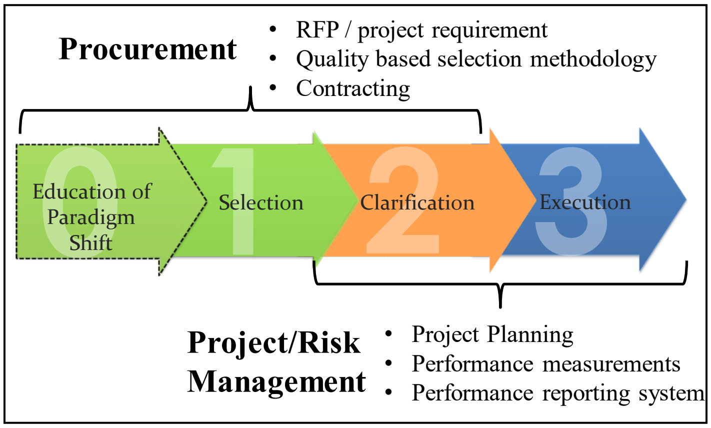


Figure 2: The Best Value Approach.

Many of these ideas are different from the traditional delivery models. However, the BVA system has documented the following performance (Rivera, 2017; PBSRG.com, 2018):

- 2000+ projects and services delivered (construction and non-construction)
- \$6.6B of projects and services delivered with a 98% customer satisfaction and 9.0/10 client rating of process
- Services delivered: construction, facility maintenance, IT, professional (design), redesign of systems and organizations and supply chain applications
- \$18M in research funding generated, due to the effectiveness of decreasing buyer cost of services on average by 31% (57% of the time, the highest performing expert was selected and was the lowest cost)
- Contractors/experts could offer the client/owner 38% more value and decreased client efforts by up to 79%
- 90% of all project cost and schedule deviation is caused by the owner's non-expert stakeholders
- Change order rates were reduced to as low as -0.6% (Rivera, 2017)
- CIB W117 has worked with over 123 unique clients (both government and private sector) and received 12 National/International Awards using the BVA
- 5 to 30% cost savings are achieved on the projects
- The BVA is the most licensed technology to come out of Arizona State University licenses (64)
- It is internationally recognized through repeated testing (Canada, Netherlands, Sweden, Norway, Finland, Botswana, Malaysia, Australia, Democratic Republic of Congo, France). Education efforts are in Poland, Saudi Arabia, India, Vietnam and China
- Audited/verified four times: The State of Hawaii Audit [State of Hawaii Report 2002 (DISD)]; The Dutch Study on the Impact of PIPS (Duren & Doree, 2008); The Corps of Engineers (COE) PARC, 2008 (Kashiwagi, 2018); The Western States Contracting Alliance (WSCA) Agreement, 2011 (PBSRG, 2018)

Research on the BVA identifies that it is one of the only delivery methods that has repeated documentation showing that it can improve construction performance. It also is one of the only construction delivery methods developed in the last 20 years that has shown to improve construction performance in both developed and developing countries.

Problem

Previous research suggests that the BVA is a potential solution to performance issues in the Vietnamese construction industry (VCI) and the Kingdom of Saudi Arabia's construction industry (KSACI) (Algahtani, 2018; Le, 2018). While the Chinese Construction Industry (CCI) is very similar to the VCI and KSACI, the CCI has unique risks regarding government and political involvement. Research identifies that this could be caused due to the socialist government of China, causing both the buyer and the contractor to be owned by the government (CCIA 2016). The governmental differences between the CCI and the VCI and KSACI might affect the ability of the BVA to improve the performance of the CCI.

Proposal

It is proposed that the Best Value Approach might be a potential solution for CCI performance issues, but further validation is required. This study proposes to investigate the applicability of the BVA within the CCI. The study would include (1) confirming the performance issues and risk within the CCI aligns with the literature and (2) investigating the opinion of the CCI stakeholders regarding the use and viability of BVA as a solution to performance issues in the CCI.

Methodology

Through survey research, the authors confirmed the literature results and further explored the CCI stakeholder's opinion regarding the BVA. The survey method consisted of a questionnaire to identify the following:

1. The current performance of projects in the CCI
2. Scorings of literature's top risks in the CCI
3. BVA Concepts potential to improve performance of the CCI
4. The viability of the BVA in the CCI.

The survey was tested with a pilot group before questioning a larger population (final survey). The collected survey was quantitatively analyzed using IBM SPSS Statistics v25. The research team used the following techniques:

1. Cronbach's alpha coefficients to identify the difference in results from the test survey and the final survey
2. Mean score to identify the degree of impact each risk had or the degree to which the professional agreed or disagreed with a statement

3. Factor analysis was used to derive interrelationships among the risk factors. These are described in the following sections.

After an analysis of the survey results, a comparative analysis was performed with existing literature to draw further conclusions from the results.

Development and Format of Survey

Surveying professionals in the CCI is a difficult process as most professionals in the CCI do not understand English well, which is the written language of most research and explanations of the BVA. Development of the survey went as follows:

1. Created a draft survey based on previously published survey information
2. Translated the survey into Mandarin
3. The review and critique of draft survey by a panel consisting of the author and two Chinese construction professors
4. Tested the survey through professionals from a Chinese construction group to give feedback on questions and issues with the survey
5. Creation of the final survey based on feedback from test survey

The final survey was distributed through social media and direct contact. A link was provided for the professionals to fill the survey out on the web. The finalized survey included four major parts (see Appendix A):

1. Basic information – The respondents are asked for personal information including their name, company, and number of years of professional experience.
2. Current satisfaction of CCI - Questions included: (1) The current satisfaction with construction services on a five-point Likert scale: '5 high satisfaction, 3 don't know, and 1 low satisfaction', (2) the estimate percentage of overall projects that are delayed, (3) estimate average percentage of delay for each project, (4) estimate percentage of overall projects that are over budget and (5) estimate average percentage over budget for each project.
3. Impact of Risk Factors to Performance – Based on literature (Chen, et al., 2020), the top 8 risks from a list of 15 were provided in the survey and the professional was asked to identify the performance impact of each of the risks to the performance of the CCI. The questions used a five-point Likert scale of 1 to 5 to measure the respondents' evaluation of the CCI. The numerical values assigned for the Likert Scale are as follows: '5 = High Impact, 3=Don't know, 1 = Low Impact'.
4. Best Value Approach – Based on workshops and interviews with an expert BVA panel consisting of the creator of the BVA approach, two Chinese professors in the construction industry and multiple BVA practitioners, four key BVA concepts were identified for the survey. Professionals were asked to identify if they believed each of the BVA concepts could improve performance in the CCI. The rating was done on a five-point Likert scale: '1 Disagree, 3 Don't know, and 5 Agree'. As a final question the professionals were then asked if they believed a system identified by the four BVA concepts would be accepted in the CCI.

There were a total of 204 construction professionals that participated in the survey. Of the respondents, 67 (33%) were from the test survey. The final survey was then sent out to 140 construction professionals, 137 of them completed the survey, giving a response rate of 98%. Out of the 137 that filled out the final survey, 50% of them were vendors.

Test Survey Results

The test survey was sent out by the principal of the College of Construction at the Fujian University of Technology. The principal sent the survey to multiple industry and academic groups to obtain an accurate assessment of the survey and potential results. Unfortunately, the test survey was unable to collect personal information on the professionals filling out the survey. The response rate of the survey was 89%, with responses from project managers, engineers, and academics from the buyers' organizations.

The responses to professionals' satisfaction with the CCI services is shown in Table 2. From the 67 responses, 43% identified that they are not satisfied with the current CCI performance, 27% are undecided, and only 30% of respondents are satisfied.

Table 2: Test Survey: Satisfaction Rating

Satisfaction Rating	Responses	Percentage
Unsatisfied (1 or 2)	29	43%
Don't know (3)	18	27%
Satisfied (4 or 5)	20	30%

The survey results for the risk factors in the CCI are shown in Table 3. The mean response score and ranking is shown in Table 3. The highest prioritized risk factor (70% agreement) was project financing. Project financing was one of the top risks in both the KSACI and VCI, however, past research did not identify it as one of the top 3 risks in the CCI. The second highest ranked risk was management skills (60% agreement). The third factor was the skill level of labor (48% of agreement). The risk with the least agreement was outdated technology (30% agreement).

Table 3: Risk Measurement of Test Survey

Risk Factors	Mean	Survey Rank
Project Financing	4.090	1
Management Skills	3.776	2
Skill level of labor	3.388	3
Relationships and Guanxi	3.358	4
Legal and Contract Issues	3.284	5
Government Control	3.239	6
Lack of expertise in construction services	3.224	7
Outdated Technology	2.985	8

The opinions of the effectiveness of the BVA concepts and viability of BVA concepts in the CCI are shown in Table 4. Table 4 provides the mean score and prioritized the concepts based on the level of agreement. More than 50% agreed that the BVA concepts would improve CCI performance. However, when asked if they believed the BVA would be accepted in the current CCI environment, only 34% agreed. Although all the ideas and actions of the BVA are believed to be able to improve the CCI, the majority (65%) do not know or disagree that CCI could use BVA.

Table 4: Professional Opinion of BVA System from Test Survey

	Test Survey		
BV Concept	**Agree**	**Don't know**	**Disagree**
If the contractor was required to document each stakeholder's performance, price and all risks cause the delay/over budget of the project, would CCI performance improve?	54%	25%	21%
Would a selection system that hires contractors based off of performance and price improve the performance of the CCI?	49%	24%	27%
If we hire an expert contractor by using the selection system mentioned above, making the expert contractor responsible for the planning, risk management, and project management of a project, will it improve performance of the project?	60%	31%	9%
Do you think if there is a selection system that could make all of vendor's past performance transparent, it could eliminate "guanxi" in CCI environment?	51%	36%	13%
Viability of BVA Concepts in CCI	**Agree**	**Don't know**	**Disagree**
Do you think this system will be accepted by CCI environment?	34%	40%	25%

Final Survey Results

After the test survey was sent out, modifications were made to the survey and then it was sent out again to multiple companies and organizations in Fuzhou, Fuzhian province in China. The major modifications that were made to the survey were as follows:

1. Professional background information was requested from the respondents (i.e. name, years of experience, position, etc.)
2. Professionals were asked to estimate the performance of CCI projects (i.e. percent delayed and percent over budget)
3. Some questions were modified in the Chinese version to minimize confusion

The finalized survey was sent out over a period of six months. It was difficult to find Chinese organizations that were willing to participate in the survey. The researchers found 140 construction professionals willing to take the survey and 137 of them completed the survey. The response rate was 98%. The results of this survey were then analyzed in Tables 5–11. The demographics of the final survey are found in Table 5. For the second phase, 68 respondents worked for construction vendor side (50%), 18 for designers (13%), 15 for owners (including real state owner and government department, 11%) and 7 for project management which is consultants (5%). The participants held different levels of positions, 51 of which were engineers

(37%), 27 were project managers (20%), and 10 were designers (7%). 58% of respondents had more than 6 years of professional experience.

Table 5: Demographic Characteristics of Final Survey

Demographic Characteristics	Responses	%
Company		
Construction Vendor	68	50%
Design Institute	18	13%
Real Estate Owner	9	7%
Project Management	7	5%
Government Department	6	4%
University	4	3%
Inspector	2	1%
Total	114	
Industry Experience		
0-5 years	47	34%
6-10 years	50	36%
11-20 years	23	17%
Over 20 years	7	5%
Position		
Engineer	51	37%
Project Manager	27	20%
Designer	10	7%
Government Worker	5	4%
Cost Engineer	4	3%
Manager	3	2%
Professor	3	2%
Marketing	2	2%
Inspector	2	2%
Logistics	2	2%
BIM Technology	1	1%
Construction Vendor	1	1%
Safety Manager	1	1%
Structure Identification	1	1%

Project Performance

The responses to professionals' satisfaction with the CCI services is shown in Table 6. Only 21% of all respondents are satisfied with the CCI. Respondents with more than five years of experience are less satisfied with performance.

Table 6: The Satisfaction with Current CCI Performance

Industry Experience	n	Unsatisfied	Neutral	Satisfied
Overall	137	42%	37%	21%
0-5 Years Exp.	47	34%	40%	26%
5+ Years Exp.	80	49%	33%	19%

In order to measure the perceived performance of the projects in the CCI, respondents were asked to estimate schedule delays and budget deviations (see Table 7). Respondents estimated what percentage of all CCI projects was delayed or over budget. Then they were asked to estimate the impact of each factor. The majority of projects are delayed, while nearly 45% of projects are over-budget.

Table 7: Performance of CCI Projects

Survey Question	Mean	Median	Mode
How many projects are delayed?	57.7%	63%	80%
What is the average delay for each project?	34.2%	20%	20%
How many projects are over-budget?	44.9%	42.5%	50%
What is the average budget deviation for each project?	23.2%	20%	10%

Risk Analysis

The survey result of the risk factors in the CCI is shown in Table 8. Respondents were asked to identify which factors they agreed or disagreed with (on a Likert scale; 1 is low impact and 5 is high impact).

Table 8: Ranking of top CCI Risk Factors

Rank	Risk Factors	Mean
1	Project financing	3.810
2	Management skills	3.701
3	Legal and contract issues	3.474
4	Relationships and Guanxi	3.423
5	Skill level of labor	3.234
6	Government control	3.234
7	Lack of expertise in construction services	3.212
8	Outdated technology	2.934

The relationships between each of the risk factors were further investigated in order to identify the most significant ones. Factor analysis was used to first measure the multivariate interrelationships between and within the risk factors, and second, analyze the structure and correlations between the variables by defining a set of common underlying dimensions (also known as factors or components) (Hair, 1998). The Kaiser-Meyer Olkin (KMO) and Bartlett's Test of Sphericity were conducted to verify the legitimacy of the factor analysis. In this study for the final survey, Bartlett's test approximate of Chi-square is 335.288 with 28 degrees of freedom, which is significant at the 0 level of significance, suggesting that the population correlation matrix is not an identity matrix. The KMO statistic of 0.793 is also greater than 0.5 which is satisfactory for the factor analysis.

The Principal Component method was utilized for factor extraction. The Oblimin rotations with Kaiser Normalization rotation method were selected for this analysis. Two (2) components were identified with Eigenvalues to be greater than 1 (shown in Table 9). These two components account for 57.04% of the variance in construction non-performance.

Table 9: Total Variance Explained

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.469	43.367	43.367	3.469	43.367	43.367	3.147
2	1.094	13.672	57.039	1.094	13.672	57.039	2.365

Table 10 shows the two (2) component loadings extracted from the factor analysis and these exclude the factors with loading values of less than 0.5. The two components are labeled as follows:

- Component 1 – Project Experience and Technology Risks
- Component 2 – Government Involvement and Financing

Table 10: Factor Analysis Loading Results

Components	**Eigenvalue**	**Variance (%)**	**Risk Factors**	**Factor Loading**
1	3.469	43.367	Management Skills	0.911
			Lack of expertise in construction services	0.886
			Skill level of labor	0.736
			Outdated Technology	0.609
2	1.094	13.672	Government Control	0.899
			Relationships and Guanxi	0.713
			Project Financing	0.531

Component 1 – Project Experience and Technology Risks

All of the risks grouped in Component 1 relate to skill level or available technology. According to the factor loading analysis, this component has a more significant impact on the overall perception of project risk (43.4% variance).

Component 2 – Government Involvement and Financing

The risks associated with Component 2 are government control, relationships and Guanxi, and project financing. Each of these three risks has direct ties to government involvement or Chinese culture.

The Chinese government is responsible for funding most of the largest construction projects in China. The government uses a classification system that assigns contractors on a certification scale from A to D, A being the highest and D being the lowest. All of the largest projects are assigned to A Contractors. While 56% of contractors are privately owned, only 0.12% of A Contractors are privately owned (CCIA 2016, NBSC 2018). The rest are owned by the government. This means that the largest projects (most expensive) are primarily dependent on government funding. Smaller contractors can win bids for government projects by fostering "good relations" with government organizations (Guanxi). In China, both 'project financing' and 'relationships and guanxi' are directly linked to government involvement and financing.

Perceptions of the Best Value Approach

The results of the BVA concepts and viability of BVA concepts in the CCI are shown in Table 11. Over 50% of respondents agreed with the four BVA concepts. When asked whether CCI would be likely to implement these BVA concepts, only 40% of respondents believed the CCI could implement BVA (46% don't know 14% disagree).

Table 11: Professional Opinion of BVA System from Final Survey

	Final Survey		
BV Concepts	**Agree**	**Don't Know**	**Disagree**
If the contractor was required to document each stakeholder's performance, price and all risks cause the delay/over budget of the project, would CCI performance improve?	51%	34%	15%
Would a selection system that hires contractors based off of performance and price improve the performance of the CCI?	58%	31%	11%
If we hire an expert contractor by using the selection system mentioned above, making the expert contractor responsible for the planning, risk management, and project management of a project, will it improve performance of the project?	62%	25%	13%
Do you think if there is a selection system could make all of vendor's past performance transparent, that could eliminate "guanxi" in CCI environment?	50%	26%	24%
Viability of BVA Concepts in CCI	**Agree**	**Don't know**	**Disagree**
Do you think this system will be accepted by CCI environment?	40%	46%	14%

Comparison between Test Survey and Final Survey

To support the validity of the final survey, it was compared to the test survey results to see if the opinions of the two populations showed any degree of disagreement and to measure statistical validity. After performing multiple tests, the overall statistics show that the test survey and the final survey results are statistically similar.

The Cronbach's Alpha Coefficients that test the internal consistency reliability of the survey results for the Test survey and the Final survey are 0.79 and 0.8 respectively. Litwin & Fink (1995) suggested that consistency is high when Cronbach's alpha is above 0.7. This confirmed that there is high internal consistency among the answers.

Both surveys show the majority of professionals are not satisfied with current Chinese Construction Industry (see Table 2 and Table 6). The final survey has more data for further significance. Both surveys suggest that the greatest risk in the CCI is project financing. There were only two risks that scored differently between the two surveys: "legal and contract issues" and "skill level of labor", see Table 12.

Table 12: Comparison of Risk Factor between Test Survey Result and Final Survey Result

	Test Survey	**Final Survey**
Risk Factors	**Rank**	**Rank**
Project Financing	1	1
Management Skills	2	2
Skill level of labor	3	5
Relationships and Guanxi	4	4
Legal and Contract Issues	5	3
Government Control	6	6
Lack of expertise in construction services	7	7
Outdated Technology	8	8

The last section of the survey that was analyzed was the BVA concept section. The test survey and the final survey results for this section were similar. Analysis of the results showed that the ratings for each BVA concept were the same. The major difference that occurred in the evaluation of the BVA concepts was in the selecting a contractor based on performance and price and if the professional thought the BVA system would be accepted in the CCI environment.

The test survey showed a lower ranking of these statements, and the final survey showed a greater approval of these statements. This might be due to the different constituents that answered the questions. The test survey being more closely connected with the government and the final survey was less connected with the government.

Discussion of the Results

The survey results shown herein offer insights into in the performance of the CCI, risks that cause poor performance, and viability to apply BVA concepts to address those risks. In analyzing the survey results and comparing the results to previous research, the authors have made observations unique to the CCI. These observations are discussed in greater detail in this section.

Validating Risks of the CCI

In previous research, the authors compiled a list of top risks in the CCI according to a detailed literature search (Paper 2). These risks were listed in the survey, and respondents were asked to rank their impact on overall performance in CCI. Table 13 below compares the ranking of risks between the final survey and the previous literature search. Observation suggests that most of the rankings are inconsistent with each other. The closest ranked risks (lowest average scores) are ‘legal and contract issues’ and ‘relationships and Guanxi’. These two factors are top risks according to both sources (the survey and the literature). No conclusions can be made regarding the importance or impact of the other risks without further validation and case study tests. As shown in Table 8, all risks show a mean score greater than 3 (other than ‘outdated technology’). This suggests that the suggests that, on average, survey respondents believe that each risk does have some impact on CCI project performance. This validates the literature research in that each of the reported risks is somewhat impactful, but this research cannot quantify the scale of that impact (‘outdated technology’ is inconclusive).

Table 13: Comparing Risk Impact from Survey Responses to Literature Research

	Final Survey	**Literature**	**Average**
Risk Factors	**Rank**	**Rank**	**Avg.**
Project Financing	1	6	3.5
Management Skills	2	5	3.5
Legal and Contract Issues	3	1	2
Relationships and Guanxi	4	2	3
Skill level of labor	5	7	6
Government Control	6	8	7
Lack of expertise in construction services	7	4	5.5
Outdated Technology	8	3	5.5

Government Involvement in the CCI

As discussed in previous sections, 44% of all contractors are managed by the Chinese government (NBSC 2018). Because of the nature of the Chinese contractor classification system, only 0.12% of private contractors are selected to build the largest construction projects in China (CCIA 2016). To make the situation worse, China’s state-owned construction enterprises are large and inefficient, many have administrative processes and technology that are outdated and not competitive. Most of them have an equity debt ratio of 75% (He, 2000). Small contractors win more government contracts when using relationships (“Guanxi”).

One of the most important factors for contractors (private and public) to win bids is Guanxi. Guanxi is an ancient Chinese term that describes personal relationships. Today, Guanxi is used in business to form partnerships and select contractors. Research studies have shown that Guanxi is perceived by project stakeholders as the most important criterion determining the success rate of a project (Wang, X. and Huang, J., 2006).

In order to gain a better understanding of Guanxi in China, the authors included a question in the survey that asks, "What causes Ganxi?", or in other words, why Guanxi exists in China. Table 14 shows the response categories and the number of respondents for each category.

Table 14: The Reasons for Guanxi in China

Responses Categories	**Number of Respondents**
Government involvement	21
Chinese Culture	12
Supervision/legal system	8
Bidding process	4
Subcontracting	6
Clients withholding information	4
Total	55

Since this question was a written response, answers varied between each respondent. Regardless, the results show that most of the respondents believe that Guanxi exists (or continues to exist) because of the government involvement in the CCI.

Of the 55 responses to this question, six described a subcontracting system unique to the CCI. The authors have created a model to illustrate one example of this system (see Figure 3).

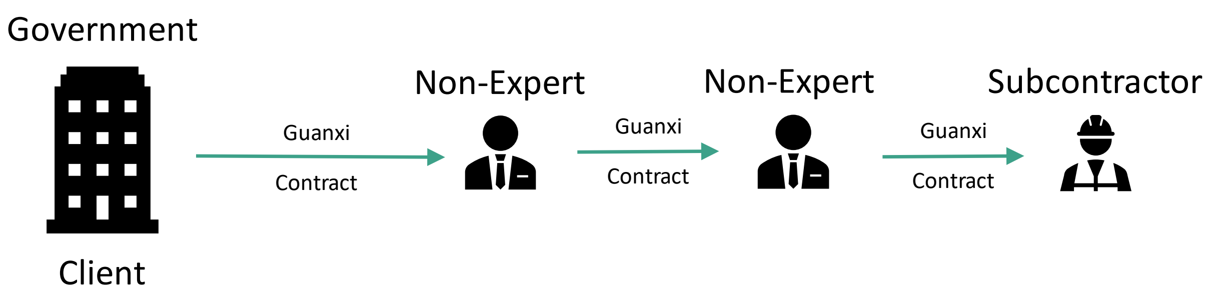


Figure 3: Guanxi and Subcontracting in the CCI

When the Chinese government bids for a project, they may award the project bid to a contractor based on a preexisting relationship (Guanxi). In some cases, the awarded contactor may not have the resources or expertise to complete the project. When awarded, the contractor may not receive any funding until the project is complete, so it is the contractor's responsibility to cover the cost of material and labor. When the contractor cannot cover upfront costs, they may hire another contractor (also based on a preexisting relationship). As was in the first case, this new contractor may not have the abilities or funding to complete the job either. Thus, the second contractor will then hire another subcontractor to fund and complete the work.

When the work is completed, the client pays the first contractor who then pays the other subcontractors involved. The authors were unable to find evidence that suggests any other countries use this subcontracting system. This example of Guanxi may link several risks identified by the literature search (project financing, government control, relationships and guanxi, contract issues, and management skills).

Conclusion

Literature research identified that the Chinese construction industry (CCI) is suffering from low performance and inefficiency. Literature has identified the BVA as a potential solution for the CCI based on similar developing countries (the Kingdom of Saudi Arabia and Vietnam) that exhibit characteristics of the CCI (Paper 1). The BVA was developed by Dr. Dean Kashiwagi at Arizona State University. The solution had been tested for more than 20 years and had performance results on more than 500 projects. The system has been audited 3 times by third parties to verify the legitimacy of its performance documentation.

To further identify if the same solution that Vietnam and the Kingdom of Saudi Arabia identified could also help the CCI, a study was performed comparing the risks of each of these countries (Paper 2). The risk analysis identified that the CCI shared most of the issue causing low performance in the other countries. However, the results showed that there were some issues dealing with project control and finances that were different in the CCI than in the other countries.

This paper performed further research by surveying CCI professionals to validate literature (performance and risk) and identify if the CCI professionals believe that the concepts of the BVA could improve the performance of the CCI and are viable in the CCI. Since most CCI professionals only speak Mandarin, and the original survey that was created was in English, two surveys were administered, the first being a test survey and the second being the final survey. Both surveys found the following:

1. Most CCI professionals are not satisfied with the current project delivery method.
2. The CCI is struggling to complete projects on-time and on-budget (with more than 50% of projects being delayed and 40% of projects being over-budget).
3. The top eight risks that the literature identified were verified as being issues by the CCI professionals.
4. The CCI professionals identified that they felt the BVA concepts would improve the performance of the CCI.
5. The CCI professionals did not know if the BVA system would be accepted in the CCI environment.

This research was able to verify the low performance of the CCI and common risk factors. It also was able to identify a potential solution (BVA) that the professionals in the CCI believe would improve the performance of the CCI. However, there are many professionals are unsure if the BVA would be viable in the CCI. Further research is needed.

Recommendations

It is proposed that further research be performed testing the BVA in the CCI. The following would be suggested:

1. Provide more education and information to CCI participants on the BVA and conduct expert interviews.
2. Gather more information and case studies of how Guanxi operates and affects projects in the CCI.
3. Test the BVA on a pilot project in the CCI. Documenting the performance and the perceptions of all the CCI stakeholders.

The BVA shows great potential in being able to improve the performance of the CCI. However, since the CCI has some unique characteristics from other countries that the BVA approach has been used by. Implementation of the BVA should go slowly and more research and test should be performed to verify the BVA will improve the performance of the CCI.

References

Algahtany, M. (2018). Dissertation, Ph.D. Assessment and Development of Contractors' Mitigation Practices Towards Risks out of Contractors' Control in the Saudi Construction Industry. Arizona State University.

ASU News. (2018). ASU ranked most innovative school in US for the fourth straight time. ASU Now: Access, Excellence, Impact. Web. 10 October 2018. Retrieved from https://asunow.asu.edu/20180909-asu-news-ranked-most-innovative-US-school-fourth-time

Chen, Y., & Chong, O. (2018). Risk Factors and Potential Solutions for the Construction Industry in China. Journal for the Advancement of Performance Information and Value, 10(2), 34-47.

Chen, Y., & Chong, O. (2020). Comparing the Chinese Construction Industry with Other Developing Countries to Identify an Applicable Solution to Low Construction Performance. Journal for the Advancement of Performance Information and Value, 12(2), 81-81

Chinese Construction Statistical Analysis. (2016). Statistical Analysis of construction industry development on 2016. China Construction Industry Association: Ministry of Housing and Urban-Rural Development Program Finance and Foreign Affairs Division.

Duren JV, & Doree, A 2008, 'An Evaluation of Performance Information Procurement System', Proceedings of the 3rd International Public Procurement Conference, PIPS, Amsterdam, Netherlands, pp. 1-24.

Hair, J. F. (1998). Multivariate data analysis. Prentice Hall. Retrieved from https://books.google.com/books/about/Multivariate_Data_Analysis.html?id=mSy3QgAACAAJ.

He, Z. F. (2000). "The status quo of education development in construction sector." Construction Economy, 213(7), 24–27 (in Chinese).

Kashiwagi, D. (1991). Development of a Performance Based Design/Procurement System for Nonstructural Facility System. Dissertation in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy, Arizona State University.

Kashiwagi, D. (2018). How to Know Everything Without Knowing Anything Volume 3, Kashiwagi Solution Model, Mesa, AZ. Publisher: KSM Inc., 2016.

Le, N. T. K. (2019). Identification of Risk Factors, Success Practices, and Feasibility of the Best Value Approach Application to Improve Construction Performance in Vietnam and Other Developing Countries (Doctoral dissertation, Arizona State University).

National Bureau of Statistics of China. (2018). The 40th anniversary of reformation and opening up of China - Series report of accomplishment of development of economy and society, No.9. Web. 7th, September 2018. Retrieved from: http://www.stats.gov.cn/ztjc/ztfx/ggkf40n/201809/t20180907_1621436.html

PBSRG. (2018). Performance Based Studies Research Group Internal Research Documentation, Arizona State University, Unpublished Raw Data.

Rivera, A. (2017). Dissertation, Ph.D. Shifting from Management to Leadership: A Procurement Model Adaptation to Project Management. Arizona State University.

State of Hawaii PIPS Advisory Committee 2002, Report for Senate Concurrent Resolution No. 39 Requesting a Review of the Performance Information Procurement System (PIPS), Honolulu, HI: U.S. Government, Available from: <http://hawaii.gov/dags/rpts/pips.pdf>.

Wang, Xiaojin, and Jing Huang. "The relationships between key stakeholders' project performance and project success: Perceptions of Chinese construction supervising engineers." International journal of project management 24.3 (2006): 253-260.

Chen, Y., and Chong, O. (2020). Comparing the Chinese Construction Industry with Other Developing Countries to Identify an Applicable Solution to Low Construction Performance. Journal for the Advancement of Performance Information and Value, 12(2), 81-81.

Appendix A

Survey

Name: ________________________ Phone: ________________________

Email: _________________________ Position: _________________________

Company: _________________________ Year of Professional Experience: _________

No.	China Construction Industry Evaluation	Estimated Percentage
1	Current satisfaction with construction services? (5 = High Satisfaction, 3=Don't know, 1 = Low Satisfaction).	
1	Estimate percentage (%) of overall projects that are delayed.	%
2	Estimate average percentage delay for each project.	%
3	Estimate percentage (%) of overall projects that are over budget	%
4	Estimate average percentage over budget for each project.	%

Please evaluate each risk on their impact to project performance on a 1-5 scale (5 = High Impact, 3=Don't know, 1 = Low Impact). If there is a risk that is not mentioned that is impactful to project performance, please put as an additional risk at the bottom.						
No.	Risks	5	4	3	2	1
1	Legal and Contract Issues					
2	Relationships and Guanxi					
3	Outdated Technology					
4	Lack of expertise in construction services					
5	Management Skills					
6	Project Financing					
7	Skill level of labor					
8	Government Control					
9	Additional risk:					
10	Additional risk:					

Please evaluate each statement from a scale of 1-5				
(5 = Agree, 3=Don't know, 1 = Disagree).				
No.	Questions	5	3	1
1	If the contractor was required to document each stakeholder's performance, price and all risks cause the delay/overbudget of the project, would CCI performance improve?			
2	Would a selection system that hires contractors based off of performance and price improve the performance of the CCI?			
3	If we hire an expert contractor by using the selection system mentioned above, making the expert contractor responsible for the planning, risk management, and project management of a project, will it improve performance of project?			
4	Do you think if there is a selection system could make all of vendor's past performance transparent, that could eliminate "guanxi" in CCI environment?			

Curriculum Framework Development: A Case Study of Implementing a Construction Management Roofing Course

Dhaval Gajjar, Ph.D., Cayla Anderson, Vivek Sharma, Ph.D and Ehsan Mousavi, Ph.D
Clemson University
Clemson, South Carolina

William Good
National Roofing Contractors Association
Rosemont, Illinois

Received: 03 November 2020; Revised: 3 March 2021; Accepted: 27 April 2021

The U.S. construction industry is currently facing the significant challenge of a declining workforce. Studies of age-related demographics show that the construction industry will not be able to meet its future workforce demands. The roofing industry, one of the essential sectors within construction, faces a similar workforce challenge, presenting a need to build a platform to prepare the next generation of leaders within the industry. With this in mind, the objective of this study was to develop a curriculum framework for a three-credit course (not currently offered in the curriculum) on roofing at the undergraduate and graduate level. An industry-wide survey was developed and distributed to understand the industry's perception regarding current workforce challenges and the perceived need for a course at the higher education level. The study further provides details on the involvement of industry professionals in the course development and implementation, the impact of the course on student's learning and their perception regarding the roofing industry. The findings of the study addressed a current curriculum gap within construction management. The students indicated that they had significantly increased their knowledge about roofing and had generated an interest to explore career options in roofing.

Keywords: Roofing, Construction, Workforce, Industry Involvement, Course Design

Introduction

A declining workforce is a significant concern within the construction industry today (Albattah et al. 2015; Bigelow et al. 2019). Due to the demanding environment (Karakhan et al. 2020) and the increase in generational diversity (Legas and Sims 2011), the construction industry is in continuous development of current and future generations of workforce. O'Lawrence and Martinez (2009) suggest that developing the next generation of leaders must be addressed at all three levels (global, federal, and local levels) for sustaining the US economy. Baby boomers begin turning 65 in the year 2020 and this poses a major challenge for the construction industry at both the craft and the management level. According to the National Center for Construction and Education Research, 41% of the workforce will retire by year 2031 (Bonilla et al. 2019). Multiple efforts are in place to address workforce development at the skilled craft level for various trades (Francis and Prosser 2013; Oke et al. 2017; Sokas et al. 2019; Albattah et al. 2019; Lee et al. 2020; Kim 2020), however, developing the next generation of leaders for management positions within various trade sectors remains to be explored. It is also necessary to have informed and well-educated management personnel to attract and retain skilled craft workers.

One important aspect of developing the next generation of leaders is workforce planning, which involves a continuous process to ensure the organizational needs are being met by the workforce

© K S M , I n c

(Ahmadian et al. 2018). In 2019, a survey conducted by the Associated General Contractors of America reported that 88% of contractors had difficulty finding employees for craft positions. The survey also reported that only 6% of the surveyed companies were able to hire managerial positions without any difficulty (Associated General Contractors 2019). Chaluvadi (2017) also concluded that the lack of skilled labor is a significant problem for 82% of the surveyed builders. The shortage of workforce and skill gap is attributed to the low attraction among the younger generation into the construction industry (Torku et al. 2019). Hence, in order to motivate the workforce towards professional growth and skill development, investing in educating today's youth is key for workforce attraction, satisfaction and high retention rates (Hyari et al. 2010; Ayodele et al. 2020). A well-educated workforce comes from the next generation of leaders that possess skills to respond continually to technical innovations in the construction industry (Dulaimi 2005).

Within construction, roofing is one of the essential trades that involves installation of different roof systems as part of the building envelope. Without the correct installation of those roof systems, the assets within the building, such as property and people, are at risk due to the possibility of roof system failure (Shafique et al. 2018). A well-educated and skilled workforce that can manage and install a quality roofing system is critical for the efficient functioning of a building. The three main primary sectors within the roofing industry include:

1. Manufacturing of roofing materials by building material manufacturers
2. Distribution of the materials from the roofing material manufacturer to the roofing contractor for installation, performed by wholesale distributors
3. Installation of the roofing materials performed by roofing contractors.

In the most recent study available, the roofing industry represented about 8 percent of the overall construction industry workforce (Fredericks et al. 2005). Like general contractors and other sub-contractors, the roofing industry sector is also suffering from critical workforce problems pertaining to labor shortage at both management and skilled craft positions (Choi et al. 2018). Karatas (2019) suggests that only 15 percent of all employees in the roofing industry are 24 or younger and almost half of the employees are between 35 and 54 years old. Moreover, employment trends show a surplus of openings for workforce in the roofing industry (Albattah et al. 2019). Although development in roofing technology (e.g., drones) has decreased the number of workers required for roof installation, the complexities associated with each project still require an educated and trained workforce (Baskaran et al. 2007; Bouafif et al. 2018).

To address this workforce challenge, it is important that the younger generations are educated about the roofing industry at the higher education level (Farrow 2011). Similar to general contractors, Bigelow et al. (2019) discovered that the sub-contractors in the construction industry have also started recruiting from higher education institutions. The accrediting body, Accreditation for Construction Education (ACCE), provides accreditation for construction management schools in the US and has outlined twenty student learning objectives (SLO's) that higher education institutions need to meet. Teijeiro et al. (2013) suggest that curriculum within a construction management or engineering program should be assessed periodically to ensure relevance to avoid discrepancies between academic competencies and industry needs. It was discovered that the roofing industry was one such sector that experienced this discrepancy.

In response, there was a need to develop a course specific to the roofing sector at the higher education level to educate students about the roofing industry and to develop the next generation of leaders for management positions. As a result, the objective of this study was to develop and implement a curriculum for a new three-credit course (not currently offered in the curriculum) specifically on roofing by using the expertise of professionals in the roofing industry. Previous studies have shown that coursework developed with an active involvement of the industry has a positive effect on student learning (Sharma and Sriraram 2012; Zhao et al. 2015). A significant part of this study was also to measure the impact of the course through student perception surveys.

Methodology

The research methodology for this study is shown in Figure 1.

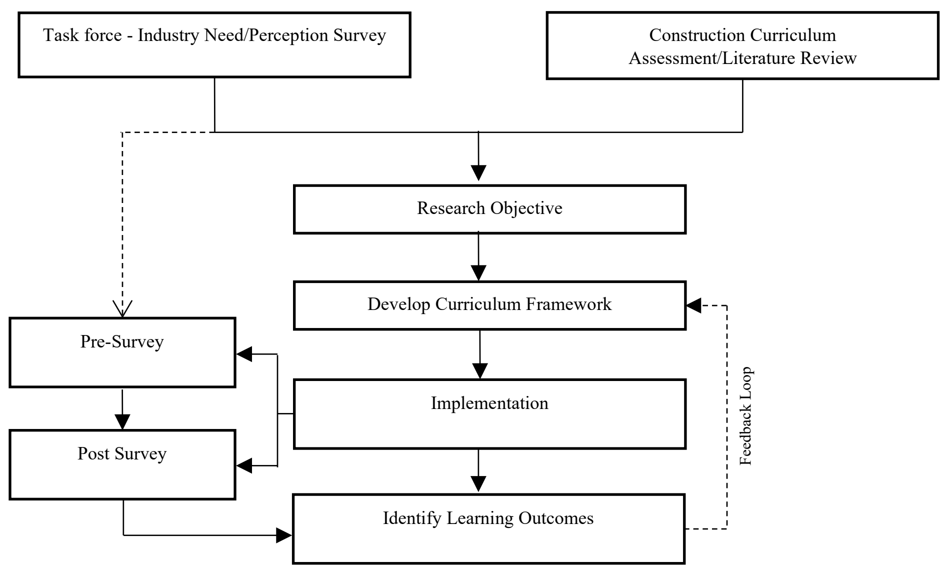


Figure 1: Study Methodology

Based on the literature review and the current construction curriculum assessment, it was determined that there is a need for the roofing sector course at the higher education level.

Industry Need / Perception Survey

This phase included the development and distribution of the initial survey to assess the roofing industry professionals' perception of developing a new roofing course at the higher education level. As part of this phase, a task force of nine industry professionals was created to provide industry expertise, offer feedback and offer key suggestions on developing the curriculum and implementation of the course. Each of the industry's key sectors (contractor, manufacturer, and distributor) was represented on this task force.

The initial industry perception survey was developed jointly by the researchers and the task force. The main components of the industry perception survey were:

1. Professional's background information
2. Professional's view on the current state of roofing workforce
3. Professional's view on offering a roofing specific course at the higher education level
4. Professional's view on providing employment opportunities in the roofing industry for those that have formal roofing education in an academic setting.

The survey was distributed using Qualtrics to 400 roofing professionals by accessing the membership organizations such as, Roofing Alliance and National Roofing Contractors Association (NRCA). A total of 167 responses (42%) were received, as shown in Table 1. Others included consultants, insurance carriers, law firms and technology/software providers.

Table 1: Company Background

Company Background	Data	Percent
Roofing Contractor	124	74%
Roofing Manufacturer	19	11%
Roofing Distributor	6	4%
Others	18	11%
Total	**167**	**100%**

Research Objective

Based on the literature review and the industry perception survey, the following aims were determined for this study.

1. Develop a framework for the curriculum of a three-credit roofing course using the expertise of roofing industry professionals.
2. Identify and rank the key topics to be included in the course.
3. Implement a three-credit roofing course.
4. Measure the difference in student's perception about the roofing industry prior to and after the course offering.
5. Provide a framework for developing other trade-specific courses for the undergraduate and graduate levels for higher education.

Develop Curriculum Framework

Since the roofing industry is such a diverse and specialized field with multiple types of roofing systems, one of the challenges of developing a curriculum framework was to understand the type of content and the concepts that were necessary to be included as part of this roofing course. Hence, a second survey was developed and distributed to the roofing professionals for their input and feedback on the topics that must be covered in the roofing course, with a special emphasis on the specific skillsets required of a college graduate before entering the roofing workforce. The involvement of industry partners in updating the curriculum helped in incorporating the concepts that are needed from an industry perspective (Laguador and Ramos, 2014). A second survey was also developed jointly by the researchers and the task force.

Prior to full distribution, a pilot survey was conducted with the task force members to verify the clarity of the questions and the survey responses. Feedback from the pilot study included adding specific topics to be covered in the course: career options in roofing, understanding roof specifications, roof estimating, and business management.

The main components of the final curriculum development survey were:

1. Professional's background information
    a. Contact information.
    b. Type of company (contractor, manufacturer, distributor or other)
    c. Roof system specialization (low-slope, steep-slope or both)
2. Ranking of top ten out of the twenty topics that the professionals deemed appropriate to be covered in the course. Topics that are relevant to each scope of work are also shown (Contractor – C; Manufacturer – M, Distributor – D).
    a. Types and Installation Details of Roofing Systems (C, M)
    b. Building Envelope Systems (C, M)
    c. Building Function (C, M)
    d. Building Codes in Roofing (C, M)
    e. Installation Details of Roof Components (C, M)
    f. Reading Roofing Blueprints and Specifications (C, M, D)
    g. Roof Estimating (C, M)
    h. Roof Scheduling (C, M, D)
    i. Roof Safety (C, M, D)
    j. Communication (C, M, D)
    k. Site Logistics (C, M, D)
    l. Roof Repair and Maintenance (C, M)
    m. Finance (C, M, D)
    n. Roof Procurement / Sourcing (C, M, D)
    o. Managing Roofing Business (C, M, D)
    p. Field Crew Management (C)
    q. Career Options in Roofing (C, M, D)
    r. Manufacturing and Distribution Channels
    s. The Roofing Industry and the Environment (C, M)
    t. Technology in Roofing (C, M, D)
3. Professional's availability in course assistance
    a. Product Donations
    b. Content donations
    c. Guest lectures

The survey was distributed using Qualtrics to 167 participants that responded to the industry perception survey. The key concepts to be covered in the roofing course were selected by ranking the top ten topics from each sector: contractors, manufacturers, and distributors. The topics that were listed as top ten by all three entities were selected to be included in the roofing course. Based on this topic ranking, a final syllabus schedule was developed, as shown in Appendix A.

Implementation

Based on the development of the curriculum, the roofing course was offered to both undergraduate and graduate students. A total of 21 students (11 undergraduate and 10 graduate) enrolled in this roofing sector course as shown in Figure 2. Two students (9.5%) were civil engineering majors (one undergraduate and one graduate), while nineteen were construction management majors.

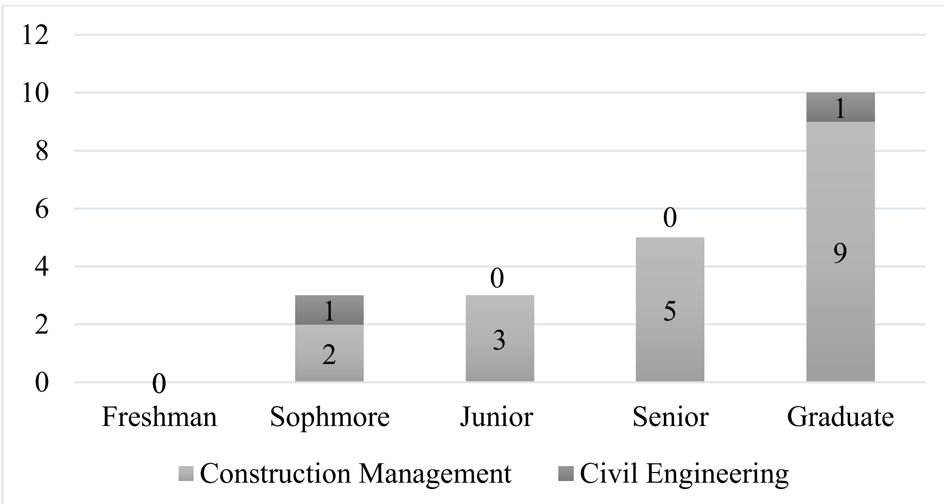


Figure 2: Student Background

Based on the input and feedback from the task force members and due to the involvement of the roofing industry professionals as guest lecturers, the course had the following characteristics:

1. Offered one day of the week for 2.5 hours
2. Class section evenly split between guest lectures and critical thinking in-class assignment
3. Weekly quizzes based on the covered concepts
4. Two exams: mid-term exam and final exam
5. Semester project
    a. Undergraduate: Roofing Professional Interview and Report
    b. Graduate: Compile Qualifications Package for a Roofing Project

One of the important components of this phase was understanding the impact of this course on student's learning and their perception about the roofing industry. To that end, pre (at the beginning of the semester) and post (at the end of the semester) perception surveys were distributed to both undergraduate and graduate sections to assess their perception about the roofing industry.

The main components of the pre-and post-survey is outlined in Table 2. A comparative analysis between preferred aspects and the perception questions of pre-and post-surveys were performed.
Table 2: Perception Survey

Survey Component	Pre-Survey	Post-Survey	Comparative Analysis
Student Background	X	X	
Preferred Aspects	X	X	X
Overall Learning		X	
Overall Satisfaction		X	
Perception Questions	X	X	X

Analysis

The analysis for this study was performed in three sections: industry survey, curriculum development and course implementation.

Industry Survey

A total of 167 roofing industry professionals (out of 400) responded to the initial industry survey. Table 3 outlines the results of the survey.

Table 3: Industry Perception

Statement	Strongly Disagree		Disagree		Neither		Agree		Strongly Agree		Weighted Average
	#	%	#	%	#	%	#	%	#	%	
Lack of workforce is a major challenge in the roofing industry today.	9	5%	1	1%	4	2%	18	11%	135	81%	4.61
University graduates lack the basic knowledge regarding the roofing industry.	4	2%	4	2%	9	5%	41	25%	109	65%	4.48
Educating university students about the roofing industry can help tackle workforce issues.	4	2%	12	7%	19	11%	53	32%	79	52%	4.14
University programs should include roofing course as part of the curriculum.	3	2%	5	3%	12	7%	43	26%	101	60%	4.43

The initial industry survey showed that 92% of survey respondents either strongly agreed or agreed that the lack of workforce is a major challenge in the roofing industry. The survey results validated the initial findings in the literature that workforce development within the roofing industry was a major challenge. 84% of the industry participants also either strongly agreed or agreed that university graduates lack basic knowledge regarding the roofing industry. 84% of survey respondents strongly agreed or agreed that educating university students about the roofing industry could help tackle workforce issues (attracting next generation of leaders) and 86% of the industry participants strongly agreed or agreed that university programs should include a roofing course as part of their curriculum.

Also, 156 out of 167 (93.4%) industry participants responded that they were more likely to provide employment opportunities for students with some type of formal roofing education in an academic setting. Hence, the survey findings, along with the existing literature, suggest a need for a roofing specific course at the higher education level.

Curriculum Framework Development

The topics covered in the course must address the current industry needs, and therefore, a survey was developed and distributed to the roofing industry professionals to identify key topics. The initial list of twenty topics within the roofing industry was generated based on input from the task force members in the pilot phase. Figure 3 outlines the combined ranking of the twenty topics from different entities in the roofing industry.

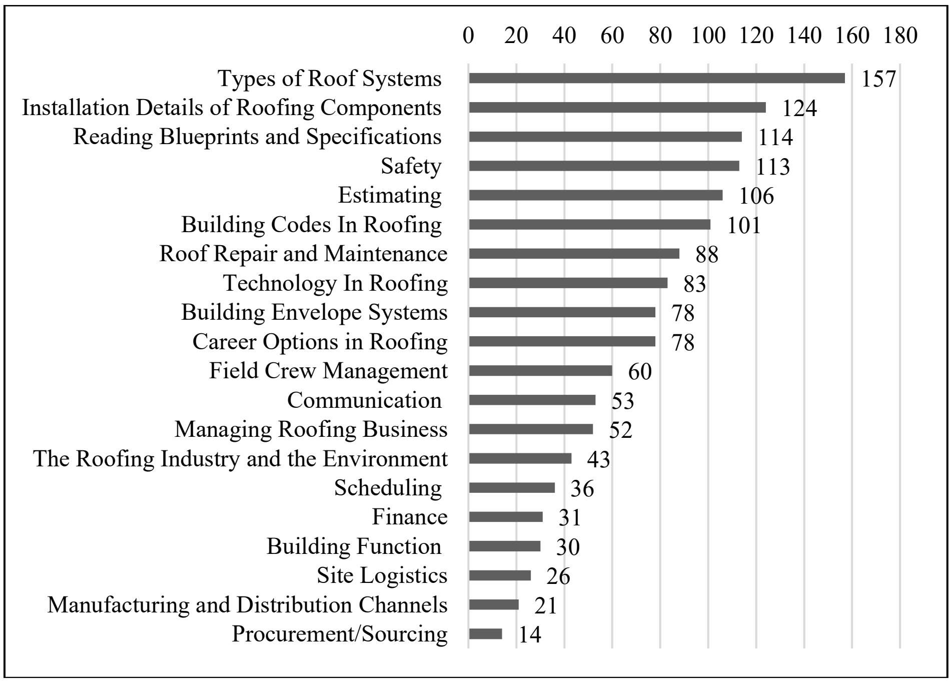


Figure 3: Combined Topic Ranking

However, the combined ranking was heavily favored towards the roofing contractor since the roofing contractor represented 74% of the total survey responses. Further analyses were needed to identify the top ten topics from each major entity, as shown in Table 4, to avoid skewed outcomes toward the roofing contractor survey responses.

Table 4: Topic Rank by Sector

Rank	Contractors	Manufacturers	Distributors
1	Types of Roof Systems	Types of Roof Systems	Types of Roof Systems
2	Installation Details of Roofing Components	Building Envelope Systems	Estimating
3	Reading Blueprints and Specifications	Installation Details of Roofing Components	Installation Details of Roofing Components
4	Safety	Reading Blueprints and Specifications	Safety

5	Estimating	Technology in Roofing	Roof Repair and Maintenance
6	Building Codes in Roofing	Safety	Reading Blueprints and Specifications
7	Roof Repair and Maintenance	Career Options in Roofing	Building Codes in Roofing
8	Technology in Roofing	Building Codes in Roofing	Manufacturing and Distribution Channels
9	Field Crew Management	The Roofing Industry & The Environment	Building Envelope Systems
10	Career Options In Roofing	Estimating	Career Options in Roofing

The final topics for the roofing course were selected based on a two-factor analysis. The first factor of topic selection was any topic ranked among the top ten by all three entities. For example, if the contractor participants ranked "types of roofing systems" in the top ten, an "X" was marked on the table. Any topics that were ranked as top ten by a minimum of two entities were used as the second factor for topic selection. Topics that did not meet the two-factor selection criteria were not selected for this course. Table 5 outlines the details of the two-factor analysis.

Table 5: Top Ten Topics

Topics	**Top 10 Topic Selection**		
	Contractors	**Distributors**	**Manufacturers**
First Factor Selection			
Types of Roof Systems	X	X	X
Installation Details of Roofing Components	X	X	X
Reading Blueprints and Specifications	X	X	X
Roof Safety	X	X	X
Roof Estimating	X	X	X
Career Options in Roofing	X	X	X
Building Codes in Roofing	X	X	X
Second Factor Selection			
Roof Repair and Maintenance	X	X	
Technology in Roofing	X		X
The Roofing Industry & The Environment	X		X
Topics Not Selected			
Building Envelope Systems			X
Roofing Procurement / Sourcing		X	
Roofing Manufacturing / Distribution Cannels		X	
Roofing Field Crew Management	X		
Communication			
Managing Roofing Business			
Scheduling			
Financing			
Building Function			
Site Logistics			

99 out of 167 (59.2%) industry participants agreed to assist in developing the course by providing lecture content, product donations, site visits, projects case studies, and online/in-person guest lectures. Table 6 outlines the details of the industry members' course participation. Over half of the survey respondents volunteered to participate as in-person guest lectures.

Table 6: Industry Participation

Activity	Total (out of 167)	Percent
In-person Guest Lecture	95	56.8%
Volunteer Site Visits	81	47.9%
Lecture Content	69	41.3%
Project Case Studies	69	41.3%
Virtual Guest Lecture	68	40.7%
Product Donations	48	28.7%

Course Implementation

The roofing course was offered as an undergraduate and graduate course based on the topics selected in the curriculum phase and the industry members' participation in assisting with in-person guest lecture, site visits and lecture content. The analysis of the pre and post surveys is shown below.

Pre-Survey

The beginning of the semester survey (i.e. pre-survey) was created to understand the students' background, current knowledge about the roofing industry, interest in enrolling in the course, and perception about the roofing industry prior to the course offering. The pre- survey was distributed during the second week of the course offering. Table 7 shows the student background details, either with prior work experience or a previous formal roofing course.

Table 7: Student Background

Question	Yes		No	
	#	%	#	%
Do you have any prior experience working in the roofing industry?	0	0%	21	100%
Have you ever enrolled in a roofing specific course prior to this course?	2	10%	19	90%
Do you have a family member that works or owns a roofing related business?	0	0%	21	100%

Table 7 shows that enrolled students had no prior experience working in the roofing industry. Only two out of the nineteen students had enrolled in a formal roofing industry-specific course. The two students who have had some experience in a prior roofing course were part of a national roofing competition team prior to implementing this course.

One of the aspects of the pre- survey was to understand the student's motivation in enrolling in this course, as shown in Table 8. Students were asked to rate each statement on a scale of 1 to 10, with one being least important and ten being most important, along with an open-ended question for any other reason.

Table 8: Student Motivation

Rank	Reason	Average (out of 10)	Standard Deviation
1	Learn more about the roofing industry	8.62	1.46
2	Various topics covered in this course	8.57	1.80
3	Industry members' participation	7.81	2.52
4	Recommended by a faculty member/advisor	6.14	3.75
5	Learn about different career options in the roofing industry	6.00	3.23
6	Class day/time	4.86	3.07
7	Recommended by a fellow student	2.86	3.00

Table 8 shows that the curiosity to learn more about the roofing industry, various topics covered in the course, and industry member's participation were the top three reasons for student enrollment in this course. Typically, student enrollment in a specific course heavily replies upon the recommendation by a faculty member and advisor, which was ranked fourth. Table 8 also showed that the industry member's involvement in both curriculum development and course implementation was a critical factor for student enrollment.

The pre- survey also focused on collecting and analyzing enrolled student's perception of the roofing industry at the beginning of the course, as shown in Figure 4.

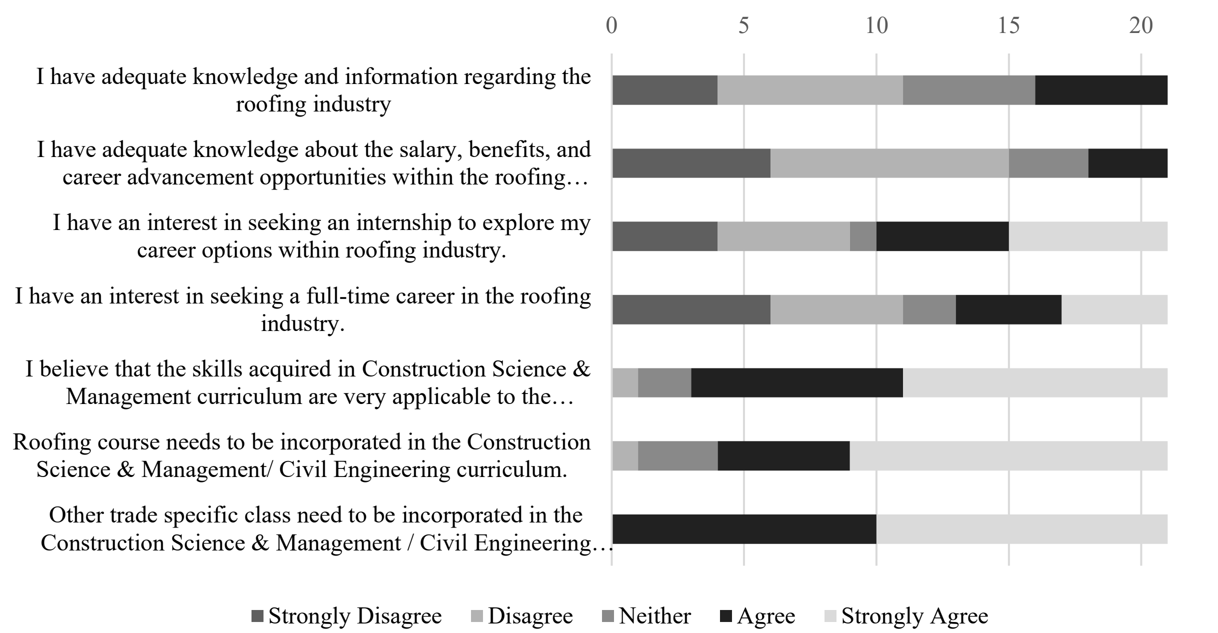


Figure 4: Pre-Survey Student Perception

Figure 4 shows that only five students (23.8%) enrolled in the course agreed that they have adequate knowledge and information regarding the roofing industry. Moreover, only three students (14.2%) enrolled agreed that they have adequate knowledge about the salary, benefits, and career advancement opportunities within the roofing industry, indicating there is a lack of knowledge among students regarding the roofing industry. This showed that there was a lack of knowledge among students about the roofing industry. Since the survey was distributed in the second week and the topic for the first week was roofing introduction and different career options in the roofing industry, eight students (38.1%) strongly agreed or agreed that they have an interest in seeking a career in the roofing industry.

Seventeen students (80.9%) strongly agreed or agreed that the roofing course should be incorporated into the construction management / engineering curriculum. All twenty-one students (100%) also strongly agreed or agreed that other trade-specific courses also need to be incorporated within the curriculum.

Post-Survey

The end of the semester survey (i.e. post-survey) was created to understand the student's preferred aspects of the course, the courses' impact on student learning about the roofing industry, the perception of the roofing industry, overall course satisfaction, and developing additional courses. Table 9 shows the students' preferred aspect about the course. Students were asked to rate each statement on a scale of 1 to 10, with 1 being least preferred aspect and 10 being most preferred aspect, along with an open-ended question for any other reason.

Table 9: Students Preferred Aspects

Rank	Criteria	Average (Out of 10)	Standard Deviation
1	Industry professionals delivering guest lectures	9.33	0.96
2	Various topics covered in this course	8.90	1.45
3	Layout/structure of the individual class (lecture + in-class assignment)	8.62	1.39
4	Semester Project	8.38	2.01
5	Weekly Assignments	7.57	2.96
6	Class Day / Time	7.52	2.71

Table 9 shows that the industry professionals' involvement in delivering guest lectures, various topics covered in the course, and layout and structure of the individual class were the top three preferred aspects. The layout and structure of the class was an even split between guest lecture and a critical thinking group assignment.

Table 10 shows the student's perspective on the topics that they perceived they had learned the most. Students were asked to rate each statement on a scale of 1 to 10, with 1 being least learned and 10 being most learned.

Table 10: Student Learning

Rank	Topic	Average (Out of 10)	Standard Deviation
1	Low Slope Roofing System – BUR, Modified Bitumen	8.71	1.85
2	Low Slope Roofing System – TPO, EPDM, PVC	8.71	2.23
3	Low Slope Roofing System – Fluid Applied Roofing Systems, Green Roofs, Solar Roofs	8.67	1.53
4	Steep Slope Roofing System – Slate/Metal Panels	8.29	1.93
5	Roofing Estimating	8.24	2.23
6	Safety in the Roofing Industry	8.30	2.32
7	Roof Repair & Maintenance	8.05	2.01
8	Reading Roofing Blueprints	7.86	2.74
9	Reading Roofing Specifications	7.86	2.90
10	Steep Slope Roofing System – Asphalt Shingles	7.71	2.57
11	Technology in Roofing	7.83	2.55

Table 10 shows that the top three topics that students learned the most were low slope roofing systems, which can be categorized as "different types of roofing systems". Topics students reported learning the least about include reading roofing specifications, steep slope roofing system—asphalt shingles, and technology in roofing. However, the percent difference between the first ranked topic and the tenth-ranked topic was only 12%.

The post-survey also focused on collecting and analyzing the perception of enrolled students regarding the roofing industry at the end of the course offering, as shown in Figure 5.

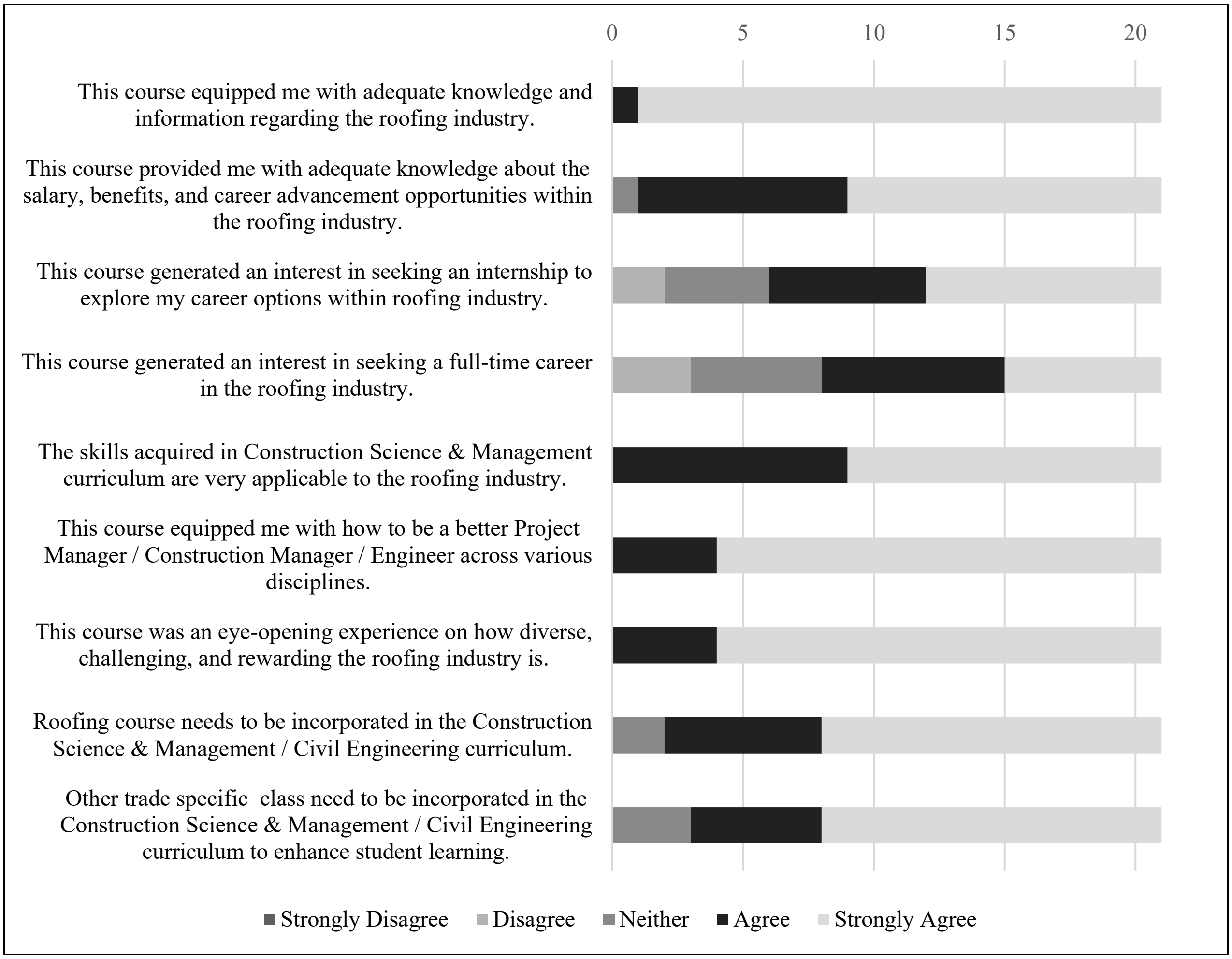


Figure 5: Post-Survey Student Perception

Figure 5 shows that all twenty-one students (100%) enrolled in the course strongly agreed or agreed that this course had equipped them with adequate knowledge and information regarding the roofing industry. Moreover, twenty students (95.2%) strongly agreed or agreed that this course equipped them with adequate knowledge about the salary, benefits, and career advancement opportunities within the roofing industry. At the end of the course, fifteen students (71.4%) strongly agreed or agreed that they have an interest in seeking an internship to explore their career options in the roofing industry. All twenty-one students (100%) also strongly agreed or agreed that this course prepared them to be a better Project Manager / Construction Manager / Engineer across various disciplines. All twenty-one students (100%) of the students also strongly agreed or agreed that this course was an eye-opening experience on how diverse, challenging, and rewarding the roofing industry is.

Comparative Analysis

In order to understand the impact of the roofing course, a comparative analysis of the perception questions between the pre-survey and post survey was performed as shown in Figure 3.

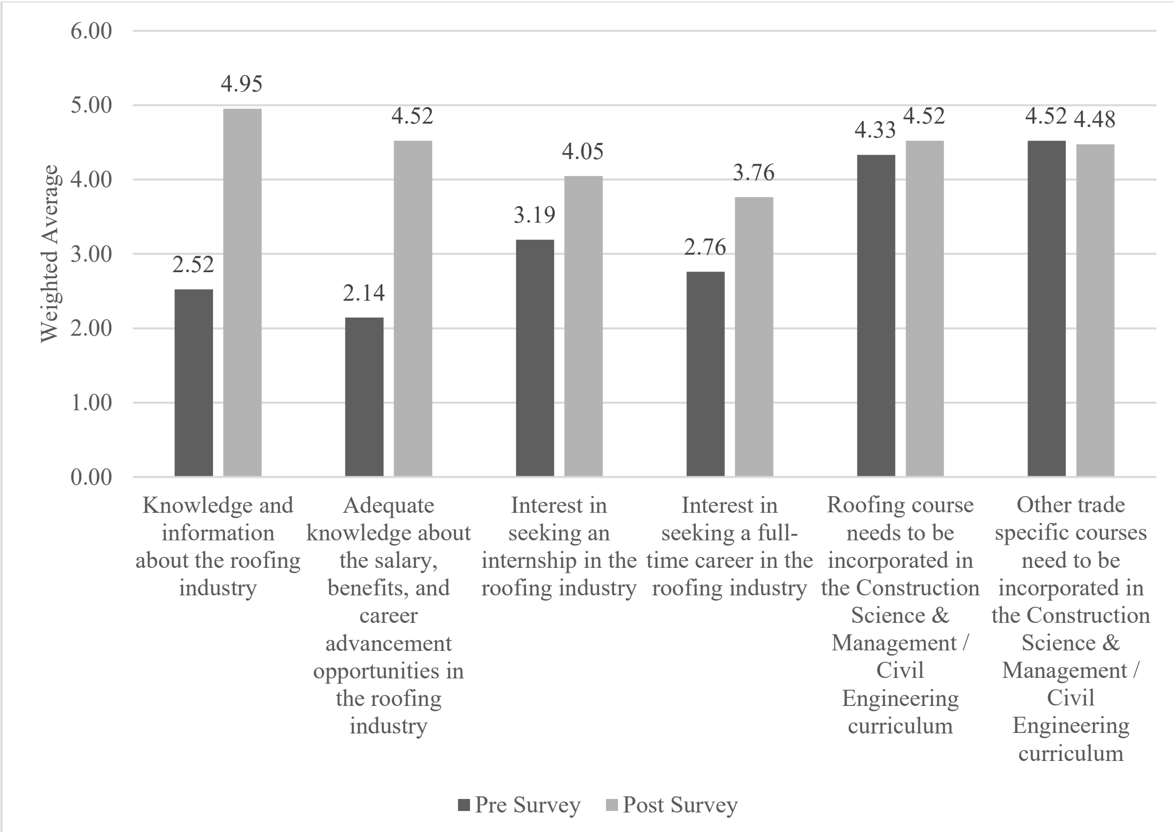


Figure 6: Comparative Analysis

Figure 6 shows a significant increase with a percent difference of 65% in students' adequate knowledge and information about the roofing industry. There was a percent difference of 71.5% in student's understanding of the salary, benefits, and career advancement in the roofing industry. Interest in seeking an internship and interest in seeking a full-time career in the roofing industry also showed a percent difference of 23.8% and 30.7% respectively.

The students were also asked to provide their overall satisfaction with this course on a scale of 1 – 10 with one being not satisfied at all and ten being very satisfied. The overall satisfaction for the course was 9.1 out of 10. 75% of the students rated this course at 9 or higher and 95% of the students rated this course at 8 or higher. Moreover, 75% of the enrolled students expressed an interest in the development of a certificate program in roofing that offers two additional courses.

Conclusion

The study aimed to understand the industry's perception of the current workforce, its perception of offering a roofing specific course at the higher education level, develop the curriculum, implement a three-credit roofing specific course through industry's involvement and understand the impact of this course on student's learning and their perception of the roofing industry. Based on the industry perception survey, it was concluded that the survey's findings aligned with the existing literature. The availability of current roofing workforce and the development of a future workforce is a major challenge faced by the roofing industry. From this study, 92% of survey respondents agreed that the lack of workforce is a major challenge in the roofing industry today. In order to address this challenge, educating higher education students is critical. From this study, 84% of survey respondents agree that educating university students about the roofing industry can help tackle workforce issues. Hence, from the industry perception survey, it was concluded that there is a need for a roofing sector course at the higher education level, especially since trade-level sub-contractors have started to recruit their future workforce from higher education institutions.

The curriculum for the roofing course was developed by utilizing roofing professional's expertise through an industry-wide survey. A task force, composed of roofing contractors, roofing manufacturers, and roofing distributors, was able to provide ongoing, continuous feedback throughout the study. The study was successfully able to capture the needs of the roofing industry and the concepts that the industry deemed important to be incorporated into the curriculum. Moreover, one of the top three reasons for the student's motivation in enrollment from the pre-survey and one of the top three preferred aspects from the post survey were the "various topics" covered in the course. That was made possible by the active involvement of industry experts in curriculum development and through guest lectures. The layout of the actual class period consisted of an even split between industry professional guest lectures to educate students based on their subject matter expertise and a critical thinking group assignment. Students ranked the "involvement of industry professionals" in the actual course offering as one of the top three reasons for course enrollment and one of the top three preferred aspects of the course. It was therefore concluded that active involvement of roofing industry professionals in both the curriculum development and the implementation phase was a critical success factor.

Comparing the pre- and post-perception surveys, the roofing course was successful in providing the enrolled students with adequate knowledge and information regarding the roofing industry and the various employment opportunities within the roofing industry. The interest in seeking an internship and interest in seeking a full-time career in the roofing industry increased by 23.8% and 30.7%, respectively. The students also reported an overall satisfaction of 9.1 out of 10 for the course.

The study concluded that offering a roofing specific course was not only able to address the current curriculum gap but also provided students with adequate information about the roofing industry and generated student's interest to explore roofing as their potential career path. The framework that was chosen—using industry perception surveys, creating a task force of industry experts and involving industry in the course development and layout—is one that can be easily replicated by other construction management programs, and for other trades.

As for the limitations of this study, it only focuses on one of many trade-level sub-contractors within the construction industry. Similar courses for other trades need to be developed by assessing the current curricula and identifying gaps between construction industry needs and academia. Also, this study was conducted over a period of one semester. The ongoing effectiveness of the course needs to be measured over multiple semesters. Out of the twenty-topics identified, only ten topics were covered in this course. Future additional courses, as part of a certificate program, need to be developed to include additional topics identified by this study.

References

Ahmadian Fard Fini, A., Akbarnezhad, A., Rashidi, T. H., & Waller, S. T. (2018). Dynamic programming approach toward optimization of workforce planning decisions. Journal of Construction Engineering and Management, 144(2), 04017113.

Albattah, M. A., Goodrum, P. M., & Taylor, T. R. (2019). New metric of workforce availability among construction occupations and regions. Practice Periodical on Structural Design and Construction, 24(2), 04019003.

Albattah, M. A., Goodrum, P. M., & Taylor, T. R. B. (2015). Demographic Influences on Construction Craft in the U.S. and Canada. 5th International/11th Construction Specialty Conference, 10.

Associated General Contractors. (2019). 2019 Workforce Survey Results. Retrieved June 18, 2020, from https://www.agc.org/sites/default/files/WorkforceDevelopment_2019_OpenShop_0.pdf

Ayodele, O. A., Chang-Richards, A., & González, V. (2020). Factors Affecting Workforce Turnover in the Construction Sector: A Systematic Review. Journal of Construction Engineering and Management, 146(2), 03119010.

Baskaran, B. A., Paroli, R. M., & Kalinger, P. (2007). Advancements and changes in the North American commercial roofing industry. In International Conference on Building Envelope Systems and Technology (Vol. 2007, pp. 275-286).

Bigelow, B. F., Perrenoud, A. J., Rahman, M., & Saseendran, A. (2019). An Exploration of Age on Attraction and Retention of Managerial Workforce in the Electrical Construction Industry in the United States. International Journal of Construction Education and Research, 1–15. https://doi.org/10.1080/15578771.2019.1611678

Bigelow, B. F., Zarate, V., Soto, J., Arenas, J., & Perrenoud, A. (2019). Attracting and Retaining Tradespeople, an Evaluation of Influencers on Construction Workers in Two Different Trades in Texas. International Journal of Construction Education and Research, 15(3), 163–178. https://doi.org/10.1080/15578771.2017.1280103

Bonilla, A., Gajjar, D., & Sullivan, K. (2019). Study of Various Construction Job Functions to Address Workforce Challenge. Journal of the American Institute of Constuctors, 44(1), 6-13.

Bouafif, H., Kamoun, F., Iqbal, F., & Marrington, A. (2018, February). Drone forensics: challenges and new insights. In 2018 9th IFIP International Conference on New Technologies, Mobility and Security (NTMS) (pp. 1-6). IEEE.

Chaluvadi, A. (2017). Top Challenge for Builders is Labor Cost/Availability. Retrieved November 05, 2017, from http://eyeonhousing.org/2017/01/top-challenge-for-builders-is-laborcostavailability/?_ga=2.13283319.1529703213.1512502251-1400158639.1512502251

Choi, J. O., Shrestha, P. P., Lim, J., & Shrestha, B. K. (2018, March). An investigation of construction workforce inequalities and biases in the Architecture, Engineering, and Construction (AEC) Industry. In Construction Research Congress 2018: Sustainable Design and Construction and Education.

Dulaimi, M. F. (2005). The influence of academic education and formal training on the project manager's behavior. Journal of Construction Research, 6(01), 179-193.

ENGLISH, J. (2002). The communication problems experienced by workforce on-site, and their possible solutions. Journal of Construction Research, 3(02), 311-321.

Farrow, C. B., Liu, J., & Tatum, M. C. (2011). Curriculum delivery and assessment for net generation construction students. International Journal of Construction Education and Research, 7(2), 109-125.

Francis, V., & Prosser, A. (2013). Career Counselors' Perceptions of Construction as an Occupational Choice. Journal of Professional Issues in Engineering Education and Practice, 139(1), 59–71. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000125

Fredericks, T. K., Abudayyeh, O., Choi, S. D., Wiersma, M., & Charles, M. (2005). Occupational injuries and fatalities in the roofing contracting industry. Journal of Construction Engineering and Management, 131(11), 1233-1240.

Hyari, K., El-Mashaleh, M., & Kandil, A. (2010). Optimal Assignment of Multiskilled Labor in Building Construction Projects. International Journal of Construction Education and Research, 6(1), 70–80. https://doi.org/10.1080/15578771003590284

Kim, S., Chang, S., & Castro-Lacouture, D. (2020). Dynamic Modeling for Analyzing Impacts of Skilled Labor Shortage on Construction Project Management. Journal of Management in Engineering, 36(1), 04019035. doi:10.1061/(asce)me.1943-5479.0000720

Lee, W., Migliaccio, G. C., Lin, K., & Seto, E. Y. (2020). Workforce development: Understanding task-level job demands-resources, burnout, and performance in unskilled construction workers. Safety Science, 123, 104577. doi:10.1016/j.ssci.2019.104577

Laguador, J. M., & Ramos, L. R. (2014). Industry-partners' preferences for graduates: Input on curriculum development. Journal of Education and Literature, 1(1), 1-8.

Legas, M., & Sims, C. H. (2011). Leveraging generational diversity in today's workplace. Online Journal for Workforce Education and Development, 5(3), 1.

Karakhan, A. A., Gambatese, J., & Simmons, D. R. (2020). Development of Assessment Tool for Workforce Sustainability. Journal of Construction Engineering and Management, 146(4), 04020017.

Karatas, A. (2019). A STUDY OF THE U.S. ROOFING INDUSTRY AND ITS WORKFORCE. CSCE Annual Conference, 5.

Noon, R. K. (2000). Forensic engineering investigation. CRC Press.

O'Lawrence, H., & Martinez, L. (2009) Influence of Workforce Education and Development on the Growth of Today's Economy. Online Journal for Workforce Education and Development, 4(1), 4.

Oke A., Aigbavboa C., Khangale T. (2018) Effect of Skills Shortage on Sustainable Construction. In: Charytonowicz J. (eds) Advances in Human Factors, Sustainable Urban Planning and Infrastructure. AHFE 2017. Advances in Intelligent Systems and Computing, 600. Springer, Cham

Reider, D., Knestis, K., & Malyn-Smith, J. (2016). Workforce education models for K-12 STEM education programs: Reflections on, and implications for, the NSF ITEST program. Journal of Science Education and Technology, 25(6), 847-858.

Reynolds, C. (2003). Rewriting the curriculum: A review and proposal of forensic engineering coursework in US universities. In Forensic Engineering (2003) (pp. 307-319).

Roberts, K. E. I. T. H. (1997, September). The electrical earth leakage technique for locating holes in roof membranes. In Proceedings of the Fourth International Symposium on Roofing Technology, Gaithersburg, Md (Vol. 347).

Schwatka, N. V., Butler, L. M., & Rosecrance, J. R. (2012). An aging workforce and injury in the construction industry. Epidemiologic reviews, 34(1), 156-167.

Shafique, M., Kim, R., & Rafiq, M. (2018). Green roof benefits, opportunities and challenges – A review. Renewable and Sustainable Energy Reviews, 90, 757–773. https://doi.org/10.1016/j.rser.2018.04.006

Sharma, V., & Sriraman, V. (2012). Development and Implementation of an Industry Sponsored Construction Management Capstone Course Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://peer.asee.org/21203

Sokas, R. K., Dong, X. S., & Cain, C. T. (2019). Building a Sustainable Construction Workforce. International Journal of Environmental Research and Public Health, 16(21), 4202. doi:10.3390/ijerph16214202

Teijeiro, M., Rungo, P., & Freire, M. J. (2013). Graduate competencies and employability: The impact of matching firms' needs and personal attainments. Economics of Education Review, 34, 286-295.

Torku, A., Bayrak, T., Ogunlana, S., Chan, A. P. C., & Owusu-Manu, G. (2019). Are the Ageing Workforce Satisfied with the Construction Work Environment? 11th International Conference (CITC-11), 9.

Ventre, J., & Weissman, J. (2009). Workforce development: A survey of industry needs and training approaches (No. IREC401-013). Interstate Renewable Energy Council.

Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C., & Nikkhoo, P. (2015). Building Collaborative Construction Skills through BIM-integrated Learning Environment. International Journal of Construction Education and Research, 11(2), 97–120. https://doi.org/10.1080/15578771.2014.986251

Appendix A

Date	Subject
Week #1	Course Introduction; Introduction to Roofing; Career Options in Roofing
Week #2	Steep Slope Roofing Systems - Asphalt Shingles, Concrete / Clay Tiles, Wood Shakes
Week #3	Steep Slope Roofing Systems – Slate, Metal Panels
Week #4	Low Slope Roofing Systems – Built-up Roofing, Modified Bitumen
Week #5	Low Slope Roofing Systems – Single-ply Thermoset and Thermoplastic
Week #6	Low Slope Roofing Systems – Fluid Applied Roofing Systems, Photovoltaic Roof, Vegetative / Green Roof
Week #7	Reading Roof Blueprints
Week #8	Reading Roof Specifications
Week #9	*Mid-term Examination*
Week #10	Roofing Estimating I
Week #11	Roofing Estimating II
Week #12	Safety in the Roofing Industry
Week #13	Roof Repair & Maintenance
Week #14	Technology in Roofing
Week #15	Final Exam

Acknowledgement

Thank you to the Roofing Alliance, a foundation of National Roofing Contractors Association, for funding this study.

Table of Contents

CIB W117 .org

ISSN
216-0464 (Online)
2169-0472 (CD-ROM)