# การเลือกวิธีการก่อสร้างสะพานคอนกรีตแบบแยกส่วนในประเทศไทย : กรณีศึกษา โครงการก่อสร้าง รถไฟฟ้าสายสีม่วง (สัญญาที่ 2 )

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต สาขาวิชาโครงสร้างพื้นฐานทางวิศวกรรมโยธา ภาควิชาวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2555

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# THE SELECTION OF CONSTRUCTION METHOD FOR CONCRETE SEGMENTAL BRIDGE IN THAILAND: A CASE STUDY OF MRT PURPLE LINE (CONTRACT 2)

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A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Engineering Program in Infrastructure in Civil Engineering

Department of Civil Engineering

Faculty of Engineering

Chulalongkorn University

Academic Year 2012

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Thesis Title:	THE SELECTION OF CONSTRUCTION METHOD FOR CONCRETE SEGMENTAL BRIDGE IN THAILAND: A CASE STUDY OF MRT PURPLE LINE (CONTRACT 2)
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ทิภารัตน์ ถือทอง เอื้อพันธุ์พงศ์: การเลือกวิธีการก่อสร้างสะพานคอนกรีตแบบแยกส่วนในประเทศ ใทย: กรณีศึกษา โครงการก่อสร้างรถไฟฟ้าสายสีม่วง (สัญญาที่ 2) (THE SELECTION OF CONSTRUCTION METHOD FOR CONCRETE SEGMENTAL BRIDGE IN THAILAND: A CASE STUDY OF MRT PURPLE LINE (CONTRACT2)) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.คร.นพคล จอก แก้ว, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ.คร.ธนิต ธงทอง, 151 หน้า.

การออกแบบสะพานและเทคโนโลยีในการก่อสร้างได้ถูกพัฒนาอย่างรวดเร็วในทศวรรษที่ผ่านมา และ ถูกถ่ายทอดสู่วิศวกรอย่างแพร่หลาย แต่การตัดสินใจเลือกเทคนิกการก่อสร้างพื้นสะพานยังจำเป็นต้องใช้ วิศวกรผู้ชำนาญการเฉพาะทางในด้านเทคนิกการก่อสร้างขั้นสูง ในการศึกษานี้ได้ประยุกต์วิธีการของ กระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytical Hierarchy Process: AHP) ในการพิจารณาปัจจัยที่ใช้ในการ ตัดสินใจเพื่อเลือกวิธีก่อสร้างพื้นสะพานประเภทชิ้นส่วนคอนกรีตสำเร็จรูปที่เหมาะสมสำหรับประเทศไทย โดยใช้โครงการก่อสร้างรถไฟฟ้าสายสีม่วง (สัญญาที่ 2) เป็นกรณีศึกษา โดยศึกษาการก่อสร้างพื้นสะพานและ ขั้นตอนของการเลือกเครื่องมือที่ใช้ยกอย่างเหมาะสม

จากผลการศึกษาพบว่าบึจจัยสำคัญที่ส่งผลต่อการตัดสินใจถึงการเลือกวิธีก่อสร้างที่เหมาะสมมี 6 ปัจจัย กือบึจจัยขนาดของโครงการ ปัจจัยเงื่อนไขของหน่วยงานก่อสร้าง บึจจัยต้นทุน บึจจัยด้านเวลา บึจจัยทางด้าน สุขภาพและความปลอดภัย และปัจจัยด้านผลกระทบต่อสิ่งแวดล้อมผลการประยุกต์ใช้ปัจจัยดังกล่าวในการ เลือกระบบการก่อสร้างพื้นสะพาน 5 ระบบและเครื่องมือยก 12 วิธี กับโครงการกรณีศึกษาพบว่าระบบการ ก่อสร้างพื้นสะพานที่เหมาะสมคือ ระบบการก่อสร้าง Span-by-Span และเครื่องมือยกที่เหมาะสมคือ Under Slung Gantry

ภาควิชา	วิศวกรรมโยธา	ุลายมือชื่อนิสิต
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# ## 5271642121 : MAJOR INFRASTRUCTURE IN CIVIL ENGINEERING KEYWORDS : BRIDGES DECK CONSTRUCTION METHOD/ SEGMENTAL BRIDGE DECK SELECTION

THIPARAT THOOTHONG EUAPUNPONG: THE SELECTION OF CONSTRUCTION METHOD FOR CONCRETE SEGMENTAL BRIDGE IN THAILAND: A CASE STUDY OF MRT PURPLE LINE (CONTRACT 2). ADVISOR: ASST. PROF. NOPPADON JOKKAW, Ph.D., CO-ADVISOR: ASSOC. PROF. TANIT TONGTHONG, Ph.D., 151 pp.

Over the past decade, bridge design and construction technology has undergone rapid development. Although knowledge and technology in the field of bridge design has been studied and transferred to engineers, specialist engineers and specialists in advanced construction techniques are still required to make decisions. However, within the decision-making process, experts still face difficulties and complexities in selecting the suitable method of bridge deck construction. In this study, the Analytical Hierarchy Process (AHP) was applied in consideration of the factors, and is used for selecting the suitable method of bridge deck construction and erection equipment system. The MRT Purple Line (contracts 2) construction project was used as a case study.

The results of this research reveal there are six main factors influencing the selection of bridge deck construction method, namely size of project, construction site condition, cost, time, health and safety, and environmental impact. Following the application of these factors to select the five types of superstructure and 12 types of erection equipment in the case study, the results show that the most suitable superstructure is the Span-by-Span method and the most suitable erection equipment is the Under Slung Gantry.

Department:	Civil Engineering	Student's Signature
Field of Study:	Civil Engineering	Advisor's Signature
Academic Year:	2012	Co-advisor's Signature

## ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Assistant Professor Noppadon Jokkaw, Ph.D. (my Advisor), and Associate Professor Tanit Tongthong, Ph.D. (my co-advisor) for their guidance, thoughtful and insightful instruction and continuing support. Their patience has assisted the growth of my learning and for this, I am forever grateful.

I would like to thank and express my gratitude towards three more important people; chairperson: Associate Professor Thares Srisatit,Ph.D, internal examiner: Assistant Professor Vachara Peansupap, Ph.D., and external examiner: Wanchalearm Kornkasem, Ph.D. for their valuable suggestions and comments.

Mr. Natthawut Cheencharoen holds a great place in my heart, with his guidance and passion. His assistance in contacting and coordinating valuable information from professionals was paramount in this research. I am writing this page to show my appreciation of his work. Thank you so much.

I would like to thank all specialists, in particular Mr. Athiwat Noonma for the data pertaining to the MRT Project and AHP model.

I am thankful to all lecturers in the Infrastructure for Civil Engineering division, Chulalongkorn University, who provided me with useful instruction, guidance, and invaluable knowledge. Many thanks to my friends, who have supported, encouraged, discussed and helped me.

# CONTENTS

# Page

ABSTRACT (THAI)iv
ABSTRACT (ENGLISH)v
ACKNOWLEDGEMENTSvi
CONTENTSviii
LIST OF TABLESix
LIST OF FIGURESx
CHAPTER I INTRODUCTION
1.1 Introduction
1.2 Problem Statements
1.3 Objectives
1.4 Scope of Research
1.5 Research Methodologies
1.6 Expected Outcomes
CHAPTER II LITERATURE REVIEWS
2.1 Introduction
2.2 Literature Review
2.2.1 Bridge Deck Construction
2.2.2 Literature Review of Analytic Hierarchy Process
2.2.3 Literature Review of the Superstructure Design Stage
2.2.4 Erection Equipment Design Stage Review
2.3 Conclusion
CHAPTER III RESEARCH METHODOLOGY
3.1 Research Methodology Framework
3.2 QuestionnaireDetails
3.3 Experts Interviews
3.4 General Information aboutExperts
3.5 Analysis Tools
3.5.1 Scoring Method
3.5.2 Analytic Hierarchy Process (AHP)14
3.6 Conclusions
10

viii

CHARPTER IV THE STUDY OF BRIDGE DECK CONSTRUCTION METHOD	19
4.1 Bridges Deck Construction Methods.	.19
4.2 Precast Bridge Segment	.19
4.2.1 Incremental Launching Method	.22
4.2.2Span-by-Span Method	.24
4.2.3 Span-by-Span Method Using Erection Launching Gantry	.26
4.2.4 Span-by-Span Erection with Launching Gantry: Underslung Gantry	.27
4.2.5 Span-by-Span Erection with Launching Gantry: Overhead Gantry	.27
4.2.6 Span-by-Span MethodUsing Crane Erection Equipment	.29
4.2.7 Balance Cantilever Method	.30
4.2.7.1 Balance Cantilever by Launching Gantry	.32
4.2.7.2 Balance Cantilever by Lifting Frame	.33
4.2.7.3 Balance Cantilever Erection with Crane	.34
4.3 Conclusions	.35
CHAPTER V THE ANALYSIS OF IMPORTANT FACTORS FOR SELECTION	
OF BRIDGE DECK CONSTRUCTION	.36
5.1 Factors InfluencingDecisionMaking	. 36
5.2 Factors inSelecting Bridge Deck Construction	
5.3 FactorsinSelection of Erection Equipment	.41
5.4 Conclusion	.42
CHAPTER VI PROJECT CASE STUDY	.44
6.1 The MRT Purple Lline (Bang Yai to Bang Sue)	.44
6.2 Project Characteristics	.44
6.2 Actual ConstructionMethods	
6.3 Superstructure Construction Method	.46
6.4 Selection of aSuitable Method for Superstructure System	. 48
6.5 The Analysis, Results and Discussion for Selection of Erection Equipment Selection	n
Phase	
6.6 Comparison with Actual Construction Method	. 61
CHAPTER VII CONCLUSIONS	.62
7.1 Conclusions	. 62
7.2 Limitations	. 62
7.3 Further study	. 63

Page

REFERENCES	64
APPENDICES	66
APPENDIX A	67
APPENDIX B	
APPENDIX C	
APPENDIX D	
VITAE	

# LIST OF TABLES

Table 2.1: Suitable Span Length of Segmental Bridge (AASHTO, 1999)
Table2.2: The Details of Each Project
Table 2.3: Yasmeen'sImportant Factors behind Selection of Bridge Construction
Method9
Table2.4: Important Factors behind the Selection of the Suitable Construction
Method by Youssef10
Table 3.1: Experts' Group Details
Table 3. 2: Example of Scoring Method15
Table 3. 3: Example of Average Score of Factors    15
Table 3. 4: Example of Factors Screening
Table 3.5: Pair-Wised Matrix    16
Table 3.6: AHP Score Meaning
Table 3.7: The RI Value Sample
Table 5.1: Screening Factors for Bridge Deck Construction
Table 5.2: Weight of Important Factors for Selecting Superstructure
Table 5.3: Weight of Important Factors for Selecting Erection Equipment41
Table 6.1: Weight of Factors for Selecting Superstructure System
Table 6.2: Weight of Factors for Selection of Erection Equipment Phase

# LIST OF FIGURES

# **CHAPTER I**

# **INTRODUCTION**

# **1.1 Introduction**

As this world continues to grow, so does the use of bridges and, in turn, their contribution to both economic and social development. Thailand has undergone rapid growth as evidenced by the substantial development and success of its infrastructure such as its mass transit systems and bridges like the Second Stage Expressway (Figure 1.1), Burapha Withi Expressway and Suvarnaghumi Airport Rail Link, as well as many more transit systems currently under construction. Several innovative methods are being used to construct such infrastructure domestically, making Thailand a strong leader in Asia (Sauvageot, 2000).



**Figure 1.1:** View of the Completed Second Stage Expressway in Thailand Source: Sauvageot, (2000)

The Oleron Viaduct Bridge in France was the first bridge to be constructed in 1966 using the precast segmental concrete construction method. By the early 1980s, this method was introduced to the United States of America and later to Thailand with the completion of the Second Stage Expressway in 1996. (Sauvageot, 2000)

Examples of successful projects in Thailand constructed using segmental concrete construction are detailed as follows.



# Figure 1.2: The BuraphaWithi Expressway Project in Thailand Using the Erection GantryMethod Source: Sauvageot, (2000)

Until 2010, the Burapha Withi Expressway was the longest bridge in the world (see Figure 1.2). Its viaducts consist of six lanes that used the precast segmental concrete design over the entire distance of 56 kilometers. The launching gantry method incorporating span-by-span techniques and the segmental concrete box girder system were all chosen as suitable methods for this project (Brockmann and Rogenhofer, 2000).

The Bangkok Mass Transit System main lines were constructed using precast segmental concrete (Figure 1.3). In total, 8,052 segments were used in the 28.7 kilometers of viaduct for the construction. By using the formwork traveler technique, balance cantilever method and cast in-situ segment systems in the project, conventional scaffolding was casted on the pier table allowing the formation of the long cantilever span; this was constructed without any interruption to the traffic below. (Sauvageot, 2000)

There are many projects in Thailand that have applied the concrete deck structure. Because of this, this research focuses on concrete deck construction.



Figure 1.3: Construction of the Bangkok Mass Transit System Project with Long Span over Rama IV Flyover in Thailand Source: Sauvageot, (2000)

# **1.2 Problem Statement**

Segmental concrete bridge deck construction involves many techniques. Contractors should carefully consider the many criteria and constraints in order to select an appropriate method for each project. Experts and specialist subcontractors have to abide by technical requirements such as construction cost, appropriate construction period, environmental impact, site conditions, local authority requirements, and other major factors. These factors were derived from the review of previous studies and professional interviews.

With the Burapha Withi Expressway construction project, professionals compared two concrete precast system methods – box-precast and the full span precast segments –to determine which was most suitable. They examined the span-by-span and the balance cantilever methods as these had beneficial factors for construction environmental impacts, transportation of precast segments, construction time, efficiency and safety. It was concluded that the balanced cantilever method would be used in conjunction with the box precast segment system. (Brockmann and Rogenhofer, 2000)

Currently, there exists little by way of consistent and logical guidelines for building bridges. The activity is still very much dependent on the professionals' opinion and experience.

The aim of this research is to study the factors involved in the decision making behind bridge deck construction. Following this, appropriate selection methods will be proposed.

# **1.3 Objectives**

- 1) To study and define the important level of factors used to determine bridge deck segmental concrete construction in Thailand.
- 2) To study a case by applying the factors derived from the investigation to decide the appropriate construction method and compare with an actual construction project.

## **1.4 Scope of Research**

- 1) The focus of this research is to investigate the construction of the segmental concrete bridge decks within Bangkok and its vicinities.
- 2) The study commenced after the owner and contractor signed the contract agreement.
- 3) Based on the segmental bridge, this research focuses on the superstructure system and erection equipment. Medium and large-scale projects were considered for study.
- 4) This study aims to consider the method of bridge deck construction in the phase of the design of superstructure system and the erection equipment suitable for the whole project.

#### **1.5 Research Methodologies**

- 1) Investigate, review and compile evidence from previous research and professional interviews to determine methods of construction for the segmental concrete bridge deck in the superstructure system design phase and erection equipment.
- 2) Investigate factors from research, books, journals and interviews that have been considered for the construction of the segmental concrete bridge deck.
- 3) Screen, analyze, discuss, and rank the important factors from fifteen professionals' opinions using the Analytic Hierarchy Process (AHP) techniques to determine the important levels of factors.
- 4) Investigate the adaption of factors and tools using the Purple Line MRT (Contract 2) as case study.
- 5) Analyze and assess the adaptive factors and tools involved in comparison with an actual bridge construction case and define the similarities and differences.

# **1.6 Expected Outcomes**

From the investigation and research, the expected outcomes are:

- 1) Ascertain the main factors and define the important level of factors used to select the methods of segmental concrete bridge deck construction.
- 2) Adapt a selection technique for the case study project in order to choose the methods of segmental concrete bridge deck construction.

# **CHAPTER II**

# LITERATURE REVIEW

## **2.1 Introduction**

The purpose of this chapter is to present the past research involved in selecting suitable construction methods for bridge deck construction, describing the influences, achievements, and other factors that have determined decisions. The overall objective in this chapter is to determine a suitable method in the superstructure design process that is based on the erection equipment design phase. Two construction methods have been used: the balanced cantilever method and the span-by-span method. In Thailand, previous projects have been completed such as the Burapha Withi Expressway, Bhumiphol Bridge I and II (Industrial Ring Road Project), and the Mass Rapid Transit (MRT). These projects were efficiently selected and constructed. Importantly, many experts have previously reviewed completed or several ongoing projects. Each review is described below.

#### **2.2 Literature Review**

#### 2.2.1 Bridge Deck Construction

Sauvageot (2000) compared the advantages and disadvantages of the precast segment systems and cast in-situ systems. He stated that although the cast in-situ construction process was a slow one, it can illustrate the importance and careful consideration of temperature as this affects the overall concrete setting process. Simple equipment such as the formwork traveler was applied because the precast segmental constructions needed to be installed quickly and easily. Although a pre-casting yard and transportation system was required for this method, he concluded that a large-scale project needed suitable high-tech equipment.

#### 2.2.2 Literature Review of Analytic Hierarchy Process

Pan (2008) researched the National Taiwan Freeway in Taiwan as the case study to explore a suitable method of bridge deck construction, focusing on the 'Fuzzy AHP' approach. He carefully considered the following three methods: full span precast by launching, advance shoring, balanced cantilever, based on five important factors that would influence his decision: cost, safety, duration, environmental impact and shape. Pan decided the advanced shoring method was the most appropriate for this bridge construction.

Sun (2005) concluded that the Analytic Hierarchy Process (AHP) method was used to ascertain the important factors and suitable methods of bridge deck construction within China. Several facts and opinions from literature reviews and professionals were investigated with the result focusing on five factors: safety, durability, economy, constructability and aesthetic features.

Saaty (2011) also based his research on bridge deck construction and the AHP model to determine his decision process. He chose the Monngahela Bridge in Pittsburgh in the United States of America as his case study. Saaty also considered three types of bridges and their suitability for his project: Cable Stay Bridge, Truss Bridge and Tied Arch Bridge. Ultimately, the Tied Arch Bridge was selected due to the minimized costs of construction, minimized impact on the environment, the lifecycle and the fact that it was aesthetically pleasing.

Ralls (2005) described how he used the AHP model in his research to describe seven pertinent points – lifecycle cost, construction time, quality of construction, the time of repair, traffic disruption, environmental impacts and the effects on local business within the area. He analyzed the prefabrication and cast in-situ methods, choosing the prefabrication method as suitable for bridge deck construction.

EL-Diraby (2001) focused his research on the importance of six main points in the planning and design of bridge decks, namely safety, accessibility, carrying capacity, schedule performance and budget performance. The AHP model was used as a tool to determine the outcome. He concluded and ranked his findings as follows: safety 24%, accessibility 19%, carrying capacity 19%, schedule performance 19% and budget performance 19%.

Goh (2010) also focused his study around the appropriate methods for constructing bridge decks using the AHP model. He concluded that the following points aided his decision: cost of construction, social and environmental impacts.

As mentioned above, EL-Diraby (2001) focused his research on the planning stage of bridge deck construction. He aimed to identify the pertinent points using the AHP model and concluded with the qualitative factors that affect safety in the following areas: impacts on surrounding communities and businesses, environmental impacts and quantitative costs that would ultimately affect the traffic flow.

Yasmeen (2010) used the AHP model to determine the best method for bridge deck construction taking into careful consideration the opinions from professionals. He concluded that the deck x-section (box section), height over ground, span length, type of concrete (any limitations due to the available technologies), obstacles (waterways, railways, roads, valleys, utilities), environment (touristic routes, downtown, desert or agrarian areas), horizontal curvature, area for crane work, site accessibility, soil conditions and land topography as important factors in building bridges.

# 2.2.3 Literature Review of the Superstructure Design Stage

Concrete segment bridge types are classified as complex as it is difficult to determine the appropriate methods and make the correct decisions in this area of construction. A collaborative approach is needed and the following findings have been discussed and reviewed.

AASHTO (1999) noted that the definition of the design and construction of bridge concrete segments and differences need to be considered. The following were carefully considered: horizontal and vertical alignment, geometry of bridge, construction schedule, span length and site access as well as the size of the project, the construction schedule, the length of the bridge, and access to the workplace. In addition, the limitations of segmental bridges were recorded as follows:

- 1) Truck length should not exceed 2.4-3.0 m. and the total weight must not exceed 40-60 tons.
- 2) In the case of transportation by truck, road width is to be carefully considered.
- 3) In the case of transportation by ship, the river width is to be carefully considered.
- 4) Segments weight is not over 80 tons per trip.
- 5) 80-100 tons per trip is limited for the erecting gantry.

Table 2.1 illustrates the suitable span length of segmental bridge deck types. Table 2.2 illustrates the details of the large-scale projects in Thailand. Four large-scale projects focusing on Hope Well, 2<sup>nd</sup> stage expressway, Bang Na expressway section C were reviewed. He discovered that many criteria had not been considered carefully enough and were causing problems such as not enough area spacing, high traffic congestion, high impact flooding, and poor soil conditions. He concluded that a suitable structure technique and suitable method for an elevated highway used the precast segment system. Experts supported his results as there were minimized periods of construction, low costs, ease of transportation and overall flexibility.

Item	Methods	Depth	Span length
		Super structure (m.)	(m.)
1	Span by span		
1.1	Precast	1.8 to 2.4	33 to 45
1.2	Cast-in-place/ Precast	2.1 to 3.6	36 to 48
2	Incremental Launch		
2.1	Cast-in-place	2.4 to 3.6	up to 72
3	Balance Cantilever		
3.1	Precast	1.8 to 6.0	60 to 135
3.2	Cast-in-place	1.8 to 12	78 to 225

**Table 2.1:** Suitable Span Length of Segmental Bridge (AASHTO, 1999)

Item	Projects	Total Distance	Number of
		(km.)	(lane)
1	Hope Well	60	4
2	2nd Express way	39	6
3	Bang-Na Express way	54	6
4	Bang-Na Express way sec. C	30	4

 Table 2.2: The Details of Each Project

Rogenhofer and Brockmann (2000) studied the longest bridge in the world which was located in Bangkok –the Bang Na Expressway. Many important factors were considered in determining the best method of construction. The span-by-span method using concrete segments was employed as it possessed many advantages; it was easy to install, worked quickly and quality control was easy to monitor. Many quantitative and qualitative measures were taken to ensure proper construction. Quantitative factors consisted of the production planning system and the transportation of the materials, while the qualitative factors were social, cultural and geographical location.

Yasmeen (2010) stated that during the design process many criteria are considered. He chose Qantara River at 48+50km located on the Suez Canal as his case study and as a result discovered 11 criteria as outlined in Table 2.3.

Item	Criteria	Descriptions
		*
1	Deck X-Section	Box section, Beam and slab
2	Site Condition	Height above ground
3	Span Length	
4	Type of concrete	
5	Obstacles	Water way, Rail way, Valleys
6	Surrounding Area Nature	Touristic, Downtown
7	Horizontal Curvature	The radius of curvature
8	Area for crane maneuvering	
9	Site Accessibility	
10	Soil Condition	
11	Land Topography	

 Table 2.3: Yasmeen's Important Factors behind Selection of Bridge Construction Method.

Youssef (1987) studied the selected suitable method of bridge construction using the preliminary design process. The factors are presented below in Table 2.4.

tem	Main Criteria	Description
1	Cost	Unit cost (cost/sq.m)
		Cost of operation, maintainant
2	Duration	Time for normal operation
		Erection and Dismatting
3	Bridges Physical Charecteristics	Deck Carvature
		Deck Up/ Down Grade
		Super structure hight above ground
		Span length
4	Construction method charecteristic	Machine and Labour Intensive
		Personal working in site
		Third party
		Aesthetics
		Availability of system components
		System complexity
		Effect of constructiion method on design
		Method applicable for all design
5	Stake Holders Objective	Increasing Competitive Advantage
		Future Use
6	External Constraints	Managerial Capabilities
		(site, labour, and equipment control)
		Contractor's past experience
7	Surrounding Environment	Commercial Aspects
		Environmental Requirement
		Site Condition

 Table 2.4: Important Factors behind the Selection of the Suitable Construction

 Method by Youssef (1987)

## 2.2.4 Erection Equipment Design Stage Review

Farkas A. (1999) described how the AHP model was used in civil engineering projects and the Monogahela River Bridge in Pittsburg Untied States of America was the focus of his case study. The variables in this study helped determine the disadvantages in methods and focused on suitable bridge types. Three alternatives were discussed: the Truss Bridge, the Cable-Stay Bridge and the Tie-Arch Bridge by government and private sectors. The outcome showed that the Truss Bridge was the most suitable method as detailed below.

- 1) The engineering feasibility was commensurate with the technical knowledge and experience of both the designer and contractors with regard to the bridge type.
- 2) Low overall costs were considered in the overall benefits.
- 3) Maintenance cost was considered within the routine and critical working stages
- 4) Focus on aesthetics within the architecture.
- 5) History affects the eco-system and the surrounding environment.
- 6) Lifecycle and maintenance construction classified as long-life.

# 2.3 Conclusion

The purpose of this chapter was to illustrate the past research into choosing a suitable method of bridge deck construction. The influences drawn upon to assist in the decision-making process, suitability and sustainability were also derived from the past research studied. Notably, the AHP model was used throughout many case studies to assist in finding the best method of bridge deck construction. The next chapter explains the methodologies used in this research.

# **CHAPTER III**

# **RESEARCH METHODOLOGY**

# 3.1 Research Methodology Framework

This research intends to identify the appropriate construction techniques involved in the many methods of bridge deck construction. The characteristics were based on previous research and professional interviews – they have been compiled and illustrated in the following five steps.

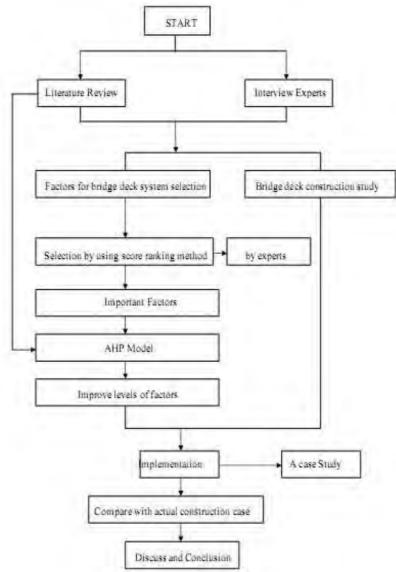


Figure 3.1: Research Methodology Flowchart

In the first step, bridge construction methods, erection equipment, as well as the related factors were considered in the selection process. The appropriate bridge construction and the erection equipment were considered under the important factors. Past research was reviewed and experts interviewed to find out the important factors which appear in the second step. In this procedure, fifteen experts were interviewed again, representing the three groups of designers, contractors and sub-contractors. The aim was to find the important factors, which score higher than the mean value. In the third step, the AHP method was applied to analyzing the selection of appropriate bridge deck construction under the consideration of the important factors previously chosen. All of these processes were performed by fifteen experts who made the decision. The selection of suitable method and suitable erection equipment of the bridge deck construction appeared in this stage. In the fourth stage, a case study was chosen for implementing the above analysis process. In the fifth step, the difference between actual project and case study was compared in terms of the methods of construction of superstructure and erection equipment, as well as an explanation of the differences and supporting reasons. The last stage was the discussion and conclusion of the findings.

## **3.2 Questionnaire Details**

The questionnaire comprised two parts: the first concerned the personal details such as name, company and experience. The second part concerned the superstructure and erection equipment. Finally, the experts considered and selected the suitable method of bridge deck system and erection equipment.

## **3.3 Expert Interviews**

The purpose of the experts being interviewed was to determine the important factors and select an appropriate method for bridge deck system and erection equipment. The experts met the criteria if had more than eight years experience in the field. They also had to compare several construction systems and different erection equipment to find out a suitable method.

#### **3.4 General Information of Experts**

Experts were classified into three groups: contractors, owners and consultants.

Table 3.1: Experts' Group Details.

Experience	Designer	Main Contractor	Sub Contractor	Total
	(person)	(person)	(person)	(person)
Minimum 8 years	7	3	5	15
Percentage	47%	20%	33%	100%

Table 3.1provides a breakdown of the experts' group, who had experience of a minimum eight years. They consist of 47% designers, 20% main contractors and 33% contractors.

# **3.5 Analysis Tools**

#### 3.5.1 Scoring Method

Each variable weight was considered based on an average method. The details are presented below.

The average of each sample was determined by the average weight of the data obtained through a formula based on statistical calculations.

Given,

"W" is the degree of agreement that starts from 0 to 5.

"X" is the frequency of each agreement.

"N" is the total number of experts.

"n" is the number of factors.

So,

Mean x = ((W1\*X1) + (W2\*X2) + (W3\*X3) + ... Wn\*Xn) / N

Table 3.2 illustrates the various variables that appear in the left column. The second to the sixth columns represent the priority weighting of each alternative. The last column shows the number of experts that provided feedback on each variable.

For example;

Factor	Very disagree	Disagree	Unprejudiced	Agree	Very agree	Total Experts
	- 1	2	3	4	5	
Factor A	2	3	5	2	3	15
Factor B	4	5	1	1	4	15
Factor C	3	4	1	2	5	15
Factor D	3	4	2	3	3	15
Factor E	2	3	2	3	5	15
	14	19	11	11	20	<u>-</u>

Table 3.2: Example of Scoring Method

**Table 3.3**: Example of Average Score of Factors

	1	A	B	C	D	E	F	G	
	Factor	Very disagree	Disagree	Unprejudiced	Agree	Very agree	Total Experts	Everage	
		1	2	3	4	5	(N)		
1	Factor A	2 -	- 3 -	5	2 -	3	15	3.07	
2	Factor B	4	5	1	<b>1</b> 11-	4	15	2.73	
3	Factor C	3	4	1	2	5	15	3.13	
4	Factor D	3	4	2	3	3	15	2.93	
5	Factor E	2	3	2	3	5	15	3.40	
-		14	19	11	11	20	-	3.05	

Table 3.3 reflects the average of each variable according to the different opinions of the fifteen experts. The average appears in column G.

Table 3.4: Example of factors screening

		A	В	C	D	E	F	G	h
	Factor	Very disagree	Disagree	Unprejudiced	Agree	Very agree	Total Experts	Everage	Result
	1.00	1	2	3	4	5	(N)	1.11.1	
1	Factor A	2	3	5	2	3	15	3.07	acceptable
2	Factor B	4	5	1	1	4	15	2.73	Unacceptable
3	Factor C	3	4	1	2	5	15	3,13	acceptable
4	Factor D	3	4	2	3	3	15	2.93	Unacceptable
5	Factor E	2	3	2	3	5	15	3,40	acceptable
		14	19	11	11	20		3.05	

Table 3.4 illustrates the results of the acceptance of each factor. In this study, the acceptance average score is above 3.05.

## 3.5.2 Analytic Hierarchy Process (AHP)

Saaty (1994) defined the AHP model as a simple decision-making method based on the process model of human behavior. AHP distinguishes priority problems, weight and compares the factors of each identified problem within the hierarchy. The AHP model captures both subjective and objective evaluation measures by providing useful mechanisms for determining the consistency of evaluation measures and it also provides alternative suggestions brought forward by the team; thus reducing bias in the decisionmaking process. The process of decision-making has many complexities so this model is used to clarify this complexity. As a result, the AHP model was applied to analyze all relevant factors and identify an appropriate decision.

One advantage of this method is the tools used in the decision making process, which are analyzed by professionals.

Equation 3.1 illustrates the matrix used in consideration. A statistical equation utilized in the analysis of the problems.

г 1	•••	a1n	
:	۰.	:	
[1/a1n	•••	1	

The objective of		Factor					
comparison	A1	A2	$\rightarrow$	An			
A1	1	3	-	-			
A2	1/3	1	-	-			
$\downarrow$			-	_			
Factors: An	-	-	-	1			

 Table 3.5: Pair-wise matrix

Table 3.5 shows the value of each of the variants which result from the matrix multiplication, referred to in Equation 3.1.

 Table 3.6: AHP Score meaning

The intensive level of importance	Meaning
1	Equal importance
2	Modurate importance
3	Strong importance
4	Very strong
5	Extreamly strong

n  

$$\sum_{i=1}^{n} a_{ii} = 1.0.....(3.3)$$
  
 $i = 1$ 

When;

$W_i$	=	Rating weight of factors
$\mathbf{V}_{\mathrm{i}}$	=	Average of factor
n	=	The number of average scores

Equation 3.2illustrates the score weight of each alternative. Moreover, the numerical interpretation of each weight is presented in Table 3.7.

## Consistency analysis

This value is intended to observe the compliance of each pair of alternatives under the same factors used to make the comparison.

 $\lambda \max = \sum_{i=1}^{n} \left[ \sum_{j=1}^{n} \operatorname{aij} W_{j} \right] \dots (3.4)$ 

a. This case means the matrix is corresponding.

 $\lambda$  max = number of principles that were compared (n)

b. This case means the matrix is not corresponding.

 $\lambda$  max >number of main criteria that were compared (n).

Consistency Index: CI

 $CI = \left(\frac{\lambda \max - n}{(n-1)}\right) \dots (3.5)$ 

When n = the number of criteria

Consistency Ratio: CR

 $CR = \frac{CI \text{ from calculated}}{RI \text{ from random sampling}} \dots (3.6)$ 

The CR values contain the reason analysis of the criteria consistency. This is based on many factors as follows:

- 1) Three factors of CR value factors should not exceed 5%
- 2) Four factors of CR value factors should not exceed 7%
- 3) Number of factors more than five factors, CR value factors should not exceed 10%.

If a particular value of the CR is not consistent, the results from the previous analysis shall be rechecked. The values of RI (random index) within the analysis have to prioritize the score for each individual factor (see Table 3.7).

 Table 3.7: The RI value sample

Matrix size	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

# **3.6 Conclusions**

The methodologies of this research consist of the review and compilation of evidence from previous research and professional interviews to determine the method of construction and the factors used to select the segmental concrete bridge deck, construction in the superstructure system design phase and selection of erection equipment. Then, the factors were screened using the average score. After that, the Analytic Hierarchy Process (AHP) technique was applied to analyze the factors used for selecting a suitable method of bridge deck construction.

# **CHARPTER IV**

# THE STUDY OF THE BRIDGE DECK CONSTRUCTION METHOD

## 4.1 Bridge deck construction methods.

Deck bridges consist of three main types: concrete, steel and composite deck, as shown in Figure 4.2. Concrete segments are separated into two main types of categories, namely those cast in yard and those cast in situ. The concrete segment is divided into concrete segments and the full span concrete bridge. Various techniques are involved in two main systems of concrete segment discussed are the balanced cantilever and span-byspan techniques. In addition, the cast in-situ system consists of the balanced cantilever and span-by-span techniques. The incremental launching method is classified as a special method. Several types of erection equipment have been used to construct bridges. When using the span-by-span or the balanced cantilever method, a crane or gantry is used to lift segments and install them in place. Stationary and Movable Scaffolding Systems (MSS) are commonly used in the cast-in-situ system. Furthermore, the formwork traveler is the preferred tool popular tool when compared with several other methods.

# 4.2 Precast Bridge Segment

Between 1946-1950 France pioneered in the usage of precast concrete segments, constructing six bridges utilizing this method. In Thailand, the Bangkok Light Rail Transit system that crosses the Rama IV Flyover was the first bridge to be erected using the precast concrete segments system.

The details and work of the bridge can be described as follows:

Individual pieces of concrete have a connection in the front and rear. These parts are connected using the post-tensioning system. Generally, a bridge spans 30-180 meters from 30-180 meters. The specific type of machine is carefully chosen as it must be lightweight and be able to be modified for further projects.

Figure 4.2 illustrates the box segment during erection and alignment in the construction process. In this figure, the span-by-span method was applied to the overhead gantry equipment using the precast system.

The advantages and disadvantages of this system are as follows.

## Advantages

The advantages of bridge concrete segment include the reduction in construction time and labor cost. Furthermore, the segments constructed from this process are of high quality.

# Disadvantages

This system requires a pre-casting yard which requires a good deal of investment. Due to the high investment cost, equipment, factory parts and transportation costs, the precast system is suitable for bridges with along span.

Figure 4.3 illustrates the box segment in more detail. As can be seen, the segment consists of three main parts –the gantry crane, the segment for erection and the stability tower.



Figure 4.1: Concrete Box Segment Source: IABSE, (2011)

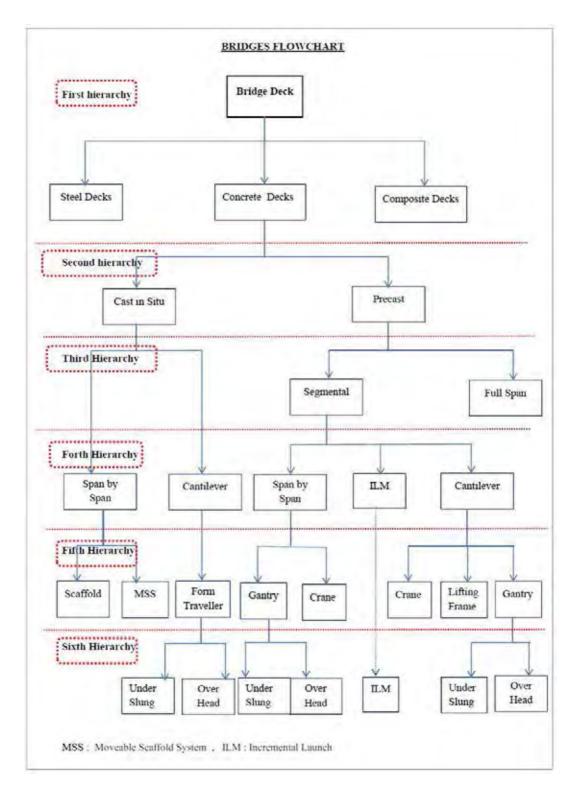


Figure 4.2: Bridge Type Category

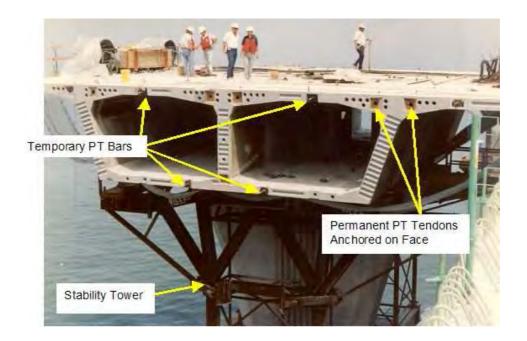


Figure 4.3: Concrete Segmental Details Source: www.fhwa.dot.gov

# 4.2.1 Incremental Launching Method

The suitable span length of a bridge starts from 10 to 30 meters. However, even if the length of the bridge starts from 100 meters to 1,300 meters, in the construction process a temporary supporting system is required as the important criteria. This is because the stability of the process of construction is considered to be of high importance. It well known that during the construction of the superstructure of the bridge, the variable cost of the construction is an important influence in decision-making. An option concerning the device used during construction has also become an important factor for consideration.

Incremental machine have a weight not over 60-65 % of total span length weight. In addition, if the length does not exceed 30 meter, the weight of the equipment varies from 1 to 2 tons per meter. In the concrete casting process, segments have been cast using stationary formwork. These are located behind the abutment, as a small pre-casting yard. A concrete segment is produced one piece per time, which is the capacity limit. Carefully, the moment and strength of completed segment while launching new segment. After that, the launching nose pushes the concrete piece forward, with the cantilever moment being suddenly reduced. Subsequently, as the segments are connected, the post-tensioning system is applied. Finally, the process of construction is repeated again whenever new segments have to be cast. The illustration of this method during launching can be seen in Figure 4.4.

This method is suitable for use in cases where the bridge is at a high level above the ground or where there are obstacles below the river, highway, deep valley, steep slope, or material delivery is limited to one side of the abutment. The limitation of this method is the vertical profile of the bridge deck with the horizontal curvature of the bridge deck being restricted. In addition, the geometry and plan of the route line be considered on three-dimension.

The advantages and disadvantages of the incremental launching method are mentioned in the following section.



Figure 4.4: Incremental Launching Method: Amal Motorway Bridge, Sweden. Source: www.Structurerae.com

## Advantages

The advantage of this method is that only one piece of equipment is required. The obligation of the engineers and experts is minimized. Moreover, the deck while the span area is cast does not need false work. In addition, the quality control of the activities on the segment casting process is easy because there is only one part at a time.

#### Disadvantages

The disadvantage of this method is that while the segment is being erected and launched the closed spans are at risk because of the bridge deck's great bending moments. Consequently, the straight line is limited and the curvature of the bridge is minimized. Additionally, a special type of equipment is required to connect the girder and pier head. The direction of the hydraulic jack system is limited to forward movement only. The method also incurs high costs through the specialists and contractors required.

## 4.2.2 Span-by-Span Method

The span-by-span construction method uses the precast segment system. The process of this method is shown in Figure 4.5. The typical span length starts from 40-50 meters. The designer has be very cautious in the design of the loading process as whenever segments are stressed there is imbalance.

The pier head segment is cast when the concrete is poured. A temporary support with small closure joints is cast at one or both pier heads. The span-by-span method uses a system of segment concrete boxes and launching gantry equipment which is specially selected. The overhead gantry equipment consists of two parallel girders for the deck segments and supporting the runways for one or two winches. The girders are supported by cross beams with truss extensions that control overturning during launching. Winch trolleys are operated along the entire unit so the main girders are braced to each other only at the ends. The girders comprise modules joined by pins and bolts and the modular nature of design often permits different assembly configurations of chords and diagonals.

## **Construction Sequence**

The cast-in-situ system using the span-by-span system is referred to as the Movable Scaffolding Systems (MSS). An appropriate span length varies from 30-50 meters as a medium span. This method requires scaffold support in the fabrication segments process. In the erection process, equipment is of high importance, such as the crane, lifting frame, and gantry. In the case of large-scale projects, many pre-cast segments are needed for erection.

# Advantages

The advantages of this method are the lightweight, low cost and low complexity. Minimum conditions are needed such as it being able to be moved in three dimensions. Moreover, the gantry can be adapted, modified and easily reused as shown in Figure 4.6.

# **Disadvantages**

The disadvantage of this method is that staff and engineers are required to investigate the concrete casting process for very high quality control.

Figure 4.5: Span-by-Span Construction Sequence Source: www.fhwa.dot.gov



Figure 4.6: The MSS Movable Formwork System Source: <u>www.Structurerae.com</u>

# 4.2.3 Span-by-Span Method Using an Erection Launching Gantry

The advantages and disadvantages of the span-by-span method using an erectionlaunching gantry are described as follows.

The two types of gantry are the overhead and the Under Slung. The external post tensioning system is used to stitch the segments together. Gantries are used to erect segments from 30 to 100 tons. The maximum weight of span starts from 400 to 2000 tons. Additionally, the capacities of gantry weights start from 200 to 1000 tons. This construction method is characterized by the length of time spent–24 hours per span. In addition, supplementary segments are delivered along the deck, starting from the rear of the gantry or at ground level. Importantly, the completion of the first span requires high stability. The stitching of the segments in this span are called post-tensioning system. The main priority of this method is the safety in completing each span.

# 4.2.4 Span-by-Span Erection with Launching Gantry: Under Slung Gantry

## Advantages

The advantage of this equipment is the high performance of the relocation and assembly process.

# Disadvantages

The disadvantages of this equipment are that it needs to use three sets of brackets and crane for relocation. Whenever wing slabs are launched on the curvature line, the performance of the launching segment is low.



Figure 4.7: Span-by-Span Method Using Under Slung Gantry Equipment Source: IABSE, (2010)

# 4.2.5 Span-by-Span Erection with Launching Gantry: Overhead Gantry

There are two types of this equipment: single and paired overhead gantries. These are complex and require self-launching or the bracket being relocated by an assistant crane. The performance of the paired overhead gantry for assembly and relocation is classified at the medium level, as the adjustment of connection beams is required for segment suspension. A single overhead gantry for assembly and relocation is classified at a low level; suspension frames and fixed connection beams are required for segment suspension performance. Both types of overhead gantry under the conditions of performable clearance below deck are high as shown in Figure 4.8.

# Advantages

The advantage of the overhead gantry is that the launcher is not complex. The requirement of a crane and lifting frame is minimized. Moreover, segment suspension provides high performance because of their wing slabs size. In addition, clearance areas above and below deck are maximized.

# **Disadvantages**

The complexities of the machine are high. Moreover, the need for engineers and specialists is high.



**Figure 4.8:** Span-by-Span Method Using Overhead Gantry Equipment Source: IABSE, (2010)

# 4.2.6 Span-by-Span Method Using Crane Erection Equipment

This method is suitable for small bridges as access is greatly limited for large machinery. A crane is flexible and has good motion. In addition, it can be moved quickly but the working space needs to be maximized and is useful in the segment supporting system and a temporary scaffold. This method is limited in the crane's capacity because in the erection process segments can be placed one by one as shown in Figure 4.9.Details of the advantages and disadvantages are discussed below.

# Advantages

The advantage of this method is the low requirement of engineers and specialists. While the crane is working, it can be relocated easily and quickly and another task can be performed.



**Figure 4.9:** Erection of False Work with Crane Souse: IABSE, (2010)

#### **Disadvantages**

The disadvantages of this method are the slow working speed and the large area required for the crane while working. Moreover, good quality soil is required to support the machine while running.

# 4.2.7 Balanced Cantilever Method

At present, cable-stayed bridges are a common sight. Balanced cantilever erection is one such construction method for this type of bridge although the concrete segment system has also been used. The suitable span length for decks is' if 60 is min and 70 max. However, a span length of 40meters has also been used. The erection process of a bridge spanning 100 meters takes approximately 7-12 days. In addition, a total of three days is required for connecting segments in the case of wet joints. The construction process is illustrated in brief in Figure 4.10. In the first stage, many segments are transported to the work site. Then, the cranes are installed on the ground or lifting frames, which are placed on the completed span. In the third step, segments are erected by placing them in accurate arrangements already placed on both sides of the pier. In the fourth stage, the concrete segment is cast in place at the pier head segment. Following this, the precast segment is installed on both sides of the first piece, which has already been completed. Finally, the post-tensioning system is used to stitch the segments together arrangement on the top and bottom dimensions.

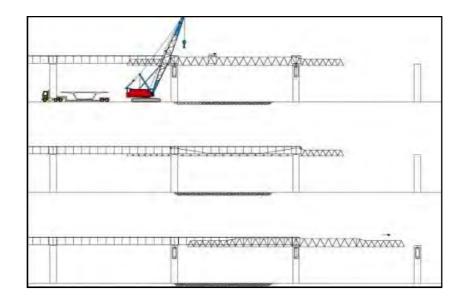


Figure 4.10: Balanced Cantilever Construction Process Source: www.<u>fhwa.dot.gov</u>



Figure 4.11: Balanced Cantilever Construction Using a Lifting Frame Source: www.launching-gantry-operator.com

Figure 4.10 illustrates the construction sequence of the balanced cantilever method. Balanced cantilever bridges using box girder segments are shown in Figures 4.11 and 4.12.

## Advantages

The advantage of this method is that the construction process of the superstructure and substructure can be started at the same time. Then, segments can be produced in the casting yard which is of high quantity and high quality. This method can also reduce the concrete creep and shrinkage effect. Importantly, the geometry casing is easily matched and controlled during installation

#### Disadvantages

The disadvantage of this method concerns the limitation in transportation according to the size and weight which ranges from 40 to 80 tons. An appropriate investment is optimized for a large-scale project. In addition, the completed previous span is a station for supporting frames



Figure 4.12: Balanced Cantilever Bridge Source: www.4bridges.eu

# 4.2.7.1 Balanced Cantilever by Launching Gantry

Figure 4.13 illustrates the sample project of this method; the advantages and disadvantages are described below.

# Advantages

The advantages of the balanced cantilever by launching gantry are as follows.

In the process of delivery segment, during the launching on the completed deck, the existing traffic is not interrupted. The requirements of temporary work on ground are needed at a low level. Moreover, a number of cranes are required in the stage of erection equipment selection. The gantry access on site is a low requirement.

# Disadvantages

This method requires pre-casting yards and experts.



**Figure 4.13:** Balanced Cantilever by Launching Gantry Source: www.launching-gantry-operator.com

# 4.2.7.2 Balanced Cantilever by Lifting Frame

This is regularly used in cases of suspension and cable-stay bridges. The typical length spans from 100 to 120 meters as shown in Figure 4.14.

# Advantages

This equipment is classified as simple equipment in the temporary working process. Lifting frames are used for bridges with the cable-stay system over obstacles such as deep rivers, valleys, and canyons.

#### **Disadvantages**

The disadvantages of this method are the pier head segments are cast in place influencing the surrounding environment.



Figure 4.14: Lifting Both Segments Using a Lifting Frame Source: www.launching-gantry-operator.com

# 4.2.7.3 Balanced Cantilever Erection with Crane

The balanced cantilever method with crane is selected for erecting precast concrete segments from ground to deck. Figure 4.5 illustrates the construction process of erecting segments and preparation for installation on the pier head.

# Advantages

The advantage of this equipment is that it does not require other equipment. The erection is suitable for large-scale projects. Furthermore, the requirement for engineers and specialists is minimized.

# Disadvantages

A disadvantage is that access is needed along the entire length of the bridge. Ground improvements may also be necessary. Also, while, cranes are working, all other procedures must wait.

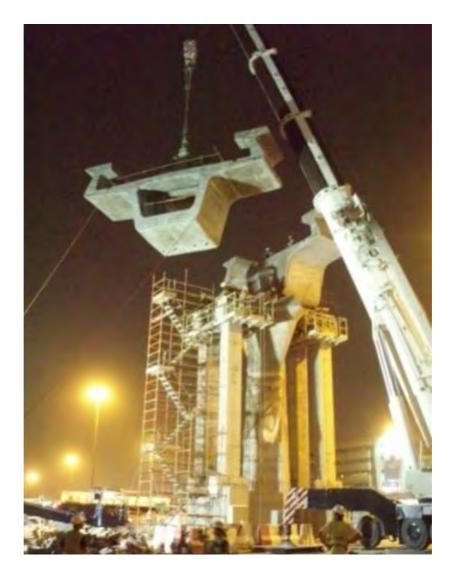


Figure 4.15: Pier Head Segments are Erected by Crane Source: www.launching-gantry-operator.com

# **4.3 Conclusions**

In summary, the details above illustrate all of the methods of bridge deck construction. The advantages, disadvantages, and limitations of each method are described. The objective from the previous stage is to analyze the factors, investigate and identify the most suitable method of bridge deck construction.

# **CHAPTER V**

# THE ANALYSIS OF IMPORTANT FACTORS BEHIND THE SELECTION OF BRIDGE DECK CONSTRUCTION

## 5.1 Factors influencing decision-making

In this study, the factors involved in the selection of a suitable bridge deck construction method were analyzed. The study first explores the factors from the literature review and expert interview. After that, the factors were screened using a scoring method of the opinion of 15 experts in bridge construction.

From the literature review and expert interviews, 13 factors involving the selection of bridge deck construction were explored as follows: cost, time, bridge's physical characteristics, orientation, health and safety, aesthetic, construction method characteristics, managerial capabilities, contractor's past experience, commercial aspects, environmental requirements, site condition, and size of project.

The result of the factor screening using average score shows that the six most important factors influencing the selection of a suitable method of bridge deck construction were cost, time, construction site condition, health and safety, size of project, and environmental impact.

Table 5.1 and Figure 5.1 illustrate the priority of each factor as ranked by the professionals. The highest ranking is the cost of project followed by time and construction site condition, respectively. In fourth is health and safety. This is followed by the size of project and, lastly, environmental impact.

Factors	Number of expert										0	Priorities Vector	Paultine					
Factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	ounnary	Priorities vecto:	Ranking
Cost	5	5	5	4	4	5	4	4	5	5	4	5	4	4	4	67	4.47	1
Time	5	5	4	5	4	5	5	4	4	4	4	4	4	4	3	64	4.27	2
Bridges physical charecterisric	3	4	3	4	4	3	3	3	3	3	2	2	2	3	3	45	3.00	9
Orientation	3	2	3	3	3	3	3	4	3	4	3	3	3	3	4	47	3.13	8
Health and safety	5	4	3	3	5	4	2	3	5	4	4	5	5	5	5	62	4.13	4
Aesthetic	3	3	4	5	2	4	5	3	4	3	3	2	2	3	3	49	3.27	7
Construction method charecteris	3	3	3	3	4	4	3	3	3	2	2	2	3	3	3	44	2.93	11
Managerial capabilities	2	2	3	3	3	2	3	2	2	2	4	2	3	2	3	38	2.53	12
Contractor past experience	3	3	3	2	2	2	3	3	2	2	2	3	3	2	2	37	2.47	13
Comercial Aspects	5	2	4	3	3	5	3	3	3	2	2	2	2	3	3	45	3.00	9
Environmental Requirement	5	4	4	5	3	3	4	4	4	3	3	3	3	3	3	54	3.60	6
Site condition (criteria)	4	4	5	5	4	3	4	4	5	5	3	3	5	5	4	63	4.20	3
Size of project/Scale of project	5	5	4	3	5	5	4	4	3	3	3	3	3	5	5	60	4.00	5
																675	45.00	
																Average	3.46	
																Max.	4.47	
																Min.	2.47	

 Table 5.1: Screening Factors for Bridge Deck Construction

The definitions of each factor follow.

# Cost

Cost refers to the cost of the overall construction, including the repair cost in the future. The overall cost includes both the substructure and superstructure. Consideration is also required as concerns the costs of labor and materials.

# Time

The time factor refers to the project duration in the construction period as well as repairs to be considered in the future. The observation of project duration should be considered to cover all construction projects, starting from substructure to superstructure.

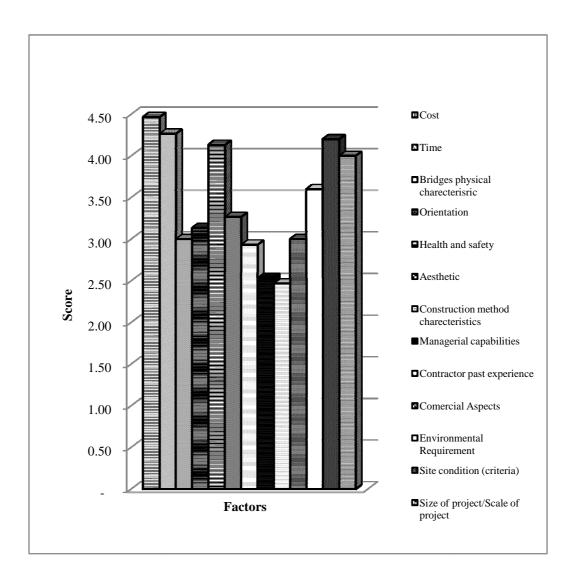


Figure 5.1: The Screening of Factors Scored 1-5

## **Site Condition**

This factor is of great importance when considering the appropriate construction methods because of the differences among site constructions. Therefore, conditions or limitations are carefully considered and include the following: route line project, environmental geography, nature routes, obstacles, water environment, local area, bar area, the location of the construction of the bridge across the river(such as shallowness and depth), in addition to alternatives such as geological and rock layer conditions. Furthermore, the source and quantity of the property construction as well as other hydrology data are considered as part of the basic sequence in the initial design of the bridge deck system design process.

#### **Health and Safety**

This factor is one of the most important. During construction, safety in terms of the lives and assets of the workers and people in the surrounding area require careful consideration. Therefore, a plan to deal with the problems that will arise in the future needs to be considered in the process of design. For example, the security of life and properties needs consideration as well as behavior affecting the lives and property of the people at the roadside or waterfront areas, and so on. In addition, working in an area with different machines running, working at heights, working when a machine breaks are also due consideration. In fact, there are many things to consider during construction.

#### **Environmental Impact**

Therefore, in order to deal with problems arising in the future a plan is required. As mentioned above, the safety as regards life and property and the effect on the people and property at the roadside or waterfront areas need to be considered.

In addition, consideration of safety is required as machinery is operated at heights or in the midst of malfunctioning.

Sustainable development is achieved by careful planning and consideration for the future environment. As a result, consideration of the environmental impact, before, during, and after the construction is an important factor. The planning of any bridge construction should try to minimize the environmental impact, especially in areas of historical importance. Natural habitats and conservation areas must be protected. In addition, the construction project should consider impacts on the construction, such as pollution of air, water, noise, or remaining chemicals.

#### **Size of Project**

The segment system is selected according to the size of the project. This system is expensive because the concrete parts must be produced in a factory, thus costs are added to the budget. As it is necessary to employ local experts on higher salaries, this also incurs further cost. All this must be considered before selecting the method of bridge construction.

# **5.2 Factors Behind the Selection of Bridge Deck Construction**

As already defined and detailed, there are six important factors to be considered, prioritized according to importance in the bridge deck system design process. Table 5.2 presents the factors prioritized using the Analytic Hierarchy Process (AHP), the details of which details include:

The cost factor is considered a highly important factor by the experts. Specialists are required to include all costs to be met during the construction. However, cost is not the only factor to be considered.

Project time is the second in importance. The construction experts stated that the duration of the construction work needs to be carefully planned. If the construction needs to be extended, construction costs will increase.

Factor	Priority Vector	Ranking
Size of project	0.27	1
Site Condition	0.15	4
Cost	0.10	5
Time	0.09	6
Safety and Health	0.18	3
Environmental Impact	0.21	I
	1.00	

Table 5.2: Weight of Important Factors for Selecting Superstructure

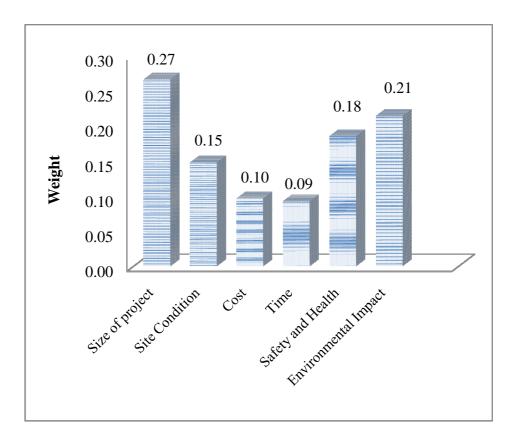


Figure 5.2: Weight of Important Factors for Selecting Superstructure

Construction experts are required to consider the restrictions and the status of the construction area. The site condition also determines the type of construction technique to be used. Therefore, the most suitable construction methods or techniques were chosen.

The health and safety factor was ranked fourth. Experts agreed that safety of life and property must be considered on both the construction site and the surrounding area. Therefore, the most suitable construction methods and techniques are chosen in relation to safety and security.

The size of the project is fifth. Before deciding to invest, it is important to consider the size of the project. It is necessary to consider the suitability of the project before selecting a construction method or technique, and several factors need consideration. The size of the project, therefore, determines the cost.

Environmental impact is sixth. The experts agreed that although many construction methods and techniques are available, consideration must be given to choosing only those suitable for sustaining the environment. The investments and costs have been classified as being of high importance.

Each of the six factors in turn determines the system to be used in construction of the permanent structure. The significance of looking into each factor is of prime importance and results in the form of the system to be used in construction. Each step in the construction determines the appropriate tools or techniques required for selection. There are also six important factors prioritized in the selection of suitable erection equipment as detailed below.

# **5.3 Factors Behind Selection of Erection Equipment**

The six most important factors are presented in Table 5.3, following analysis using the AHP method.

The size of the project was ranked as being the first priority. Experts agreed that it was important to consider the size of the project in relation to the investment.

It was necessary to consider the suitability of the project in the selection of the construction method or technique. Other factors also determine the appropriate construction methods or techniques to be considered. The total cost of construction requires being within the designated budget. Therefore, it is appropriate to consider the size of the project before choosing the construction method or technique. Because of these reasons, this is the most important factor.

Cost was the second factor. Experts agreed that the cost of construction is of major importance as all costs are required to be kept within the scope of the agreed budget. However, if experts only considered this factor, the results would not be thorough enough as other important factors should be considered.

Time was the third factor. Experts agreed that the timing of the construction is important and to be kept within the period originally planned. Construction costs are increased when the construction period overruns. In addition, various other factors are affected, such as the environmental impact. These reasons support the fact that time factor was ranked third in importance.

Health and safety was the fourth factor. Experts agreed that the safety of both life and property on the site and surrounding areas was an important factor. Therefore, security is considered in the choice of an appropriate construction method or technique. Therefore, these reasons support the fact that health and safety is an important factor.

Table 5.3: Weight of Important Factors for Selecting Erection Equipment	nt
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Factor	Priority Vector	Ranking
Size of project	0.22	1
Site Condition	0.10	6
Cost	0.20	2
Time	0.18	3
Safety and Health	0.17	4
Environmental Impact	0,12	5
	1.00	

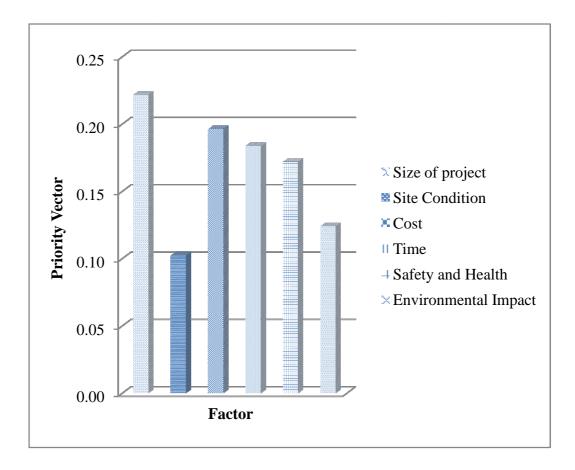


Figure 5.3: Weight of Important Factors for Selecting the Erection Equipment

Environmental impact is the fifth factor. Experts agreed that this factor is important as choosing the wrong method or technique could adversely affect the environment. Sustainable development is achieved through careful planning. Therefore, these reasons support the fact that the environmental impact is an important factor.

Last came the site condition. Experts agreed that the condition of the construction site condition is an important factor in considering the appropriate construction method or technique to be used. Also, it has to be established whether the area is adequate enough to store the necessary equipment and materials. This factor is important in finding the suitable method for the chosen location.

# **5.4 Conclusion**

This chapter addressed the important factors used for the selection of bridge deck construction. There are six important factors, namely cost, time, safety, environmental impact, size of project, and project site condition.

These factors will be implemented in a case study for selecting a suitable bridge deck construction method as detailed in Chapter five.

# **CHAPTER VI**

# **PROJECT CASE STUDY**

## 6.1 The MRT Purple Line (Bang Yai to Bang Sue)

The MRT Purple Line is a new line built to connect the Blue Line extension to the north and the Orange Line. The connection of the projects service passengers in the northwest suburbs of Bangkok and the south through the center of the city. The goal is to relieve traffic congestion. The superstructure line has been designed as an elevated structure.

## **6.2 Project Characteristics**

In the city area, an underground construction system was selected. It has been planned for the remaining area to use the construction system of common deck viaducts with double tracks supported by piers placed in the middle of the road. However, the portal frame system is to be considered when the single pier cannot support the bridge deck construction.

After the factors influencing the selection bridge deck construction method were screened and analyzed as to their importance, these factors were then applied to selecting the suitable construction method in the case study (The MRT Purple Line (Contract 2)).

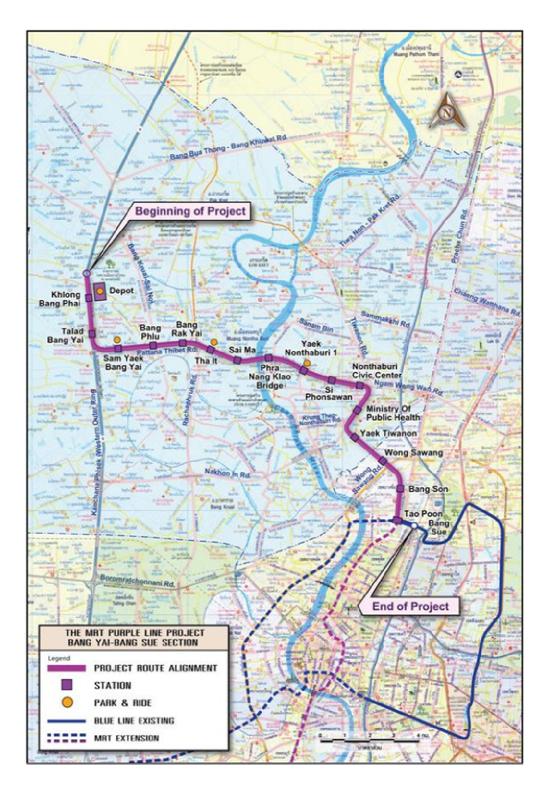


Figure 6.1: The MRT Purple Line Project, Bang Yai to Bang Sue Alignment Source: MRT, (2011)

The above figure illustrates the MRT Purple Line Project, Bang Yai to Bang Sue Alignment comprising 14 stations with the details as follows.

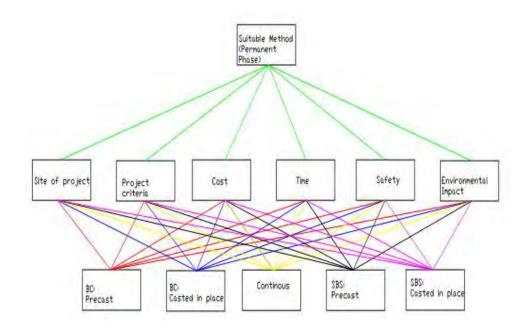
- 1) Khlong Bang Phai Station is located above the central line of Kanchanapisek road between Khlong Bang Phai and KhlongThanon area.
- 2) Talad Bang Yai Station is located above Kanchanapisek road near the Bang Yai market business area.
- 3) Sam Yaek Bang Yai station is located over the Rattanathibet road.
- 4) Bang RakYai Station is located above Rattanathibet road between Bang Phlu intersection and Ratchaprueng interchange at the crossing between Rattanathibet and Ratchaprueg roads.
- 5) Sai Ma Station is located above Rattanathibet road at SoiThaLhung.
- 6) PhraNanhKlao Bridge Station is located south of the existing Phra Nang Klao Bridge.
- 7) YaekNonthaburi Station is located above the Rattanathibet road central line near the Nothaburiby-pass road and adjacent to Central Rattanathibet.
- 8) Si Phonsawan Station is located above Rattanathibet road near SoiRattanathibet 22.
- 9) Nonthaburi Civic Center Station is located above Rattanathibet road near the KhaeRai intersection.
- 10) Ministry of Public Health Station is located above Tiwanon road, in front of the Ministry of Public Health's entrance.
- 11) YaekTiwanon Station is located on the Krungthep-Nonthaburi road withinSoiKrungthep-Nonthaburi 12-14.
- 12) Wong Sawang Station is located on Krungthep-Nonthaburi road withinSoi Bangkok-Nonthaburi 52-56.
- 13) Bang Son Station is located on Krungthep-Nonthaburi road at Talad Bang Son residential area.
- 14) Tao Poon Station is a four level, 189m long station located at the intersection of Pracharat 2 road and Bangkok-Nonthaburi road (Tao Poon).

# **6.2 Actual Constructions Methods**

The construction method used for the superstructure was span-by-span using an overhead gantry. The construction method is described below.

## 6.3 Superstructure Construction Method

Important factors influencing the selection of the most suitable methods for the superstructure and the erection equipment were analyzed in the last chapter. In the bridge deck system design phase, there are five systems utilized in the superstructure as shown



in Figure 6.2. The six most important factors were used to consider the suitable superstructure.

Figure 6. 2: Selection of Bridge Deck Construction Method

The weight from five systems factors was analyzed using the Analytic Hierarchy Process (AHP) method and experts' opinion as shown in Table 6.1.

A suitable construction method for the superstructure was analyzed using the Analytic Hierarchy Process (AHP) method as shown in Figure 6.3. The details are shown in appendices D.

Factor	Priorities Vector	Size of project	Project Criteria	Cast	line	Safety	Eavirooncatal Inpact	Method	Multiply Matrix	Ranking
Size of project	0.27	0.15	0.10	0.11	0,10	0.11	0,10	SBS: Cast In-situ	0.12	4
Project Criteria	0.15	0,46	0,40	0,38	0.40	0.42	D.42	SBS: Precast	0.42	I.
Cost	0.10	0.13	0.14	0.16	0.16	0.14	0.13	Continous: Incremental	0:14	3
Time	0.09	0.13	0.12	0.10	0.09	0.09	0.10	BC:Cast In-situ	0.11	5
Safety	0.18	0.13	0.24	0.25	0.25	0.24	0.25	BC:Precast	0.22	2
Environmental Impact	0.21							1.0	1.00	

**Table 6.1:** Weight of Factors for Selecting Superstructure System

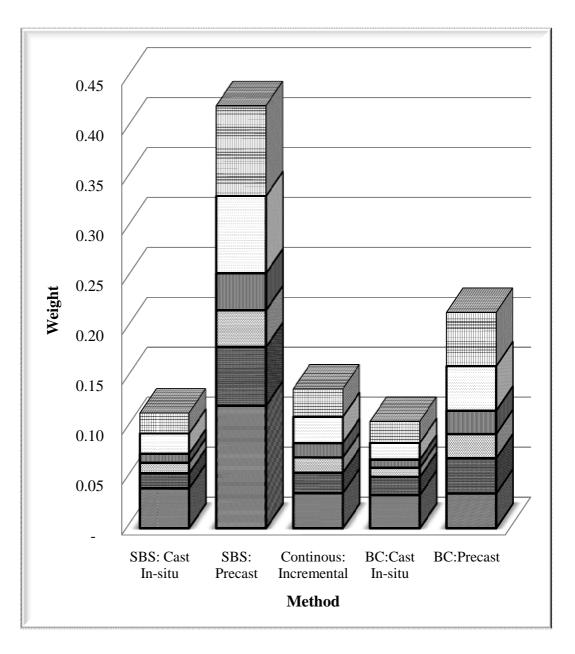


Figure 6.3: Weight of Factors for Selecting Superstructure System

# 6.4 Selection of a Suitable Method for Superstructure System

Five alternative superstructure methods were considered. The three main types were the balanced cantilever, continuous, and span-by-span methods. The two subsystems were precast segment and cast in-situ. Figure 6.3 and Table 6.1 present weighting of each factor and the details are described below.

The five alternative methods of superstructure system are as follows:

1) Balanced cantilever method using pre-cast segment system

- 2) Balanced cantilever method using cast in-situ system
- 3) Continuous method using incremental launch system
- 4) Span-by-span method using pre-cast segment system.
- 5) Span-by-span method using cast in-situ system.

The six important factors used in the selection of the superstructure system are as follows:

- 1) Size of project
- 2) Construction site condition
- 3) Cost
- 4) Time
- 5) Health and safety
- 6) Environmental impact

The five alternative methods were considered based on the six important factors. The suitable method for use can be described below.

The consideration was based on the six important factors, and several method were investigated: span-by-span method using precast segmental equipment (SBS: PRECAST), span-by-span method using cast-in-situ equipment (SBS: CAST-IN-SITU), balanced cantilever method using precast segmental system (BC-PRECAST), balanced cantilever method using cast-in-situ system (BC-CAST-IN-SITU), continuous method using incremental system (CONTINOUS-INCREMENTAL).

The experts prioritized each factor, ranking first the size of the project. They also provided supporting reasons such as the consideration and comparison of each method; the first thing to consider is the size of the investment, which, in effect, means the size of the projects. The second important factor is the environmental impact. The environment would be adversely effected if during construction inappropriate machinery is used. Third is health and safety. The safety of road users requires consideration as unexpected events can occur causing loss of life or property. The fourth important factor is cost and time. The experts agreed that cost and time were the last consideration in the design stage of the construction.

# Discussion based on size of project factor

First is the span-by-span method using the precast segment system (SBS: PRECAST). Specialists supported this system as it requires a pre-casting yard to cast concrete segments. Although this required a large investment, it is used during the entire construction. This system is not appropriate for small projects. For this reason, this method was ranked as first.

The second is the span-by-span method using the cast-in-situ system (SBS: CAST-IN-SITU). This method is used when a scaffold support structure is required during construction. However, this method is only suitable for small to medium sized

investments. In addition, it can also be used to work quickly and is easy to use. For these reasons, this method was ranked second.

The third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). This method requires ironworkers, carpenters and a factory to produce the concrete as it is poured on site. This method is ideal for projects with medium size investments. For these reasons, this method was ranked third.

The fourth method is the balanced cantilever method using the pre-cast segment system (BC: PRECAST). The experts supported this method by stating it to b fast, user friendly and low cost for the substructure. However, it is still necessary to utilize a pre-casting yard and to cast concrete segments. In addition, both the construction and post tensioning systems are complex. For these reasons, this method was ranked fourth.

The last is the balanced cantilever method using the cast in-situ system (BC: CAST-IN-SITU). Experts regarded this system as cheap but also have a little process with regard to erection and post tension. Therefore, this method is not suitable for use in large-scale projects.

# Discussion based on site condition factor

Under the site condition factor, the most suitable method is the span-by-span method using the pre-cast segment system (SBS: PRECAST). The experts viewed this method as having no constraints due to climate change. Additionally, the quality control of the concrete pouring process is simple and can be used for any future projects.

Second is the balanced cantilever method using the pre-cast segment system (BC: PRECAST). The experts saw this method advantageous in that there was no need to stop traffic. Additionally, the quality control of the concrete pouring process is simple and can be used for any future projects.

Third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). This method in the experts' opinion had the bonus of having no need to stop the traffic. In addition, it is friendly to the environment and users. However, the length of the construction period is limited with this method. Additionally, the process of quality control of concrete pouring is quite important.

Fourth is the balanced cantilever method using the cast-in-situ system (BC: CAST-IN-SITU). The experts viewed this method as being relatively low in cost. However, traffic in the construction area is required to stop. In addition, the process of quality control of concrete pouring is quite important. There are many limitations concerning the construction area using this method.

Last is the span-by-span method using the cast in-situ system (SBS: CAST-IN-SITU). The experts considered this method as incurring costs that are neither high nor low. However, traffic in the construction area is required to stop and consideration must be given to the environment below. The process of quality control of composite concrete is quite important. The limitations of this method compared to other methods in the construction area are considerable.

# **Discussion of cost factor**

First is the span-by-span method using the pre-cast segment system (SBS: PRECAST). The experts viewed this method as requiring the use of a pre-casting yard and the cost being high. However, it can be used long term. Moreover, there is no need to stop traffic and consider the environment below. Quality control of the concrete pouring process is complex. This method is quick so it is possible to decrease the environmental impact.

Second is the balanced cantilever method using the pre-cast segment system (BC: PRECAST). The cost of this method is high due to the requirement of the precasting yard. However, it can be used long term. Moreover, there is no need to stop traffic. Quality control of the concrete pouring process is complex. This method is fast so it is possible to decrease the environmental impact.

Third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). The experts regarded this method as being neither high nor low in terms of cost. Also, a pre-casting yard is not required. The process of quality control of concrete pouring is complicated. It is also possible to decrease the environmental impact. In addition, it provides security for those who live in the surrounding area. In addition, compared to other methods, the limitations of the construction area are less but it still works more slowly compared with the two previous methods discussed. Traffic below does not need to stop and no consideration is required for property below.

Fourth is the span-by-span method using the cast-in-situ system (SBS: CAST-IN-SITU). The experts viewed this method as being low cost. A pre-casting yard is not required although the process of quality control of concrete pouring is complicated. In addition, it is quite slow, has greater impact on the environment and affects road users. Moreover, it affects the security of people living in the surrounding area. Compared to the other methods, the limitations of the construction area are less, but it is slower. The traffic must be stopped and this has a high impact on the construction budget.

Fifth is the balanced cantilever method using the cast in-situ system (BC: CAST-IN-SITU). The experts considered this method to incur a low level of cost. A pre-casting yard is not required and the process of quality control of concrete pouring is complicated. In addition, it is slow and has greater impact on the environment, affecting road users and disrupting the economy. Moreover, it affects the security of those who live in the surrounding area. The traffic must be stopped and consideration must be given to the properties below. This has a high impact on the construction budget. For these reasons, this method was ranked fifth.

#### **Discussion of time factor**

First is the span-by-span method using a pre-cast segment system (SBS: PRECAST). Many experts gave several reasons supporting this method, as the work is quick and easy to install. In addition, within the process of segment pre-casting, the work is quick and production is more than one piece at a time. Based on segment casting, the process of segment installation and external pre-stressing can be easily controlled.

Second is the balanced cantilever method using a pre-cast segment system (BC: PRECAST). The experts gave many reasons for using this method as the work is quick but slower than the previous method. Moreover, in the quality control stage, there is complexity because this requires working on both sides if the span at the same time

Third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). This method involves a lot of time pushing and pulling concrete segments. The post tensioning system requires careful installation because of the weight of each piece. Quality controls have to be checked carefully.

Fourth is the span-by-span method using the cast-in-situ system (SBS: CAST-IN-SITU). Many experts gave several opinions regarding this method due to the complexity of the phase of segment casting. This method requires working simultaneously on both sides of the span. This means that more time is required.

Fifth is the balanced cantilever method using the cast-in-situ system (BC: CAST-IN-SITU). Many experts said this method of construction required more time than the previous method. Because both spans must be worked on at the same time, the method is more complicated and complex. These are the reasons behind it being considered the fifth priority.

# Discussion of health and safety factor

First is the span-by-span method using the pre-cast segment system (SBS: PRECAST). Many experts favored this method in terms of security which is at the highest level. Because the time spent is short, this means accidents are less likely to occur, benefiting both workers on the site and users. The process of stressing occurs immediately after the first process.

Second is the balanced cantilever method using the pre-cast segment system (BC: PRECAST). Many experts regarded this method as having a short construction completion time and accidents being less likely to occur benefiting both workers on the site and users. Nevertheless, the stressing phase needs stitches on both spans at the same time. This method is less safe than the previous method discussed.

Third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). Many experts viewed this method as involving a construction time that is relatively short, which means less accidents are likely to occur, benefiting both workers on the site and users. In addition, the stressing process is relatively short. Therefore, this method involves low risks compared to traditional methods. Fourth is the span-by-span method using the cast-in-situ system (SBS: CAST-IN-SITU). Many experts said this method of construction took longer to complete, therefore the risk of accidents occurring are greater, affecting both workers and road users.

Fifth is the balanced cantilever method using the cast-in-situ system (BC: CAST-IN-SITU). Many experts considered this method of construction as being more time consuming than previous methods, therefore, more accidents occurred affecting road users and workers on the site.

## Discussion of environmental impact factor

First is the span-by-span method using the pre-cast segment system (SBS: PRECAST). According to the experts, it is completed in a relatively short space of time and so has less effect on the environment. Segments are stored in the pre-casting yard from the site with good transportation. These processes are beneficial in reducing impact on the environment.

Second is the balanced cantilever method using the pre-cast segment system (BC: PRECAST). Experts concurred that this method of construction is completed quickly. Furthermore, it has less effect on the environment. Segments are stored in the pre-casting yard with good transportation. These processes are beneficial in reducing impact on the environment. This method was ranked second.

Third is the continuous method using incremental equipment (CONTINOUS-INCREMENTAL). The experts explained that this method has a detrimental effect on the environment and that as concerns construction, the work is not completed quickly. A pre-casting yard is not required in this method; therefore, planners can give less consideration to the impact on the environment.

Fourth is the span-by-span method using the cast-in-situ system (SBS: CAST-IN-SITU). The experts viewed this method as having a detrimental effect on the environment, but as for the construction, the work is not completed quickly. A precasting yard is not required in this method, therefore, suggesting that planners gave less consideration to the impact on the environment.

Fifth is the balanced cantilever method using the cast in-situ system (BC: CAST-IN-SITU).Experts said that this method has a detrimental effect on the environment, but as for the construction, the work is not completed quickly. A pre-casting yard is not required in this method, therefore, this suggests that planners take less consideration as to the impact on the environment. This method takes longer than the previous method.

The conclusions that can be drawn from the interviews with experts have been analyzed for each factor and each method. Furthermore, the analysis of superstructure system was discussed. In the conclusion of all the important factors, span-by-span using precast concrete is the most suitable method for bridge deck construction.

# 6.5 The Analysis, Results and Discussion of the Selection of the Erection Equipment Selection Phase.

After the suitable construction method of bridge deck construction was selected, the erection equipment for bridge deck construction was analyzed, as shown in figures 6.5 and 6.6.

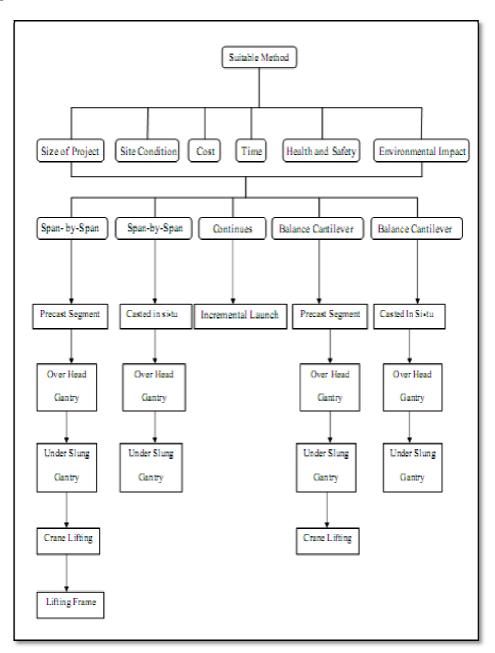


Figure 6.4: Bridge Deck Construction Framework.

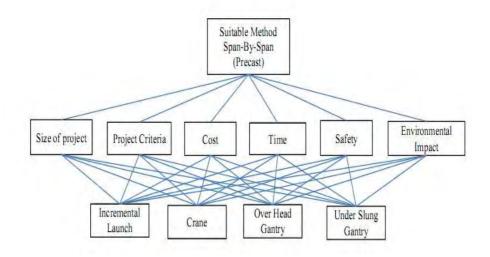
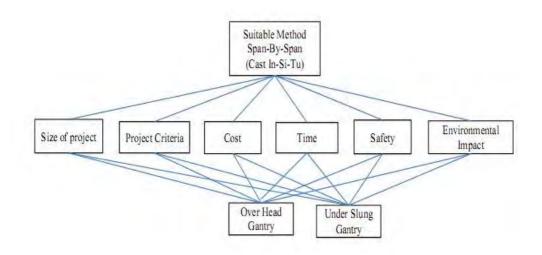
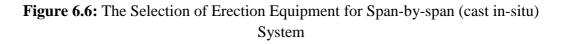


Figure 6.5: The Selection of Erection Equipment for Span-by-Span (precast) System





The erection equipment for each construction method Is as follows:

- 1) Balanced cantilever method using the pre-cast segment system involves the following erection equipment:
  - o Erection using a lifting crane
  - Erection using a crane
  - o Erection and launching using an overhead launching gantry
  - o Erection and launching using an under slung launching gantry

- 2) Balanced cantilever method using cast in-situ system involves the following erection equipment:
  - o Casting using an overhead formwork traveler
  - o Casting using an under slung formwork traveler
- 3) Continuous method
  - o Casting and pushing using an incremental launcher
- 4) Pre-cast segmental system using the span-by-span method involves the following erection equipment:
  - o Erection with a crane
  - o Erection and launching with an overhead launching gantry
  - o Erection and launching with an underslung launching gantry
- 5) Cast in-situ system using the span-by-span method involves the following erection equipment:
  - Casting using an overhead movable scaffolding system(MSS)
  - o Casting using an underslung movable scaffolding system (MSS)

The six most important factors behind the selection of the superstructure system are as follows:

- 1) Size of project
- 2) Construction size condition
- 3) Cost
- 4) Time
- 5) Health and safety
- 6) Environmental impact

Based on these six important factors, several alternative methods were considered. This stage follows on from the stage of the design of the bridge deck system, the span-by-span method using the precast segment for construction as ranked first in the process. Thus, the objective of the next stage is to identify the most suitable equipment in the erection equipment selection phase, which is described below.

Figure 6.7 and Table 6.2 summarize the results of the expert interviews and it can be seen that the span-by-span, precast concrete segment method using underslung equipment is the most suitable method for the erection equipment selection process. The details are shown in appendices C.

## Discussion of size of project factor

First is the span-by-span method using underslung gantry equipment (SBS: PRECAST UNDERSLUNG-GANTRY). The experts concluded that this method could be suitable for medium- to large-scale projects. This method requires a pre-casting yard, good transportation system, equipment and specialists. A high budget is required to support this method.

Second is the span-by-span method using overhead equipment (SBS: PRECAST OVERHEAD-GANTRY). This method requires a higher budget than the first method as the cost of the underslung equipment is more expensive.

Third is the span-by-span method using underslung equipment (SBS: CAST IN-SITU: UNDER SLUNG). The experts concluded that this method could be suitable for medium to small projects. This method works relatively slowly although the cost is not too expensive. In addition, it is essential the land can support the weight of the bridge structure and tools while work is in progress.

Fourth is span-by-span method using overhead equipment (SBS: CAST IN-SITU: OVERHEAD). The experts concluded this method could be suitable for medium to small projects. This method works relatively slowly although the cost is not too expensive. However, this method requires a larger budget than the previous methods because the cost of equipment is more expensive than the previous method.

Table 6.2: Weight of Factors	for Selection of Erection	Equipment Phase
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SBS:Over Head         0.31         0.18         0.17         0.28         0.25         0.28         0.22         0.25         2           SBS: Under Slung         0.34         0.22         0.37         0.36         0.39         0.38         0.10         0.35         1           SBS: Crane Lifting         0.07         0.42         0.18         0.09         0.09         0.12         0.20         0.14         4           SBS: Overhead MSS         0.13         0.08         0.13         0.11         0.12         0.10         0.14         5           SBS: Underslung MSS         0.15         0.10         0.16         0.15         0.16         0.12         0.17         0.14         3		Factor	Size of project	Site Condition	Cost	Dime	Safety	Environmental Impact	Priorities Vector	Priorities Vector	Dankina
SBS: Crane Lifting         0.07         0.42         0.18         0.09         0.09         0.12         0.20         0.14         4           SBS: Overhead MSS         0.13         0.08         0.13         0.11         0.12         0.10         0.18         0.12         5           SBS: Underslung MSS         0.15         0.10         0.16         0.15         0.16         0.12         0.17         0.14         3		SBS:Over Head		0.18		0,28	0.25	0.28	0.22	0.25	2
SBS: Crane Lifting         0.07         0.42         0.18         0.09         0.09         0.12         0.20         0.14         4           SBS: Overhead MSS         0.13         0.08         0.13         0.11         0.12         0.10         0.18         0.12         5           SBS: Underslung MSS         0.15         0.10         0.16         0.15         0.16         0.12         0.17         0.14         3	B	SBS: Under Slung	0.34	0.22	0.37	0.36	0.39	0.38	0.10	0.35	1
SBS: Underslung MSS 0.15 0.10 0.16 0.15 0.16 0.12 0.17 0.14		SBS: Crane Lifting	0.07	0.42	0.18	0.09	0.09	0.12	0.20	0.14	4
	2	SBS: Overhead MSS	0.13	0.08	0.13	0.11	0.12	0.10	0.18	0.12	5
0.12	S	SBS: Underslung MSS	0.15	0.10	0.16	0.15	0.16	0.12	0.17	0.14	3
									0.12		

Fifth is the span-by-span method using crane lifting (SBS: PRECAST CRANE LIFTING). The experts concluded that this method is suitable for small projects. The cost of this equipment is low and can be easily found in the market. However, it

works slowly and requires a large area for operation. Moreover, it is essential that the ground is able to support the equipment while in operation.

# Discussion of site condition factor

First is the span-by-span method using crane-lifting equipment (SBS: PRECAST: CRANE LIFTING). The experts concluded that this method is not complex and the condition of the site is not important.

Second is the span-by-span method using underslung gantry equipment (SBS: PRECAST UNDER SLUNG). The experts concluded that this method is complex requiring a pre-casting yard and good transportation system. This method has more constraints than the previous method. This method has been ranked second.

Third is the span-by-span method using an underslung form traveler (SBS: CAST IN SITU: UNDER SLUNG) and span-by-span method using overhead form traveler equipment (SBS: CAST IN SITU: OVERHEAD). The experts concluded that this method was complex and had many constraints, including the requirement of an area suitable for operating machinery. In addition, quality of the soil is paramount. However, the overall cost of this method is inexpensive.

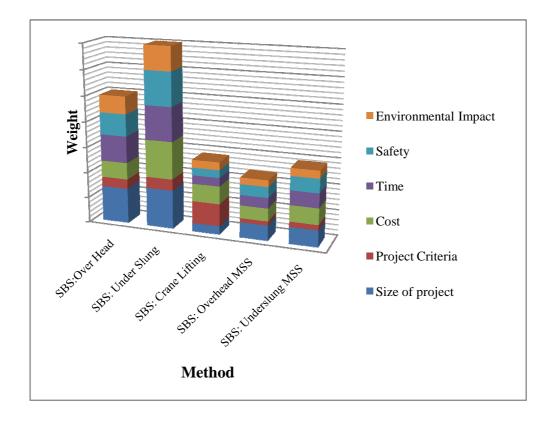


Figure 6.7: Weight of Factors for Selection of Erection Equipment Phase

#### **Discussion of cost factor**

First is the span-by-span method using an underslung gantry (SBS: PRECAST UNDER SLUNG). The experts concluded that a pre-casting yard is a high requirement. The cost of method is expensive. However, it can be used long term. There is no need to stop traffic or consider the environment below. The process of quality control during the pouring of the concrete is complex. This method is quick and it is extremely safe for those living in the surrounding area. The limitations of the construction area are low.

Secondisthe span-by-span method using overhead cast-in-situ equipment (SBS: CAST IN SITU: OVERHEAD), span-by-span method using lifting crane equipment (SBS: PRECAST:CRANE LIFTING), and span-by-span method using underslung form traveler equipment (SBS: CAST IN-SITU:UNDER SLUNG). The experts concluded that due to the requirements for a pre-casting yard, this method proves to be expensive, but it can be used long term. There is no need to stop the traffic and no need to consider the environment below. The process of quality control during the pouring of the concrete is complex.

Last is the span-by-span method using an overhead form traveler (SBS: CAST IN SITU: OVERHEAD). The experts concluded that as no pre-casting yard is required the cost of this method is low. The process of quality control during the pouring of the concrete is complex. However, this method proves to be slow and has more impact on the environment affecting road users and disrupting the economy. This method also affects the security and safety of those living in surrounding areas. The traffic below must be stopped and consideration must be given to the properties on the ground below. All these aspects have an impact on the construction budget.

# **Discussion of time factor**

First is the span-by-span method using an underslung gantry (SBS: PRECAST UNDER SLUNG). The experts concluded that this method works quickly and is easily installed. In addition, the process of segment pre-casting speeds up the construction installation of more than one piece at a time. Quality control is less complex in the process of segment installation and eternal pre-stressing.

Second is the span-by-span method using overhead gantry equipment (SBS: PRECAST OVERHEAD). The experts concluded that although this method works quickly, it is slower than the previous method. Quality control of this method is complex, which requires more time than the previous method.

Third is the span-by-span method using underslung form traveler equipment (SBS: CAST IN-SITU: UNDER SLUNG). The experts concluded that this method is slower because extra time is required for the pouring of the concrete. Time was also spent installing re-bars, stand bundle stressing and grouting. Therefore, this method is far more time consuming.

Fourth is the span-by-span method using an overhead form traveler (SBS: CAST IN-SITU: OVERHEAD), and the span-by-span method using a lifting crane(SBS:

PRECAST CRANE-LIFTING). The experts concluded that this method was slower than the previous as concrete pouring by the cast-in-situ method is far more complicated.

## **Discussion of safety factor**

First is the span-by-span using an underslung method (SBS: PRECAST UNDER SLUNG). The experts explained that this method achieves the highest level of security because construction is achieved quickly, reducing the amount of accidents to road users and workers on the site. Spans are completed one by one and stressed one span at a time. Stressing takes place immediately one span at a time. This method has been ranked first.

Second is the span-by-span using an overhead method (SBS: PRE-CAST: OVERHEAD). The experts concluded that as this method was quicker less accidents occurred and the impact to road users and workers was reduced on site. Nevertheless, as supporting equipment is required this method is less safe than the previous method.

Third is the span-by-span method using an underslung form traveler (SBS: CAST-IN-SITU: UNDER SLUNG). Many experts concluded that because this method is slow more accidents occur having an impact on road users and workers on site. Therefore, this method carries an increased risk compared to previous methods.

Fourth is the span-by-span method using an overhead form traveler (SBS: CAST-IN-SITU: OVERHEAD). Many experts concluded that because this method is slow more accidents occur impacting road users and workers on site.

Fifth is the span-by-span method using crane-lifting equipment (SBS: PRE CAST: CRANE LIFTING). Many experts concluded that because this construction is much slower than the previous method more accidents occur impacting road users and workers on site.

# **Discussion of Environmental Factor**

First is the span-by-span method using underslung equipment (SBS: PRECAST UNDERSLUNG). The experts concluded that this method of construction is completed in a short space of time, meaning there is less effect on the environment. Segments are stored in a separate area using a good transportation system. These aspects are used in the planning process to manage and reduce the impact on the environment.

Second is the span-by-span method using overhead equipment (SBS: PRECAST OVERHEAD). The experts concluded that this method of construction is completed in a relatively short space of time meaning that there is less effect on the environment. Segments are stored in a separate area using a good transportation system. These aspects are used in the planning process to manage.

Third is the span-by-span method using crane lifting equipment (SBS: PRECAST LIFTING CRANE) and the span-by-span method using movable scaffolding system equipment (SBS: CAST IN-SITU: UNDERSLUNG-MSS). The experts concluded that this method of construction requires longer completion and therefore has an adverse affect on the environment. This method works very slowly. Parts are stored on site,

not in a separate location as per previous methods. Using this method the environment is more at risk.

Fourth is the span-by-span method using movable scaffolding system equipment (SBS: CAST IN-SITU: OVERHEAD-MSS). The experts concluded that due to the construction being completed over a longer period of time the effect on the environment is increased. Segments are stored on site, not in a separate location as per previous methods. Using this method the environment is more at risk.

The conclusions for each factor and each method drawn from the interviews with experts have been analyzed. The analysis of erection equipment was discussed. In conclusion, the precast concrete segment system with the span-by-span method using an underslung gantry was the most suitable method for bridge deck construction.

# 6.6 Comparison with Actual Construction Methods

In this case study, the six most important factors were used to select the most suitable construction method of bridge deck. The result of analysis showed that the most suitable construction method for superstructure was the span-by-span precast segment and the most suitable erection equipment was the underslung gantry. When this was compared with the actual construction method of the MRT Purple Line (Contract 2), the result showed that the construction method for the superstructure was similar to the actual construction, which used the span-by-span precast segment method.

However, the erection equipment is different from the actual construction, which used an overhead gantry.

### **CHAPTER VII**

### CONCLUSIONS

### 7.1 Conclusions

The objective of this study is to define the important level of factors used to select bridge deck segmental concrete construction in Thailand.

The methodologies of this research consist of review and previous research and professional interviews to explore the method of bridge deck construction and factors used to select the segmental concrete bridge deck on the super structure system design phase and erection equipment selection. Factors were screened using the average score. After that, the Analytic Hierarchy Process (AHP) technique was applied to analyze the factors used for selecting the suitable method and erection equipment for bridge deck construction. Next, the MRT Purple Line (Contract 2) construction project was used as a case study. The results from the case study were compared with the actual construction for defining the similarities and differences.

The result of this study show that 13 factors were derived from the literature review and expert interviews: cost, time, bridge's physical characteristics, orientation, health and safety, aesthetic, construction method characteristics, managerial capabilities, contractor's past experience, commercial aspects, environmental impact, site condition, and size of project. These factors were screened by their above average score. The six important factors were cost, time, health and safety, size of project, site construction, and environmental impact. Following this, the MRT Purple Line (Contract 2) construction project was used as a case study to consider the suitable method of bridge deck construction based on the six important factors, five types of superstructure and twelve types of erection equipment. As a result, the suitable superstructure was deemed to be the span-by-span method, which similar to actual construction and the most suitable erection equipment was the underslung gantry, which differed from actual construction. This difference can be explained by the fact that, in the actual case, the specialist's consideration was based on the available equipment. Although the suitable erection equipment was the overhead gantry method, the main reason the contractor and subcontractor used overhead gantry equipment was that it can be modified and applied to this specific project.

### 7.2 Limitations

The research in this study was limited in its application to bridge deck construction. The factors should also be applied for typical span length bridge,

elevated railway and toll way. However, non-typical span length should be studied and considered on a case by case basis.

### 7.3 Further Study

This study focused on concrete bridge deck construction. However, other types of bridge construction should also be studied by using the methodologies employed in this study in the future.

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APPENDICES

APPENDIX A

### EXPERT INTERVIEW FORM



### จุฬาลงกรณ์มหาวิทยาลัย

CHULALONGKORN UNIVERSITY

ภาควิชาวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ ถนนพญาไท ปทุมวัน กรุงเทพฯ 10330 Department of Civil Engineering, Faculty of Engineering Phayathai Rd., Pathomwan, Bangkok 10330 Tel : (662) 218-6460 to 62, Fax : (662) 251-7304

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ข กันขายน 2554

เรื่อง ขอความอนุเคราะห์ข้อมูลงานก่อสร้างสะพาน

เรียน ผู้จัดการ MAA Consultants Co., Ltd.

เนื่องด้วย นางสาวที่การัดน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปริญญามหาบัณฑิต สาขาวิชาโครงสร้าง ทึ้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์ เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิค Segmental Concrete" โดยมี ผศ.ตร. นพคล จอกแก้ว เป็น อาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการ กรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระดับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของ การศึกษามีดังนี้

- ปัจจัยที่นำมาวิเคราะห์ในการพิจารณาทางเลือกในการก่อสร้างสะพานประเภท segmental concrete
- แบบสอบถามเกี่ยวกับการให้คะแนน และลำดับความสำคัญของแต่ละปัจจัยที่นำมาพิจารณา
- 3. ข้อมูลเกี่ยวกับการก่อสร้างโครงการรถไฟฟ้าสายสีม่วง

จึงเรียนมาเพื่อไปรดพิจารณาอนุมัติให้ข้อมูลดังกล่าวแก่นิสิต เพื่อเป็นประโยชน์แก่การศึกษา ขอขอบคุณล่วงหน้ามา ณ โอกาสนี้

N

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### จุฬาลงกรณ์มหาวิทยาลัย

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9 กันยายน 2554

เรื่อง ขอความอนูเคราะห์ข้อมูลงานก่อสร้างสะพาน

เรียน ผู้จัดการ Sino-Thai Engineering & Construction Public Co., Ltd.

เนื้องด้วย นางสาวทิการัคน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปรีญญามหาบัณฑิต สาขาวิชาโกรงสร้าง พื้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์ เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิด Segmental Concrete" โดยมี ผศ.คร. นพคล จอกแก้ว เป็น อาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการ กรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระคับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของ การศึกษามีดังนี้

 ปัจจัยที่นำมาวิเคราะห์ในการพิจารณาทางเลือกในการก่อสร้างสะพานประเภท segmental concrete

แบบสอบถามเกี่ยวกับการให้กะแนน และลำดับความสำคัญของแต่ละปัจจัยที่นำมาพิจารณา
 ข้อมลเกี่ยวกับการก่อสร้างโครงการรถไฟฟ้าสายสีม่วง

จึงเรียนบาเพื่อไปรดพิจารณาอนุมัติให้ข้อมูลดังกล่าวแก่นิสิต เพื่อเป็นประโยชน์แก่การศึกษา ขอขอบคุณล่วงหน้ามา ณ โอกาสนี้

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เรียน ผู้จัดการ VSL(Thailand) Co., Ltd.

เนื่องด้วย นางสาวทิการัตน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปริญญามหาบัณฑัต สาขาวิชาโครงสร้าง พื้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์ เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิด Segmental Concrete" โดยมี ผศ.คร. นพคล จอกแก้ว เป็น อาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการ กรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระดับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของ การศึกษามีคังนี้

- ปัจจัยที่นำมาวิเคราะห์ในการพิจารณาทางเถือกในการก่อสร้างสะพานประเภท segmental concrete
- แบบสอบถามเกี่ยวกับการให้กะแนน และลำดับความสำคัญของแต่ละปัจจัยที่นำมาพี่จารณา

ข้อมูลเกี่ยวกับการก่อสร้างโครงการรถไฟฟ้าสายสีม่วง

จึงเรียนมาเพื่อโปรดพิจารณาอนุมัติให้ข้อมูลดังกล่าวแก่มิสิต เพื่อเป็นประโยขน์แล่การศึกษา ขอขอบกูณล่วงหน้ามา ณ โอกาสนี้

ขอแสดงความนับถือ

(ผู้ช่วยศาสตราจารย์ ดร. นพดล จอกแก้ว) อาจารย์ที่ปรึกมา (รองสาสตรวจารย์ คร.พูลศักดิ์ เพียรสุสม) หัวหน้าภาควิชาวิสวกรรมไขธา

นิสิตประสานงาน : นางสาวทิภารัตน์ ถือทอง เยื้อพันธุ์พงศ์ โทร. 087-971 8829





### CHULALONGKORN UNIVERSITY

### FACULTY OF CIVIL ENGINEERING

QUESTIONNAIRE SURVEY "THE SELECTION OF CONSTRUCTION METHOD FOR CONCRETE SEGMENT BRIDGE IN THAILAND: A CASE STUDY OF MRT PURPLE LINE(CONTRACT 2) "

> Prepared by: THIPARAT T. Euapunpong (Master of Infrastructure in Civil Engineering)

Name of Company	;		10-10-10-10-10-10-10-10-10-10-10-10-10-1
Name of Responden	(:	11-11 (1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1	
Position	ą		
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### Objective of Questionnaire

- To compare various construction system base on application with Purple Line (Contract 2)

## Permanent Structure Design

Description of Questionnaires are described in the following

- Project Criteria Ē
  - Size of project  $1.1) \\ 1.2) \\ 1.3) \\$
- Structure type
- Existing resource : Equipment and staff's experience
- Site Condition and Requirement
- Access for material delivery and construction
- Location of Construction Site 2) 2.1) 2.2)
- Cost
- Benefit of Cost Ratio
  - Economy of Scale
- Available budget and Equipment 3.3)3.1)3.3)3.3)
- Time 4) 4.1) 4.2)
- Available Construction Time Mobilization Time
- Environmental Impact
- Hazard to animals 5) 5.1) 5.2)
- Pollution such as air, water, and noise
- Safety 6) 6.1)
- Construction safety on site Traffic disruption 6.2)

	Explanation	Judgement strongly favour other criteria over another	Judgement slightly favour other criteria over another	Two criterion contribute equally to the object	A criteria is slightly inferior to another	A criteria is strongly inferior to another
ant scale	Scale	S	4	3	4	-
Table 1: Fuzzy important scale	Vertical Judgement	The best	Better	Equally	Worse	The worst

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-	Factor	Span by	Span (SBS)	Pontomore	Balance Car	ntilever (BC)
	Cost	Cast In-situ	Precast	storutunos	Cast In-situ	Precast
SE	Cast In-situ	1	I	+	t	3
IS	Precast		-	5	5	4
	Continuous			3.1	3	2
2	Cast In-situ				8	T.
в	Precast	-				H.

### Table 3: Questionnaire meaning

0.	Questionn	aire with to access main criteria
-	How importunt is cost (Spun by Span: Cast In-situ)	when it is compured to cost (Spun by Spun : Cast In-situ)
~	How importunt is cost (Spun by Spun: Cast In-situ)	when it is computed to cost (Spun by Spun : Precast)
	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Continuous)
4	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Cast In-situ)
	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever, Precast)
10	How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Cast In-situ)
E.	How important is cost (Spar by Span: Precast)	when if is compared to cost (Span by Span : Precast)



Structural System Comparison	Factor Span by Span (SBS)	Cost Cast In-situ Pr	Cast In-situ 3	Procast	Continuous	Cast In-situ	Precast	Factor Span by Span (SBS)	Cast In-situ	4	Precast	Continuous	Cast In-situ	Precast	Factor Span by Span (SBS)	Safety Cast In-situ Pr	Cast In-situ	Precast	Continuous	Cast In-situ	Preenst	Factor Span by Span (SBS)	Impact Cast In-situ	Precast	Confirmous	Cast In-situ	Precast	Score 5 4
		Precast			-				Precast Continuous			E			Ū	Precast					-		Precast Continuous				-	3 2
	Balance Cantilever (BC)	Cast In-situ Precast				~		Balance Cantilever (BC)	Cast In-situ Precast				0	~	Balance Cantilever (BC)	Cast In-situ Precast					*	Balance Cantilever (BC)	Cast In-situ Precast				*	

### Objective of Questionnaire

Ψ.....

l'emporary Shucture Desen
Description of Questionnaires are described in the following 1) Project Criteria 1.1) Size of project 1.2) Structure type 1.3) Existing resource : Equipment and staffs experience
<ol> <li>2) Site Condition and Requirement</li> <li>2.1) Access for material delivery and construction</li> <li>2.2) Location of Construction Site</li> </ol>
<ol> <li>Cost (Cost of Construction: sub structure, superstructure, equipment, precasting yard, transportation, personal, mise.)</li> <li>Benefit of Cost Ratio</li> <li>Economy of Scale</li> <li>Available budget and Equipment</li> </ol>
<ul> <li>4) Time</li> <li>4.1) Mobilization Time</li> <li>4.2) Available Construction Time</li> </ul>
<ol> <li>Environmental Impact</li> <li>J.I. Hazard to people and anumals</li> <li>Pollution such as air, water, and noise</li> </ol>
<ul> <li>6) Safety</li> <li>6.1) Constituction safety on site</li> <li>0.2) Traffic disruption</li> </ul>

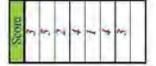
Table 1:	Fuzzy im	mportant scale
ertical Judgement	Scale	Explanation
The best	5	Judgement strongly favour other criteria over another
Better	4	Judgement slightly favour other oriteria over another
Equally	m	Two enterion contribute equally to the object
Worse	2	A criteria is slightly inferior to another
The worse	1	A criteria is strongly inferior to another

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	Factor	Span by Sp	an (SBS)	Continuous	Balance Carl	tilever (BC
	Cost	Cast In-situ	Precast	STICTION OF A	Cast In-situ	Procast
SDC	Cast In-situ	1.00	10	2	t	1
000	Precast	t	•			-
	Continuous			2		
Da	Cast In-situ				10	
Za	Precast					-

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Table 3: Ques

0	Questionna	re with to access main criteria
-	How important is cost (Span by Span: Cast In-sint)	when it is compared to cost (Span by Span : Cast In-situ)
2	How important is cost (Span by Span: Cast In-sim)	when it is compared to cost (Span by Span : Precast)
100	Q3 How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Continuous)
2	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Cast In-situ)
5	Q5 How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cuntilever: Precust)
5	Q6 How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Cast In-situ)
5	Q7 How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Precast)



	Factor		Span	Span by Span (SBS)	SBS)		A second s			Bulance Ca	Bulance Cantilever (BC)	1	
		Crist	ist In-stin		Precast		CONTINUOUS	Clist 1	Chist In-situ		Pro	Precast	
1.0	Cont	Overhend /	Under slung	Overhead	Under slung Gamry	Crine	Incremental	Under slung Gantry	Overhead	Crine	Lifting	Under slung Gantry	Overhead
	Overhend Gantry							10.00					
3	Under shing Gantry												
	Overhead Gantry-			-		Î							
2	Under slung Gantry		-										
	Crane Laffing			1									
	Continuous						E	I					
3	Under shing Gantry				1.								
	Overhead Ganiry												
	Crine Lifting	101								1			
	Lifting Frame												
-	Under slung Cantry											e.	
	Overhend Gantry		-										-

Factor		Span	Spun by Span (SBS)	SBS)		PT Sampling to a party			Balance Can	Balance Cantilever (BC		
	Cast	ast In-sinu		Precast		COMPANY	Cast	Cast In-situ		Pre	Precast	
Time	Overhead	I Under slung Gantry	Overhead Gantry	Under slung Gantry	Chine	Incremental	Under slimg Gantry	Overhend Gentry	Crine. Lifting	Lilling	Under slung Gantry	Overhead
Overhend Gantry				1								
Under slung Gantry	Ury.											
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Lifting Frame												
Under slying Gantry	Ury .										0	
Overhead Gantry-												
			Score	5	+	2	2	-	1			
			Meaning	The best	Better	Equally	Worse	The worst				

Factor	-	Spin	Spim by Spim (SBS)	(SBS)		Photosphanon and			Bulance Ca	Balance Cantilever (BC		
	Cast	CastIn-situ		Precest		Communers	Cast	IN-SETU		Pro	Precast	
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Overhend Gantry	-											
Under slung Gantry												
Overhead Gantry												
Winder slung Gantry				-								
Crane Lifting					-							
Continuous												
Understang Gantry					-		i i				1	
Overhend Gantry												
Crane Lifting									0			
Lifting Frante										1		
Understang Gantry											on	
Overhead Cantry												•

-	Factor		Spin	Spun by Span (SBS)	SBS)					Balarice Car	Balarice Cantilever (BC)		
-		Cast	Cast In-silu		Precast		Commons	Cast	Cast In-situ		Pro	Precast	
tiz-n	Environmental Impact	Overhead	head Under slung arv Gantry	Overhead	Under slimg Gantry	Cinne	Incremental	Under slung	Overhead	Creme	Lifting	Under stung Gantry	Overhend Gantry
-	Overhead Gantry	-											
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192	Under slung Ganity												
1	Crane Lifting			1		-							
	Continuous			-			0						
121	Under-stung Gantry												
-	Overhead Gantry												
-	Crane Lifting									10			
SB3	Lifting Frame		1								10		
	Under slung Gantry											M	
-	Overhead Gantry												-
				Score	5	+	5	2	-				

### **APPENDIX B**

### DATA COLLECTION FOR FACTOR SCREENING

and an endang	
ame of Respondent	
sition	
ate	

NorCiv Engineering Co.,Ltd. Sophon Ridumrongkul, Ph.D. Structure Engineer 20/10/2554

# Part A: General Information

1)What kinds of your organization function

Contractor	Owner	Consultant	Sub-Contractor	Others	
1		×			

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

PART B: I	RT B: Identified factor for selection method of bridge deck construction	ion				
Forder	Dosconintion			Score		
I attor	Description	1	7	3	4	5
Cost	Cost of construction, Cost of repairing construction problem					Ś
Time	Time for normal operation, Time for erection and mobilization					2
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section, Super			ę		
Orientation	Machine intensive, Labour intensive			3		
Health and safety	Personal working in site, Third party					3
Aesthetic	Bridge project has tipped in the favor of segmentals for their			e		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			m		
Managerial capabilities	Site control, Labour control, Equipment control		ы			
Contractor past experience				m		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement					Ś
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,					2
	Location : Surrouding are nature, accessibilities of site, Observation : Wetenman, Distance, Distance, United and					
Site condition (criteria)	Postactes - water ways, Kauways, Koads, Varteys, Cullues Possession of site : Full possessession (with out any					
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					S

Name of Company Name of Respondent Position Date

: NorCiv Engineering Co.,Ltd. : Worapatt Ritthichauy, Ph.D.

: Structure Engineer : 20/10/2554

## Part A: General Information

1)What kinds of your organization function

Contractor Owner X Consultant Sub-Contractor Others 2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

BART B:	CU-B: Identified factor for selection method of bridge deck construction	ion				
		1		Score		
Factor	Description	-	5	3	4	5
Cost	Cost of construction. Cost of repairing construction problem					5
Time	Time for normal operation. Time for erection and mobilization		-	11		Ś
Bridges physical charecteristic	Deck curvature, Deck up/down grade, Deck X-Section, Super				4	
Orientation	Machine intensive. Labour intensive		ы			
Health and safety	Personal working in site, Third party		1		4	
Aesthetic	Bridge project has tipped in the favor of segmentals for their			e		
Construction method charecteristics	Available of system components. System complexity and Effective construction method on design. Method application			ŝ		
Managerial capabilities	Site control. Labour control, Equipment control		6			
Contractor past experience		1		3		
Comercial Aspects	Contractor responsibilities. Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning. Emissions.Waters,				4	
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities	17		1		
Site condition (criteria)	Possession of site : Full possession (with out any					
	Construction area : Material and equipment storage, crane					
	soil condition. land topography route				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium			1		5

Name of Company	: NorCiv Engineering Co., Ltd.
Name of Respondent	: Piboon Tirasit, Ph.D.
Position	: Structure Engineer
	: 20/10/2554

1)What kinds of your arganization function

Contractor Owner X Consultant Sub-Contractor Others 2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

Para A			0.	Score		
ractor	nescription	-	R	3	4	5
Cost	Cost of construction, Cost of repairing construction problem				-	\$
Time	Time for normal operation. Time for erection and mobilization				4	
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section, Super			3		
Orientation	Machine intensive, Labour intensive			m		
Health and safety	Personal working in site. Third party			m	1	
Aesthetic	Bridge project has tipped in the favor of segmentals for their				4	
Construction method charecteristics	Available of system components. System complexity and Effective construction method on design, Method application			m		
Managerial capabilities	Site control, Labour control, Equipment control			m		
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement				4	
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,				4	
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities				ñ	
Site condition (criteria)	Possession of site : Full possessession (with out any			_		
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route			1		5
Size of project/Scale of project	Bridges construction were classified in maga project, medium	1			7	

- Au	; NorCiv Engineering Co., Ltd.
ndent	; Wanchai Chuenson
	: General Project Manager
	: 20/10/2554

1)What kinds of your organization function

Contractor Owner X Consultant Sub-Contractor

Others

How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

445 444			S	Score		
Factor	Description	-	7	6	4	5
Cost	Cost of construction. Cost of repairing construction problem				4	
Time	Time for normal operation, Time for erection and mobilization					S
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section, Super				4	
Orientation	Machine intensive, Labour intensive			3		100
Health and safety	Fersonal working in site, Third party			ŝ		
Aesthetic	Bridge project has tipped in the favor of segmentals for their			-		5
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			e		1
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience			2		1	
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			ŵ		
Environmental Requirement	Noise organization and cleaning. Emissions, Waters,				1	5
Site condition (criteria)	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities Possession of site : Full possesession (with out any Construction area : Material and equipment storage, crane soil condition. land topography route				-	~
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3	1	

ation ization funct	: Suchada Padermkul : Design Manager : 20/10/2554
Position       : Design M         Date       : 20/10/255         Part A: General Information       : 20/10/255         I)What kinds of your organization function       : 20/10/255         Contractor       : 0         Owner       : 0         Sub-Contractor       : 0         Others       : 0         2) How long have you work in field of special bridge	ı Manager 2554
Date       : 20/10/253         Part A: General Information       : 20/10/253         1)What kinds of your organization function       : 20/10/253         1)What kinds of your organization function       : 20/10/253         Contractor       : 0         Sub-Contractor       : 0         Others       : 0         2) How long have <i>you</i> work in field of special bridge	2554
Part A: General Information 1)What kinds of your arganization function Contractor Owner Consultant Sub-Contractor Others 2) How long have <i>you</i> work in field of special bridge	
<ol> <li>What kinds of your organization function</li> <li>Contractor</li> <li>Owner</li> <li>Owner</li> <li>Sub-Contractor</li> <li>Others</li> <li>Others</li> <li>How long have you work in field of special bridge</li> </ol>	
Contractor Owner Consultant Sub-Contractor Others 2) How long have <i>you</i> work in field of special bridge	
Others Others 2) How long have <i>you</i> work in field of special bridge	
2) How long have you work in field of special bridge	
encineer/bridge snecialist?	dge construction as senior bridge design
X More than 8 years	
Between 8 years Lower 8 years	

100			s	Score		
Factor	Description	-	2	6	4	5
Cost	Cost of construction. Cost of repairing construction problem				4	
Time	Time for normal operation. Time for erection and mobilization				4	
Bridges physical charecterisric.	Deck curvature, Deck up/down grade, Deck X-Section, Super				4	
Orientation	Machine intensive, Labour intensive		- 1	m		
Health and safety	Personal working in site, Third party		-			3
Aesthetic	Bridge project has tipped in the favor of segmentals for their		2	1		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application		-		4	
Managerial capabilities	Site control, Labour control. Equipment control			3	1	
Contractor past experience			7	15		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			e		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,			é		
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities		1			
Site condition (criteria)	Possession of site : Full possession (with out any				-	
	Construction area : Material and equipment storage, crane soil condition, land topography route				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium				Ī	5

Name of Company	: NRS Consulting Co., Ltd.
Name of Respondent	: Suchada Padermkul
Position	: Design Manager
Date	± 20/10/2554
Part A: General Information	

1)What kinds of your organization function

Contractor	Owner	Consultant	Sub-Contractor	Others
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2) How long have *you* work in field of special bridge construction as senior bridge design engineer/bridge specialist?

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1. A.			Score		
Factor	Description	-	2 3	4	5
Cost	Cost of construction. Cost of repairing construction problem			4	
l'ine	Time for normal operation, Time for erection and mobilization			4	
Bridges physical charecterisric	Deck curvature.Deck up/down grade, Deck X-Section, Super			4	
Orientation	Machine intensive, Labour intensive	-	æ		
Health and safety	Personal working in site, Third party				5
Aesthetic	Bridge project has tipped in the favor of segmentals for their		2		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application	-		4	
Managerial capabilities	Site control, Labour control, Equipment control	7	e		
Contractor past experience			5		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		3		
Environmental Requirement	Noise organization and cleaning. Emissions, Waters,		3		
Sile toudition (ordania)	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities Poceassion of site - Full nossessession (with out any				
	Construction area : Material and equipment storage, crane soil condition, land topography route	-		4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium				5

Name of Company	: MAA Consultant Co., Ltd.
Name of Respondent	: Winai Keaw
Position	: Bridge Design Manager
Date	: 21/10/2554

# Part A: General Information

1)What kinds of your organization function

Contractor Owner X Consultant Sub-Contractor Others 2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

ore than 8 years etween 8 years	ver 8 years
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0	Wanterfertun		s	Score		
ractor	Description	-	0	6	4	a.)
Cost	Cost of construction, Cost of repairing construction problem		21			\$C
Time	Time for normal operation, Time for erection and mobilization					10
Bridges physical charecterisric	Deck curvature.Deck up/down grade. Deck X-Section, Super			3	Ħ	11
Orientation	Machine intensive. Labour intensive			3		111
Health and safety	Personal working in site, Third party			1	4	
Aesthetic	Bridge project has tipped in the favor of segmentals for their	1			4	
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application				4	
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience			10			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		1			5
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,		1	'n		
	Location : Surrouding are nature, accessibilities of site,			1		
Site condition (witerin)	Postación of site - Full noscession (with out any	_				
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route			ŝ	1	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					1

Name of Respondent Name of Company Position Date

: VSL (Thailand) Co.,Ltd.

: Natthawut Cheencharoen

: Satellite Manager : 23/10/2554

# Part A: General Information

1)What kinds of your organization function

X Sub-Contractor Consultant Contractor Others Owner

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

TAN D	AT D- JUCUTICO JACCOL NUL SCIECTION DICTION OF DITUGE OCCA. CONSILICTION				
Danta	Demonstration	1	Score	re	
Pactor.	Description	-	2	3	S
Cost	Cost of construction, Cost of repairing construction problem			4	
Time	Time for normal operation, Time for erection and mobilization				4
Bridges physical charecterisric	Deck curvature. Deck up/down grade. Deck X-Section, Super			10	
Orientation	Machine intensive, Labour intensive			4	
Health and safety	Personal working in site, Third party			m	
Aesthefic	Bridge project has tipped in the favor of segmentals for their			3	-
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			m	
Managerial capabilities	Site control, Labour control, Equipment control		2		
Contractor past experience				3	
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			6	
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,		_	4	4
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities			-	
Site condition (criteria)	Possession of site : Full possession (with out any		_		
	Construction area : Material and equipment storage, crane		_	_	
	soil condition, land topography route			4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium			4	

Name of Company	: VSL (Thailand) Co.,Ltd.
Name of Respondent	: Mr. Vinit Yhupakdee
Position	: Project Engineer
Date	: 23/10/2554

# Part A: General Information

1)What kinds of your organization function

Contractor	Owner	Consultant	Sub-Contractor	Others
	-	1.1	×	

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

	More than 8 years
×	Between 8 years
	Lower 8 years

TART B:	PART B: Identified factor for selection method of bridge deck construction	ion				
1.1.4	1			Score		
ractor	Description	-	2	3	4	5
Cost	Cost of construction. Cost of repairing construction problem					3
Time	Time for normal operation, Time for erection and mobilization				4	
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section, Super			ñ		
Orientation	Machine intensive. Labour intensive					
Health and safety	Personal working in site, Third party					~
Aesthetic	Bridge project has tipped in the favor of segmentals for their				4	1
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			m		1.1
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,				*	
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities	Ú.		ù .	1	
Site condition (criteria)	Possession of site : Full possession (with out any					
	Construction area : Material and equipment storage, crane					
	soil condition. land topography route					vi
Size of project/Scale of project	Bridges construction were classified in maga project, medium	I		m	1	

Name of Company	: VSL (Thailand) Co. Ltd.
Name of Respondent	: Mr. Manop
Position	: Project Engineer
Date	: 23/10/2554

1)What kinds of your organization function

ontractor wher onsultant b-Contr hers	
ntu nsu nsu nsu ner	
o M o P P	

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

More than 8 years X Between 8 years Lower 8 years

				Score		
Factor	Description	-	5	9	4	3
Cost	Cost of construction, Cost of repairing construction problem					5
Time	Time for normal operation. Time for erection and mobilization				4	
Bridges physical charecterisric	Deck curvature.Deck up/down grade, Deck X-Section, Super			3		
Orientation	Machine intensive, Labour intensive			-	4	-
Health and safety	Personal working in site, Third party		1	11	4	
Aesthetic	Bridge project has tipped in the favor of segmentals for their			3		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application		64			-
Managerial capabilities	Site control, Labour control, Equipment control		2	1	1	
Contractor past experience			5			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,		1	3	1	
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities				-	
Site condition (criteria)	Possession of site : Full possession (with out any					
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route					S
Size of project/Scale of project	Bridges construction were classified in maga project, medium		1	6	1	

Name of Respondent       : Mr. Rami         Position       : Erection Specialist         Date       : Erection Specialist         Date       : 23/10/2554         Part A: General Information       : 23/10/2554         I)What kinds of your organization function       : 23/10/2554         I)What kinds of your organization function       : 23/10/2554         Owner       : 23/10/2554         Contractor       : 23/10/2554         Owner       : 23/10/2554         Sub-Contractor       : 23/10/2554         Owner       : 23/10/2554         Sub-Contractor       : 23/10/2554         Others       : 23/10/2554         2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?	tranta or company	: VSL (Thailand) Co.,Ltd.
Position       : Erection Specialist         Date       : 23/10/2554         Part A: General Information       : 23/10/2554         I)What kinds of your organization function       : 0/10/2554         Contractor       : 0/0/2554         Ubbecontractor       : 0/0/2554         Distribution       : 0/10/2554         Distribution       : 0/10/2554         Distribution       : 0/10/2554         Distribution       : 0/10/2554         Outractor       : 0/10/2554         Outractor       : 0/10/2554         Distribution       : 0/10/2554	Name of Respondent	: Mr. Rami
Date       : 23/10/2554         Part A: General Information       : 23/10/2554         I)What kinds of your organization function       : 000000000000000000000000000000000000	Position	: Erection Specialist
Part A: General Information 1)What kinds of your organization function Contractor Owner Consultant Sub-Contractor Others 2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Date	: 23/10/2554
<ol> <li>What kinds of your <i>organization function</i></li> <li>Contractor</li> <li>Owner</li> <li>Owner</li> <li>Consultant</li> <li>Sub-Contractor</li> <li>Sub-Contractor</li> <li>Others</li> <li>How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?</li> </ol>	Part A: General Informatio	
Contractor Owner Consultant Sub-Contractor Others Others 2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	1)What kinds of your organizat	ion function
Owner Consultant Sub-Contractor Others Others 2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Contractor	
Consultant Sub-Contractor Others Others 2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Owner	
Sub-Contractor Others 2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Consultant	
Others 2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Sub-Contractor	
2) How long have <i>you</i> work in field of special bridge construction as senior bridge design engineer/bridge specialist?	Others	
	<ol> <li>How long have you work in f engineer/bridge specialist?</li> </ol>	ield of special bridge construction as senior bridge design
	Between 8 years	
X Between 8 years	Lower 8 years	

division and a second se	LARVE D. DECIMINED DECIDE TO SCREETON INCHIOU OF BUILDER CONSTRUCTION	THAT IS NOT			
	N. A. S.	2	Score	l	Ē
Factor	neecription	1	2 3	4	\$
Cost	Cost of construction, Cost of repairing construction problem			4	
Time	Time for normal operation. Time for erection and mobilization			4	
Bridges physical charecterisric	Deck curvature.Deck up/down grade, Deck X-Section, Super		2		
Orientation	Machine intensive, Labour intensive		3		
Health and safety	Personal working in site. Third party			4	
Aesthetic	Bridge project has tipped in the favor of segmentals for their		6		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application		7		
Managerial capabilities	Site control, Labour control, Equipment control			4	
Contractor past experience		1	2		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,		6		
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities				1
Site condition (criteria)	Possession of site 1 full possession (with out any Construction area : Material and equipment storage, crane soil condition fund tonoremby conto		æ		
Size of project/Scale of project	Bridges construction were classified in maga project, medium		m		

### Part A: General Information

1)What kinds of your organization function

Contractor	Owner	Consultant	Sub-Contractor	Others
11,			×	12

2) How long have *you* work in field of special bridge construction as senior bridge design engineer/bridge specialist?

More than 8 years X Between 8 years Lower 8 years

and the second se	With Martin			Score		
ractor	Description	-	7	3	4	5
Cost	Cost of construction, Cost of repairing construction problem				4	
Time	Time for normal operation, Time for crection and mobilization				4	
Bridges physical charecterisric	Deck curvature.Deck up/down grade, Deck X-Section, Super		2			
Orientation	Machine intensive, Labour intensive			e		
Health and safety	Personal working in site, Third party					~
Aesthetic	Bridge project has tipped in the favor of segmentals for their	Ī	2		1	1
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			ŝ		
Managerial capabilities	Site control. Labour control, Equipment control			3		
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		3	2		
Environmental Requirement	Noise organization and cleaning. Emissions, Waters,			3		
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities	2				
Site condition (criteria)	Possession of site : Full possession (with out any					
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route					10
Size of project/Scale of project	Bridges construction were classified in maga project, medium			e		20

# PART B: Identified factor for selection method of hridoe deck construction

Name of Kespondent	: Structure Engineer (Bridge)
	: Structure Engineer (Bridge)
Position	
Date	: 25/10/2554
Part A: General Information	
1)What kinds of your organization function	ion function
X Contractor	
Owner	
Consultant	
Sub-Contractor	
Others	

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

X More than 8 years Between 8 years Lower 8 years

			S	Score		
Factor	Description	-	2	3	4	5
Cost	Cost of construction. Cost of repairing construction problem				4	071
Time	Time for normal operation. Time for crection and mobilization				4	
Bridges physical charecterisric	Deck ourvature.Deck up/down grade, Deck X-Section, Super			6		
Orientation	Machine intensive, Labour întensive			8		
Health and safety	Personal working in site. Third party					Ś
Aesthetic	Bridge project has tipped in the favor of segmentals for their			3	1	
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application		-	ro.		
Managerial capabilities	Site control, Labour control, Equipment control		61		F	
Contractor past experience			5			
Comercial Aspects	Contractor responsibilities. Contract Type, Procurement	1		~		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,			3		T
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities		-			
Site condition (criteria)	Possession of site : Full possessession (with out any			-		
	Construction area : Material and equipment storage, crane	1				
	soil condition, land topography route	1		1	T	5
Size of project/Scale of project.	Bridges construction were classified in maga project, medium				1	N)

Name of Company	: Italian- I liai Development Fuotic Company Linnicu.
Name of Respondent	
osition	: Structure Engineer
Date	: 26/10/2554

1)What kinds of your organization function

Contractor	Owner	Consultant	Sub-Contractor	Others	
X	117		-	100	

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

X More than 8 years Between 8 years Lower 8 years

1000	The second se		s	Score		11
Factor	Description	-	67	3	4	5
Cost	Cost of construction, Cost of repairing construction problem		2.1		4	
Time	Time for normal operation. Time for crection and mobilization		111	m	1	
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section. Super			8		
Orientation	Machine intensive, Labour intensive				4	
Health and safety	Personal working in site. Third party					Ś
Aesthetic	Bridge project has tipped in the favor of segmentals for their			6	T	11
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			m		10.11
Managerial capabilities	Site control, Labour control, Equipment control	Ĩ	1	m	1	
Contractor past experience			54			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			m		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,			3		
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities					
Site condition (criteria)	Possession of site . Full possesssion (with out any		-			
	Construction area : Material and equipment storage, crane					
	soil condition, land topography route				4	1
Size of project/Scale of project	Bridges construction were classified in maga project, medium		Ĩ		1	5

Name of Company Name of Respondent Position Date

: Unique Engineering and Construction Public Company Limited

: -: Structure Engineer (Bridge)

: 25/10/2554

### Part A: General Information

1)What kinds of your arganization function

X Contractor Owner Consultant Sub-Contractor Others 2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

X More than 8 years Between 8 years Lower 8 years

1.000		-	Score		
Factor	Description	1	2 3	4	5
Cost	Cost of construction. Cost of repairing construction problem			4	-
Time	Time for normal operation. Time for erection and mobilization			4	
Bridges physical charecterisric	Deck curvature, Deck up/down grade, Deck X-Section, Super		3		
Orientation	Machine intensive, Labour întensive		m		
Health and safety	Personal working in site. Third party		-		ŝ
Aesthetic	Bridge project has tipped in the favor of segmentals for their	1	3		
Construction method charecteristics	Available of system components. System complexity and Effective construction method on design, Method application		m		
Managerial capabilities	Site control. Labour control. Equipment control		5		
Contractor past experience		Ī	5		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		3		
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,		3		
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities		-		
Site condition (criteria)	Possession of site : Full possession (with out any				
	Construction area : Material and equipment storage, crane				
	soil condition. land topography route			1	5
Size of project/Scale of project	Bridges construction were classified in maga project, medium				5

Name of Company	: MAA Consultant Co.,Ltd.
Name of Respondent	
Position	: Bridge Management manager
Date	: 21/10/2554

## Part A: General Information

1)What kinds of your organization function

ontractor-	vner	msultant	b-Contractor	thers	
Col	ð	Col	Sub	B	l
this	221	×		10	ľ

2) How long have you work in field of special bridge construction as senior bridge design engineer/bridge specialist?

C Mo	Bet	Lov
re than	Between 8	ower 8 3
18 years	8 years.	years

			Score	re	
Factor	Description	T	2		4
Cost	Cost of construction. Cost of repairing construction problem		-	4	4
Time	Time for normal operation, Time for erection and mobilization				
Bridges physical charecterisric	Deck curvature.Deck up/down grade, Deck N-Section, Super	H		6	
Orientation	Machine intensive, Labour intensive			en.	_
Health and safety	Personal working in site. Third party	-	13		-
Aesthetic	Bridge project has tipped in the favor of segmentals for their				
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			th	
Managerial capabilities	Site control, Labour control, Equipment control			5	_
Contractor past experience				m	
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement	1		ei	_
Environmental Requirement	Noise organization and cleaning, Emissions, Waters,			4	
	Location : Surrouding are nature, accessibilities of site, Obstacles : Waterways, Railways, Roads, Valleys, Utilities		-		
Site condition (criteria)	Possession of site : Full possessession (with out any		_	_	
	Construction area : Material and equipment storage, crane		-	_	
	soil condition, land topography route		-	4	4
Size of project/Scale of project	Bridges construction were classified in maga project, medium	1		4	-

Bridges construction were classified in maga project, medium or small project, and number of Deck curvature, Deck up/down grade, Deck X-Section, Super structure heigh above the ground Location : Surrouding are nature, accessibilities of site, surrounding road network capabilities Construction area : Material and equipment storage, crane movement, area for workshop, soil condition, land topography route Obstacles : Waterways, Railways, Roads, Valleys, Utilities Possession of site : Full possession (with out any interuption), partial possession Bridge project has tipped in the favor of segmentals for their simple elegance. Construction method charecteristics Available of system components. System complexity and system integrity Effective construction method on design. Method application for all span Time for normal operation. Time for erection and mobilization Cost of construction, Cost of repairing construction problem Contractor responsibilities, Contract Type, Procurement SiteNoise organization and cleaning, Emissions, Waters, Site control, Labour control, Equipment control Description Machine intensive, Labour intensive Personal working in site, Third party Bridges physical charecterisric Size of project/Scale of project Environmental Requirement Contractor past experience Managerial capabilities Site condition (criteria) Factor Comercial Aspects Health and safety Orientation Aesthetic. Time Cost

Identified factor for selection method of bridge deck construction

T+						Number of expert	ber (	of ex	pert						0		
r actors	-	2	3	4	5	6 7	~	6	10	Ξ	12	13	14	15	- Summary	FIIONIJES VECTOR	Kanking
Cost	5	S	5	4	1	4	4	S	5	4	5	4	4	4	67	4.47	1
Time	S	S	4	5	-	5	4	4	4	+	4	4	4	3	64	4.27	-
Bridges physical charecterisric	3	4	3	4	-	6	3	e	3	2	~	3	e	3	45	3.00	6
Orientation	e	3	3	3	~	5	4	ŝ	4	ŝ	3	3	e	4	47	3.13	8
Health and safety	S	4	ŝ	3	5	4	ŝ	S	4	4	5	S	5	5	62	4.13	4
Aesthetic	З	3	4	5	0	4	3	4	3	3	2	2	3	ŝ	49	3.27	7
Construction method charecteristics	e	ŝ	3	3	-	÷	ŝ	ŝ	2	2	2	3	3	3	4	2.93	II
Managerial capabilities	2	2	3	3	~	6	2	2	2	4	2	3	2	e	38	2.53	12
Contractor past experience	3	ŝ	3	5	0	6	ŝ	2	2	2	3	3	2	2	37	2.47	13
Comercial Aspects	S	2	4	33	~	5	3	e	2	2	2	2	e	3	45	3.00	6
Environmental Requirement	Ś	4	4	5	~	4	4	4	3	ŝ	3	3	e	3	54	3.60	9
Site condition (criteria)	4	4	s	5	-	4	4	S	S	3	3	5	Ś	4	63	4.20	19
Size of project/Scale of project	S	S	4	3	5	4	4	e	3	ŝ	e	3	5	5	60	4.00	-
															675	45.00	
															Average	3,46	
															Max.	4.47	
															Min.	2.47	

APPENDIX C

CALCULATION SHEET

FOR ERECTION EQUIPMENT SELECTION

Plactors -	Size of project Site Condition	nutition	Cott	Tittle	Safety	Environmental			Afutuphy v	dirroot P	Multiply athroot Priorities Victor Multiply Matrix,	Authory Matrix	Divide
Size of project	1 1		E/3	1/3	1/3	£/1		RL	10.0	0.48	20/0	0.42	0.39
Site Condition	1 1		E/F	1/3	1/3	1/3		1.25	10.0	0.48	10.07	0.42	6.39
Cost	3 5.			-	*	*		D	135.00	2.26	15.0	107	6.81
Time	3 3							0.12	27.00	1.73	0.24	26.0	6.20
Safety and Helth	3 5		1/3	-	-			đ	15,00	1.87	0.22	1.48	0.86
Environmental	3 3		1/3.	1/3	1/5	1		010	0.20	0.76	010	673	6.92
								acceptable	Sam	7,29	1.00		30.57
										1	2	A HURK -	6,60
	Factor Size of united		Span hy S	Span by Span (SBS) Lassibility Drevest	Continuous	Ballance Castillever (BC) Chat Inselta Decemi	(BC) Protrad	81	Ministry n	diricot P	Multiply uthroot Priorites Vector Multiply Matrix	dultiply Matrix	Divide
*	Candingin		-	-5/4	1	L		1.20	0.20	0.76	0.13	0.61	4.76
as	Prenset		-		*			B	625.00	2.92	610	3.05	6.23
	Continuous	ľ	-	1/5	1			10'0	0.20	0.76	0,13	19:0	4.76
ġ	-Cast In-situ	ľ		1/5	D.	+		CR	0.20	0.76	0,13	0.61	47.6
a	Precasi		- 12	- 8/8	ĉ	1		10/0	0.24	0.76	0,13	0.61	4.76
							2	acceptable	Sum	5.98	1.00		お約
											ľ	o max =	3.04
	Factor Site Condition	9.	Span by S Cast In-situ	Span by Span (SBS) I m-sian Precast	Confinations	Balance Cantilever (BC) Cast In-stit	pr (BC) Precast	Rİ	Multiply r	threet P	Multiply uthroot Priorities Vector Multiply Marix. Divide	Authory Matrix	Divide
s	Cast In-situ		_	1/8	-			1.20	0.20	0.76	0.14	0.68	1.89
ØS	Precest	1	5	4	5	-	5	D	125,00	42.2	0,40	2.00	6.58
	Contentocaus	ſ	E	5/6.	1	- F		0.09	0.20	0.76	410	0.68	4.89
3	Cast Insetts	ľ				4		CR	1.00.1	1.00	0,18	1.00	19:57
я	Present		1	1/3	1	1		0.07	0.20	0.74	0.14	0.68	1.89
							1	an phalue	Sam	5.53	1,00		100
							í		1			A 1010X =	5.36
	Factor		Span by S	Span by Span (SBS)	Continuous	trilevy	(BC)		Multiply p	this root P	Multiply nthrow Priorities Vector Multiply Many Divide	duliphy Mairy	Divule
	101	1	Cost m-star	FFECIMI		Cast In-stitu 15	Trecast	101					1
sa	Cast Intellat		-	5/1	-	4	1/3	1.20	0.20	0.76	0,13	0.76	
s	Prezast	1	5	1	P.	*		IJ	225.00	2.47	6143	163	0.07
	Chaliman	1		2/4		-		11.0	0.33	0.83	0.15	12.0	4.87
	Confinenti	h	1(3)	1571	7		l	R	70/0	0.64	11.0	0.56	5,05
a	Prevant		9	1/3	-	-		0.09	130	1.00	0.18	0.98	25.5
							-	acceptable	Sum	5.70	1.00	Same?	27.25
							ì					A LUGA	Т

-	Continuouv		Balance Cantilever (BC) Cast In-situ Precast	freest	12	Multiply 1	th root Prio	Multiply nub root Priorities Vector Multiply Marrix Divide 0.07 0.64 0.11 0.14	phy Miantix	Divide
CIT .				£/1	17-1	10/0	100	110	100	70%
		G. 4			The second	MICTT	144	140	10.7	0,10
201				211	au	10.0	20.0	011	050	100
1/3				1	0.03	9.00	1.44	0.25	1.39	5.66
				e	acceptable	Sim	5.88	1.00	ľ	14.79
				1					A max =	5.16
Span by Span (SBS)	Continuous	1	Balance Cantilever (BC	or (BC)		Multiply n	throot Pric	Multiply nth root Priorities Vector Multiply Matrix Divide	ply Matrix	Divide
ist In-situ Precast	and		Cast In-situ	Precast	RI					
3/5	-	3		13.	1.20	0.20	0.76	0.13	0.66	\$24
1	w.	m.		÷	5	375.00	2.69	0.44	275	6.21
1/5	1	-		1/3	20.0	10.07	0.64	0.11	0.49	4.63
1/5	1	-		13	CR.	0.02	0.53	0.09	0.40	4.60
1/3	*	10		-	0.06	9.00	1.44	0.24	1.34	5.64
				9	acceptable	Sum	6.06	1.00		26.32
				ľ					A TRAY =	5.26
Span by Span (SBS) Cast in-aim Precast	Continuous		Balance Cautilever (BC) Cast In-situ Precasi	er (BC) Precast	KL	Multiply n	throat Pric	Multiply athrost Priorities Vector Multiply Matrix. Divide	phy Matrix	Divide
1/5	2	101	ľ	173	1.20	0.20	0,76	0.13	0.68	5,26
2	-	-		-	U	225.00	247	0.42	2 (4)	6.22
3/3	-			1/3	30/0	11.0	0.69	0.12	0/36	475
3/8	1	-		1/3	No.	0.02	0.51	0.00	0.42	4.63
3.0	3.	5		-	10.07	9.00	144	0,24	1.40	10.3
				, a	acceptable	Sum	2,90	1.00		26.56
								-	A max -	185

Calculation Sheet	
Case study: Structure System Designing Phase	
Comparison of factors with respect to overall satisfaction with	

|--|

Action by Expertise No. 13

Factor	ħ	\$				Maple	6		Hir-	ġ	
	Blar of Junior	Ste Consider	they.	Tune	Ger and Her	Company of	Adama	NORD BOOM	Channar Lo	Multiple Associate	Childe
Size of project	1	3	3	3	1/3	1/3	3.00	1.20	0.18	1.30	7.36
Site Condition	1/3	1	3	3	1	1	3.00	1.20	0.18	1.16	6.62
Cost	1/3	1/3	1	1	1/3	1/3	0.01	0.48	0.07	0.43	6.07
Time	1/3	1/3	1	1	1/3	1/3	0.01	0.48	0.07	0.43	6.07
Safety and Health	3	1	3	3	1	1	27,00	1.73	0.25	1.63	6.44
Environmental Impact	3	· k	E	3	ā.	I	27.00	1.73	0.25	1.63	0.44
							Sum	6.83	1.00		39.00
									λ	max=	6.50
R.I.	123	CI-	0.10	C.R.=	0.08	acceptable					

Questionnaire No.1 Action by Expertise No. 14

Factor						100	No.		Char-	and a	
	New of Langer	Suy Condition	en la	Time	Mer and Par	Constrained a	Madipalis	an and	Phones Is	Manupp, Marris	anat.
Size of project	1	\$	5	5	5	5	3,125.00	3.82	0,48	3.09	6.48
Site Condition	1/5	1	3	3	ī	1	1.80	1.10	0.14	0.84	6.10
Cost	1/5	1/3	1	F	1/3	1/3	0.01	0.44	0.06	0.34	6.23
Time	1/5	1/3	1	1	1/3	1/3	0.01	0.44	0.06	0.34	6.23
Safety and Health	1/5	1	3	3	a	1	1.80	1.10	0.14	0.84	6.10
Environmental Impoct	1/5	1	3	3		1	1.80	1.10	0.14	0.84	6.10
							Sum	8.02	1.00		37.23
					1.12				7.	- xan	6.20

RL- 15 CI = 0.04 CR = 0.03 acceptable

Calculation Sheet Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

					tan			at the second	4	
Sur or princip	Sile Conding	Gay	Time	Surge and In	financial de	And	AUG FORM	Priorities Very	Mungels And	University
τ	5	3	3	T.	0	45.00	1.89	0.27	1.96	7.18
1/5	1	5	3	1	1	3.00	1.20	0.17	1.18	6.76
1/3	1/5	1	1	1/3	1/3	0.01	0.44	0,06	0.40	6,23
1/3	1/3	1	The second	1/3	1/3	0.01	0.48	0.07	0.42	6.0
1	1	3	3	1	1	9.00	1.44	0.21	1.27	6.0
1	1	3	3	1	1	9.00	1.44	0.21	127	6.00
						Sum	6.89	1.00		38.35
								λ	max =	6.35
	( 1/5 1/3 1/3 1 1	1 5 1/5 1 1/3 1/5 1/3 1/3 1 1	1     5     3       1/5     1     5       1/3     1/5     1       1/3     1/3     1       1     1     3       1     1     3	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1       5       3       3       1       1       45.00         1/5       1       5       3       1       1       3.00         1/3       1/5       1       1       1/3       1/3       0.01         1/3       1/3       1       1       1/3       1/3       0.01         1/3       1/3       1       1       1/3       1/3       0.01         1       1       3       3       1       1       9.00         1       1       3       3       1       1       9.00         1       1       3       3       1       1       9.00         1       1       3       3       1       1       9.00	1       5       3       3       1       1       45.00       1.89         1/5       1       5       3       1       1       3.00       1.20         1/3       1/5       1       1       1/3       1/3       0.01       0.44         1/3       1/3       1       1       1/3       1/3       0.01       0.44         1/3       1/3       1       1       1/3       1/3       0.01       0.48         1       1       3       3       1       1       9.00       1.44         1       1       3       3       1       1       9.00       1.44         1       1       3       3       1       4       5.89	1       5       3       3       1       1       45.00       1.89       0.27         1/5       1       5       3       1       1       3.00       1.20       0.17         1/3       1/5       1       1       1/3       1/3       0.01       0.44       0.06         1/3       1/3       1       1       1/3       1/3       0.01       0.44       0.06         1/3       1/3       1       1       1/3       1/3       0.01       0.48       0.07         1       1       3       3       1       1       9.00       1.44       0.21         1       1       3       3       1       1       9.00       1.44       0.21         1       1       3       3       1       1       9.00       1.44       0.21         1       1       3       3       1       1       9.00       1.44       0.21         Sum       6.89       1.00       3       1       1       3.00       1.00	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$

Questionnaire No.1

Action by: Expertise No. 12

Factor						in the second			*		
	Size of Differen	Silo Gandinam	Caur	Time	Cutor and In.	Reserved of the second	Anton	and agen	Prioring Lease	Manuple Marry	Dink
Size of project	1	5	5	5	1	1	125.00	2.24	0.31	2.12	6.73
Site Condition	1/5	Ŧ	3	3	1	1	1.80	1.10	0.16	1.00	6.42
Cost	1/5	1/3	4	Ð.	1/3	1/3	0.01	0.44	0.06	0.37	6.02
Tune	1/5	1/3	1	4	1/3	1/3	0.01	0.44	0.0ó	0.37	6.02
Safety and Health	1.	Ĩ.	3	3	1	1	9.00	1.44	0.20	1.25	6.15
Environmental Impact	1	1	3	3	1	1	9.00	1.44	0.20	125	6.15
							Sum	7.11	1.00		37.50
R.L=	LØ	C.I. =	0.05	C.R. =	0.04	acceptable			X	max =	6.25

Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

											_
Factor	the of angles	Sile Contracto	Court	Tune	Sier, and Her.	Corchemental Lago	Viniter,	and and	Provinsi Varias	Manapite Marine	Device
Size of project	1	5	3	3	1/3	1/3	5.00	1.31	0.18	1.31	7.19
Site Condition	1/5	ĩ.	3	3	1/3	1/3	0.20	0.76	0.11	0.74	6.93
Cost	1/3	1/3	1	1	1/3	1/3	0.01	0.48	0.07	0.42	6.32
Time	1/3	1/3	T	T	1/3	1/3	0.01	0.48	0.07	0.42	6.32
Safety and Health	3	3	3	3	4	1	81.00	2.08	0.29	1.84	6.38
Environmental Impact	3	3	3	3	1	1	81.00	2.08	0.29	1.84	6.38
							Sum	7.19	1.00		39.51
									2	max =	6.59

Questionnaire No.1 Action

Action by Expertise No. 10

Factor						(figners			ð		
	Mar of Profes	She Continue	Sar	Time	Suley and He	Fortenand Lines	in.	aut neer	Printing Lag	Multiply Marie	Divide
Size of project	1	5	3	3	1	1	45.00	1.89	0.27	1.96	7.18
Site Condition	1/5	1	5	3	T	1	3.00	1.20	0.17	1.18	6.76
Cost	1/3	1/5	L	1	1/3	1/3	0.01	0.44	0.06	0.40	6.23
Time	1/3	1/3	1	(İ)	1/3	1/3	0.01	0.48	0.07	0.42	6.06
Safety and Health	1	X.	3	3	1	.1	9.00	1,44	0.21	1.27	6.06
Environmental Impact	1	÷.	3	3	1	1	9.00	1.44	0.21	1 27	6.06
							Sum	6.89	1.00		38.35
									λ	max =	6.39
R.I	1.25	C.I. =	0.08	C.R. =	0.06	acceptable					

### Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

Factor	See of Angles	Sie Counting	Clay	Fage.	Safer and In	Enternance Lance	Station	Att court	Phinness Partor	Malling Adding	Distile
Size of project	1	3	3	3	3	3	243.00	2.50	0.35	2.29	6.5
Site Condition	1/3	1	3	3	3	3	27.00	1.73	0.24	1.57	6.4
Cost	1/3	1/3	1	1	1	1/3	0.04	0.58	0.08	0.51	6.2
Time	1/3	1/3	1	L	1	1/3	0.04	0.58	0.08	0.51	6.2
Safety and Health	1/3	1/3	1	ĩ	ī.	T	0.11	0.69	0.10	0.60	6.1
Environmental Impact	1/3	1/3	3	3	1	1	1.00	1.00	0.14	0.93	6.5
							Sum	7.08	1.00		38.0
R.L.=	145	C.1 =	0.07	CR=	0.06	acceptable			÷	max =	6.3
R.L = Questionnaire No.1 Factor	Action	C.I. =	ettise No	C.R. =	8						
Questionnaire No.1 Factor		bv Exp	ettise No			*		- <sup>Job</sup> y Ma 1.89	A Strain Parts		
Questionmaire No.1 Factor Size of project	Action	by Exp	ettise No	Vano 10	8	Emmanuel Inger	litter		Primus Viena	Manipul Manage	*mile 7.0
Questionnaire No.1 Factor Size of project Site Condition	Action State	by Exp	ertise No	te l'ano	8	Emmanuel Inger	45.00	1.89	0.29	2,02	*## 33 7,0 6,7
Questionmare No.1 Factor Size of project Site Condition Cost	Action	by Exp	ettise No ettise 3 3	5 . 2 Jano	Magnung	fantanting	45.00 1.80	1.89 1.10	0.29 0.17	<sup>400</sup> 1,12	7,00 6,70 6,20
Questionmare No.1 Factor Size of project Site Condition Cost Fime	Action.	<sup>40000000</sup> 5 1 1/3	ertise No 3 3 1	0 3 3 1 1	Magnung	topological lange	45.00 1.80 0.04	1.89 1.10 0.58	0.29 0.17 0.09	2,02 1.12 0.55	7.0 6.7 6.2 6.2
Questionnare No.1	Action 1 1/5 1/3	<sup>40000000</sup> 5 1 1/3	ertise No 3 3	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Magnung	topological lange	45.00 1.80 0.04 0.04	1.89 1.10 0.58 0.58	0.29 0.17 0.09 0.09	<sup>tung</sup> 1,02 1,12 0,55 0,55	Ditate

### Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

Factor	alla a	dina.			Such and Her	fantineneral lag	7		Paralles Peres	Mulph Aunt	ŝ,
	Mont Profes	Sile Cardina	Case	Time	Nuce, a	Lanion	Multiple	Mar the	Pullone	Antiple	Direct
Size of project	1	3	3	3	1	1	27.00	1.73	0.26	1.59	6.1
Site Condition	1/3		λ.		1/3	1/3	0.04	0.58	0.09	0.53	6.10
Cost	1/3	1	1	I	1	1/3	0.11	0.69	0.10	0.65	6.23
l'ime	1/3	4	1	1	1	1/3	0.11	0.69	0.10	0.65	6.2
Safety and Health	0	3	1	1	1	1	3.00	1.20	0.18	1.17	6.48
Environmental Impa	act 1	3	3	3	1	)	27.00	1.73	0,26	1.59	6,10
							Sum	6.63	1.00		37.2
	R.I = 1.45	Ç.I. =		C.R. =	0.03	acceptabl	le			max=	
	Action	by : Exp	ertise No		Ó						
Questionnaire No.1 Pactor		by : Exp	ertise No	Time	Surginad Inc.	Particular Light			Providen Victor	Naulon, Marca	Think.
Questionnaire No.1 Factor	Action 1	by Exp	ertise No	2 June 5	w Step and the	w Revenues and	1.125.00	3.22	0.41	10000 10000 10000 2,91	7.0
Questionnaire No.1 Factor Size of project Site Condition	Action 1	by Exp	ertise No	Time	w w Surginadige	W W Forthermont light	1.125.00 45.00	3.22 1.89	0.41 0.24	<sup>1000</sup> 14 (101100) 2,91 1.60	7.0 6.6
Questionnaire No.1 Pactor Size of project Site Condition Cost	Action 1	by Exp	ertise No	2 June 5	w Step and the	Mar 1/3	1.125.00 0.01	3.22 1.89 0.49	0.41 0.24 0.06	<sup>vum</sup> t (bhmg) 2,91 1.60 0.39	7.0 6.6 6.2
Questionnaire No.1 Factor Size of project Site Condition Cost Fime	Action 1	by Exp 1 1/5 1/5	ertise No	2 June 5	w w Surginadige	W W Forthermont light	1.125.00 45.00 0.01 0.01	3.22 1.89	0.41 0.24 0.06 0.06	<sup>1000</sup> 14 (101100) 2,91 1.60	7.0 6.6
Questionnaire No.1 Factor Size of project Site Condition Cost Time Safety and Health	Action	by : Exp ())) 5 1 1/5 1/5 1/3	ertise No c <sup>3</sup> 5 5 1 1 1	2 300 5 5 5 1 1	- w w Sugar	Mar 1/3	1.125.00 0.01 0.01 0.11	3.22 1.89 0.49	0.41 0.24 0.06	<sup>vum</sup> t (bhmg) 2,91 1.60 0.39	7.0 6.6 6.2
Questionnaire No.1	Action	by Exp 1 1/5 1/5	ertise No C	2 June 5 5 1 1	- w w Sugar	Mar 1/3	1.125.00 45.00 0.01 0.01	3.22 1.89 0.49 0.49	0.41 0.24 0.06 0.06	<sup>Runny</sup> <sup>Volumy</sup> 2.91 1.60 0.39 0.39	7.0 6.6 6.2 6.2

Calculation Sheet Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

Questionnaire No.1	Action by : Expertise No.	3	

Factor						- input			de.	#	
	Stern Angler	Sile Continue	- di	Tune	Cafey and IS.	Supervision of the second	Hater	hith, roug	Printing Varian	Maliput. Adam	Ni We
Size of project	1	3	1	1	1	1	3.00	1.20	0.19	1.18	6.27
Site Condition	1/3	1	1	1	1/3	1/3	0.04	0.58	0.09	0.57	6.27
Cost	1	1	1	ł.	Ť.	1/3	0.33	0.83	0.13	0.82	6,27
Time	1	1	1	Г	1	1/3	0.33	0.83	0.13	0.82	6.27
Safety and Health	1	3	1	1	1	1	3.00	1.20	0.19	1.18	6.27
Environmental Impact	1	3	3	3	1	1	27.00	1.73	0.27	1.70	6.27
							Sum	6.38	1.00		37.63
									2	max=	6.27
R.1. =	1/25	$CI \approx$	0.05	C.R. =	0.04	acceptable					

Questionnaire No.1

Action by : Expertise No. 4

Factor						in the second			5	1	
	Size of Project	She Candidan	Gant	Time	Safery and In.	Enternal of the	Alden.	Inth Part	Printing Vertor	Multiple Marrie	Uninde.
Size of project	1	1	1	1	1/3	1/5	0.07	0.64	0.10	0.59	6.17
Site Condition	1	1	1	T	1/3	1/3	0.11	0.69	0.10	0.63	6.10
Cost	1	1	1	F	1	1/3	0.33	0.83	0.12	0.77	6.24
Time	ì	1	1	t	1	1/3	0.33	0.83	0.12	0.77	6.24
Safety and Health	3	3	1	1	1	1	9,00	1.44	0.22	1.40	6.49
Environmental Impact	5	3	3	3	1	1	135.00	2.26	0.34	2.08	6.17
							Sum	0.70	1.00		37.40
									).	max =	6.23
R.1.	1.25	C.I.=	0.05	C.R. =	0.04	acceptable					

### Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

the of Prov	the Conder	the state	Tinc	Sufey, and Here	European Land	-Stading	10 VIDI	Priorities Verlor	Maugay Manay	Dirute
1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.07	0,42	6.39
1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.07	0.42	6.39
3	3	1	d	3	5	135.00	2.26	0.31	2.11	6.81
3	3	1	1	1	3	27,00	1.73	0.24	1.47	6,20
3	3	1/3	1	1	5	15.00	1.57	0.22	1.48	6.86
-		1/2	1/2	1/5	1	0.20	0.76	0.10	0.73	6.92
3	3	1/3	1/3	11-5		0.20	0.70	6.10	6/12	0.92
	1 1 3 3	1 1 1 1 3 3 3 3	1 1 1/3 1 1 1/3 3 3 1 3 3 1	1 1 1/3 1/3 1 1 1/3 1/3 3 3 I 1 3 3 1 1	I         I         1/3         1/3         1/3           I         I         I/3         I/3         I/3         I/3           3         3         I         I         3         I         I         3           3         3         I         I         I         3         I         I         1         3           3         3         I         I         I         I         1	1     1     1/3     1/3     1/3     1/3       1     1     1/3     1/3     1/3     1/3       3     3     1     1     3     5       3     3     1     1     1     3	I         I/3         I/3         I/3         I/3         0.01           I         I         I/3         I/3         I/3         0.01           I         I         I/3         I/3         I/3         0.01           3         3         I         I         3         5         I35.00           3         3         I         I         1         3         27.00	I         I/3         I/3         I/3         I/3         0.01         0.48           I         I         I/3         I/3         I/3         I/3         0.01         0.48           I         I         I/3         I/3         I/3         I/3         0.01         0.48           3         3         I         I         3         5         135.00         2.26           3         3         I         I         1         3         27.00         1.73	I         I/3         I/3         I/3         I/3         0.01         0.48         0.07           I         I/3         I/3         I/3         I/3         0.01         0.48         0.07           I         I/3         I/3         I/3         I/3         0.01         0.48         0.07           3         3         I         I         3         5         135.00         2.26         0.31           3         3         I         I         3         27,00         1.73         0.24	I         I/3         I/3         I/3         I/3         0.01         0.48         0.07         0.42           I         I         I/3         I/3         I/3         I/3         0.01         0.48         0.07         0.42           I         I/3         I/3         I/3         I/3         0.01         0.48         0.07         0.42           3         I         I         3         5         135.00         2.26         0.31         2.11           3         3         I         I         3         27.00         1.73         0.24         1.47

Questionnaire No.1 Action by . Expertise No.

Factor			7		the second	tal lepart			cetor.	and a	
	Algo of project	Sine Condition	Cour	Tune	Safery and In-	Bernanderson	hits	Inter Inc	Priorities Verlag	Multiply Muris	Chinde
Size of project	1	3	3	3	1/3	1/3	3.00	1.20	0.18	1.24	6.88
Site Condition	1/3	1	1	1	1/3-	1/3	0.04	0.58	0.09	0.53	6.13
Cost	1/3	1	1	1	1	1/3	0.11	0.69	0.10	0.67	6.49
Time	1/3	1.	1	1	).	1/3	0.11	0,69	0.10	0.67	6.49
Safety and Health	3	3	1	1	1	1	9.00	1.44	0.22	1.53	7.10
Environmental Impact	3	3	3	3	1	1	81.00	2.08	0.31	1.95	6.20
							Sum	6,69	1.00		39.3
									2	max=	6.50
R.I. =	111	C.I. =	0.11	C.R. =	0.09	acceptable					

### Case study: Structure System Designing Phase Comparison of factors with respect to overall satisfaction with

Questionnaire No L	Action	by : Expe	ertise No	2	15	e.	-	_			-
Factor	Ster of Junet	Sile Condition	bur	Time	Witten wad Ig.	Enternance of the	The state	Juga tool	Hacilies Letter	Mangar, Mana	Dente
Size of project	1	5	5	5	5	3	1,875.00	3.51	0.44	2.97	6.68
Site Condition	1/5	E	3	3	3	3	16.20	1.59	0,20	1.35	6,72
Cost	1/5	1/3	1	1	1/3	1/3	0.01	0.44	0.06	0.35	6.24
Time	1/5	1/3	1	1	1/3	1/3	0.01	0.44	0.06	0.35	6.24
Safety and Health	1/5	1/3	3	3	1	1	0.60	0.92	0.12	0.73	6.32
Environmental Impact	1/3	1/3	3	3	1	I	1.00	1 00	0.13	0.79	6.27
							Sum	7.90	1.00		38.47
									λ	max=	6.41
RI	1.05	Ċ1 =	0.08	C.R. =	0.07	acceptal	de				

	히	- International
	alcutation Shee	- U
	cutatio	
	Cat	
		00

Case study: Structure System Designing Phase Comparison of factors with respect to overall substaction.

Easte anneated Impact	0.10	0.31	0.27	0.34	0.26	0.13	0.14	0,22	0,29	0.21	0,21	0,20	0.25	0.14	0.13	3.20	0.21	0.21	
Safety and Health	0.22	0.22	0.19	0.22	0.18	0.09	010	0.15	0.29	0.21	0.21	0.20	0.25	0.14	0.12	2.77	0.18	0.15	
Time	0.24	0.10	0.13	0.12	01.0	0.06	0.08	60'0	20.0	20'0	20'0.	0.06	0.07	0.06	0.06	1.38	0.00	0.09	
<sup>480</sup> 0	0.31	0.10	0,13	0.12	0.10	0.00	0.08	60'0	70,07	0.06	0,06	0,06	0.07	0.06	0.06	1.44	010	0.10	w
Sile Condition	10.02	60'0	0.09	0.10	0.09	0.24	0.24	0.17	0.11	0.17	610	010	81.0	0.14	020	2.21	0.15	0.15	,
Sire of broject	20.07	81.0	61.0	010	0.26	11-0	0.35	0.29	0,18	0.27	0.27	15.0	0.18	0.48	0.44	3.98	0.27	0.27	
Philotics Vector of Factor	1	7	m		15	0	۲	œ	6	10	11	12	13	44	15	Sum	Average	Weight	Rankina

tority	Priority Vector of Factor	sharmada sharmad	Span by Span (SBS)	Continuous	Balance Cam	Balance Camilever (BC)
		Cast In-situ	Precast		Cast In-situ	Precast
		0,11	0.42	0.12	11'0	0,25
	61	0.11	0.42	0.14	0.09	0/24
	m	0.11	0.42	0.14	0.09	0.24
		0.11	0.42	0.14	60'0	0.24
	8	11.0	SF.0	0.14	0.09	0,22
	6	60.09	0.44	0.16	0.09	0.22
ədxş	1	0.09	0.41	21.0	60'0.	0.24
	8	0.09	0.36	0.21	60'0	0.25
	6	0.11	0.41	6.17	0.07	0,24
	10	0.11	0.41	6.17	0.07	0.24
	IJ	0.11	0.35	51.0	0.08	06.0
	12	0.11	0.35	0.14	60'0	0.30
	13	01.0	0.34	- LUO	0.07	0.32
	14	0.07	0.40	0.16	60'0	0.28
	15	0.07	0.41	0.17	0.11	0.25
	Sum	1,47	6.02	2.37	1.32	3,82
	Average	0,10	0,40	0.16	0.09	0.25
	Weight	0.10	0.40	0.16	0.09	0.25
	Ranking			6	93	1
	Factor		Thue		Priority Vector	Ranking
KRK.	Cast In-situ				0.10	
	Precast				0.40	1
ous	Continous Continuous				0,16	2
BC	Cast In-situ Precast				0.09 0.25	10-19
					1.00	

Calculation Sheet

nority	Princity Vector of Factor	Span by S	Span by Span (SBS)	Continuous	Balance Cu	Balance Cantilever (BC).
	In the second second	Ctest In-situ	Precast		Cast In-situ	Precast
		0.15	0.43	0.15	0.01	0.18
	2	11.0	ED-0	0.14	0.11	0.21
	16	11.0	0.36	0.12	0.11	0'30
	4	61.0	0.38	0.18	0.12	0.18
	16	0.11	0.35	21.0	0.08	0.30
u	0	0.11	0.41	21.0	0.07	0.24
exbe	2	0,11	0.35	0.13	60.0	0.32
e to	20	11.0	0.35	410	0.08	05.30
ON	.6	0.11	16.0	0.17	0.07	0/24
ć	00	0,12	26.0	0.18	0.12	0,22
	10	0.11	10.41	0.17	0.07	0.24
	12	0.11	0.50	0.19	0.16	0,25
	13	0.09	0.37	0.12	11.0	15.0
	14	0.08	15.0	6.17	0.09	0.26
1	15	0.11	10.01	0.17	0.07	0.24
	Sum	1.61	5.74	2.39	1.45	3.78
	Average	0.11	0.38	0.16	0.10	0.25
	Weight	0.11	0.35	0.16	01.0	0.23
1	Ranking	4	-	e	6	
	Factor		Cost		Priority Vector	Ranking
SBS 0	Cast In-silu Drocout				0.11	-
Continous	Continuous				0.16	
	Cast In-situ Precast				0.10 0.25	90 .ek
					- North	

Calculation Sheet

Priority	Priority Vector of Factor	Span by 5	Span by Span (SBS)	Continuous	Balance Cantilever (BC)	filever (BC)
Contract of	and the second se	Cast In-sim	Precast		Cast In-situ	Precast
	- A	0.14	0.40	0.14	81.0	0.14
	53	11.0	0.45	0.13	0.11	0.20
	3	11.0	0.42	0.12	0.11	0.25
		0.09	0.23	0.18	0.12	0.37
	s	0.09	0.48	0.13	0,13	0.18
p	9	0.08	0,45	21.0	0,13	0.17
edxy	ĸ	60'0	0.36	0.15	6.43	0.28
e to	*	0.08	0.45	0.16	0.44	61.0
No.	6	60'0	0.46	0.16	0.14	0.16
τ	10	60'0	0,37	0.15	0.14	0.26
	11	11.0	0.37	0.12	0.14	0.26
	12	61.0	0.33	0.12	0.10	0.31
	5	0.08	0.41	0.14	01.0	0,28
	14	11.0	0.37	0.10	80'0	0.34
1	15	0.13	0.42	0.12	60/0	0.24
	Sum	1.54	5.97	2.07	1.83	3.59
	Average	0.10	0+0	0.14	0.12	0.24
	Weight	010	01-10	0.14	0.12	0.24
	Ranking	N	1	9	4	2
Π	Factor		Site Condition		Priority Vector	Ranking
SHS	Cast bi-situ				0.10	10
- 11	Precist				0.40	1
Continous	Continuous				0.14	n
BC	Cast In-situ Precast				0.12	4.6
					1.00	

nimetro.	Priority Vector of Factor	Span by Span (SBS)	an (SBS)	Continuous	Balance Cantilever (BC)	ülever (BC)
-		Cast In-situ	Precast		Cast In-situ	Precast
	1	EL.0	26.0	0.12	60.0	0.24
	ri.	0.11	0.42	0.12	0.11	0.25
	n	0.11	0.42	0.12	0.11	0.25
	•	0.09	0.42	6/14	0.11	0.24
	42	0.11	21/0	0.12	0.11	0.25
11	0	60'0	21/0	0.14	0.14	0.24
aday	r	0,07	11/0	0.14	0,13	0.26
T 10	8	01.0	0.41	11.0	01/0	0.28
in	6	60.0	0.46	0,10	60.0	0,25
	10	010	0.440	61.0	0.10	0.24
	a	11.0	0.45	0.13	0.10	0.22
	12	0.10	0.44	0.13	0.10	0.24
	13	0.05	0.41	0.14	0.11	0.26
	14	80.0	0.40	0.16	0.08	0.28
1	15	80.0	0,40	0.16	0.08	0.28
	Sum	1.43	6.34	1.95	1.50	3.77
	Average	0.10	0.42	0.13	0.10	0.25
	Weight	0.10	0.42	0.13	0.10	0.25
	Raulting	10	1	6	4	2
П	Factor	2	Environmental Impact		Priority Vector	Ranking
SBS	Cast In-sim				010	in.
	Precast				0.42	1
mous	Continous Continuous				0.13	3
BC	Cast In-situ Precast				0.10 0.25	<b>7</b> A
					1.000	

Pnonty	Priority Vietor of Factor	Spun by Span (SBS)	an (SBS)	Continuous	Balance Cantilever (BC)	tilever (BC)
		Cast In-situ	Precast		Cast In-situ	Precast
	The second secon	0.13	0.44	0.11	60'0	0.24
	¢1	0.13	0.41	0.14	0.07	0.24
	r	21/0	0.42	0.14	0.09	0.23
	7	-60'0	0.41	0.17	0.09	0.24
	\$	0.11	0.42	0.14	60'0	0.24
в	9	60/0	140	0.17	0.09	0.24
adx;	4	0.11	0.42	0,14	0.09	0.24
9 JO	8	60.0	0.41	0.17	60'0	0.24
-08	6	0.12	10.0	0,14	20.0	0.26
	-10-	010	16.0	0.14	60'0	0.26
	11	0.11	0.42	0.14	60'0	0.24
	12	11.0	0.42	0.17	0.09	0.21
	13	0.11	0.43	0.14	0.11	0.21
	14	11:0	0,42	-0.12	0.11	0.25
	15	0.13	0.41	0.10	0.10	0.26
	Stim	1.63	6.28	2.12	1.36	3.61
1	Average	0.11	0,42	0.14	0.09	0.24
	Weight	11.0	0.42	P.1.9	0.09	0.24
	Ranking	7	1	8	41	2
	Factor		Safety		Priority Vector	Ranking.
SBS	Cast In-situ				0.41	F
	Precast				0.42	1
tinous	Continous Continuous				0.14	P
BC	Cast In-situ Precast				0.09 0.24	N N

Calculation Sheet

### APPENDIX D

### CALCULATION SHEET

### FOR SUPER STRUCTURE SELECTION

					Structured Ny	Structural System Comparison of "Expert No.1"	of "Expert No.	+					
Factory	Straffpriger Ste Cenderin	in Cast	100	Stafety	Envirotreental				Multiply	ath your	Priorities Vactor	Multiply Matrix	Divide
ste of project	1 1	5	I.	-	-		a.		110	0.83			613
Site Condition		21	101	_,	-		q	171	100	0.00			0.1
Con					~		đ		115.00	1.20			0.
Lines and Mandal		20					-	2010	10-1	100	010		
Destronmental			-		-		1	0.67	160	100		100	
					ſ		propation		Sam	0.60			104
												A must be	979
	Factor	unds	Spin by Spin (SBS); Presau	Preisit	Span by Spin (S	Span by Spin (SBS), Cait In Situ			Mideply	utit roce	Priorities Vestor	Multiply Matter	Evide
	Sare of motors	Over Bead	Under Stass	Crime Liffing	Overhead OASS)	Trondey (M88)	Rt.						
	Over Head	1	1		- 0	-		111	45,00	1881	020	1.96	1815
SILS PREICAST	Tooler Strong	-		n			Ľ		00%	1.41		141	41
	Cone Lifting	NN NN	10	-	14	14	1	000	000	11.0	0.07	100	
SHE CAST IN STU	Overlight A355				-		8	NAME.	80.	100		0.00	
	CONTRACTOR DOOL		-					11100	Sun	101		1035	8
							l,					A ment	501
	Pactor	Theng	Ipen by Spin (SBS); Pressie	Pressie	Span by Span (S	Spen by Span (SBS); Cart In Sin-			Acadephy	inth root	Priorities Vector	Multiply Matrix	làvide
	Propert Citeria	Over Band	Upder Story	Cruse Liffing	(Netheral (MSS)	Detroiting (MSS)	81						
The summer of	Over Haud	1	61	10. 10.	-	-0		141	DADO	760	510	580	24
INTER OF	Condition Strains		.,				t	100	DOUCH				
the state bank	Overhead MISS	10	115	13	-	-	5	116	100	0.49			8.7
302 0440	Understany MISS	10	67	10	-1-	-		010	0.04	0.38			1
							- undeputyte		Sum	2019	001		19
												- New Y	
	Pactor	undy	by Speci (1915), Prepart	Pictori	Spen by Spen (S	Span by Span (SBS), Cast In Stitt			Matoply	oils root	Prioritigs Vector	Multiply Many	Devide
	Cont	OverHad	Under Stim	Unite Liffing	Orether MSS)	Understang (MSSO	NR.						
	Over Haad	1	10	13	101	1/1		144	000	0.41			
SISS PRECAST	Under Sling			n		n	۵		20.15	2,00			
	Crane Liffing	-	101	-	-	-	1	9010	15	601			*.
585 IN-SITU	Overhead MSS Findershare MSS		20			1	E.	11.08	8.6	100	810	0.90	200
									Sent	5.60			18
												- mark	

	Fades	Span	Spen by Spen (SBS): Prenat	Presset	Span by Span 1St	Span by Span (SBS), Cast in Situ		Mutuply	tada reat	Priorities Vector	Mudupty Mann	Divide
	Test	Over Head	Under Stung	Crass Lifting	Create of MSSI	Underland (MSS)	12			j		1
	Over Head	1	T		1	0		111 134.00				6.09
SEG PRECAST	Under Sharp	13	1	1	5		D					161
	Crute Lifting	1/5	10	I	101	1/1	9	0.09 0.00		910 H		101
REA IN LITTLE	Overliesd MSS	10	101		1	-	UR.	620	13 0.83		0.73	10.5
WT SEAM COL	Underdung MISS	13	5/1		1	1	0	0.07 0.03		011		5.07
							- addressed	Sim	188	1001		26.92
											A DIAN -	\$30
	Eastor	100k	Span by Span (SBS), Prenet	Precast	Span by Span (S)	Span by Span (SBS), Cart in Situ		Multiply	ufb reot	Priorities Vector	Multiply Matrix	Divide
	Safety and Bealfi.	Over Head	Under Sung	Creek Lifting	Overhead (0488)	Underland (MSS)	II					
	Over Head	-	1/3	-1	E	1	-	0051 [11	0 1.5	7. 026	152	2015
SEE WEICAST	· Under Sharg			ŵ5	5		5	114.00		100 22	1256	632
	Crast Lifting.	1/5	115	1	10	10	9	010 0.00			0,27	104
COL IN JUST	Overhead MSS	10	115	0	-	1	5	0.1		610 013		857
With the state	Cudenting MSS	1/1	1/3	'n	1	1	0	0.09 0.3	10.0	10 015		538
							avergueda	15	State 6.08	8 1/00		26.92
											Amin	高か
	Fader		Speed by Span (SHS)	(8)	Span by Span (SIS), Cart In Situ	<b>ISE: Cart In Situ</b>		Maldply	nth rest	Priorities Vector	Multiply Marin	Divide
	Environmental Impact	Over Head	Under Stang	Grant Lifting	Original MSRI	Or = 10,0889 - United ag (0885)	12					
	Over Head		1/3		F	2		LII - 9.00	0 1.44			1.5
SBS PRECAST	Under Slang		-			-	c	0075E1		039	2.48	255
	Craot Lifting	101	10	T	1	1	9	010 010				2.9
TTTO NUMBER	Overhead MSS	63	30	T	4	5	10	070	0.0		0,72	653
and the second second	Underdung MSS	NA.	10	1	10	1	0	0.09 0.0		010 010		24
								2mg		M 100		20.02
											4 0000	901

Factors	Size of project	Site Condition	Cost	Time	Safety,	Envirormental			Multiply	nth root	Multiply nth rost Priorities Vector Multiply Matrix	ultiply. Matrix	Divide
Size of project	-	ĸ	5	n	13	1/3		RI	3.00	1.20	0.18	1.24	6,88
Site Condition	(/3	1	1	-	1/3	1/3		123	0.01	0.48	00'0	0.53	6.13
Cost	1/3	1	1	-	-	1/3		đ	11:0-	0.69	010	0.67	61.49
Time	1/3		-	1	-	1/3		0.11	10.0	0.69	010	0.67	6.49
Stafety	£			-	I	1		C.K	00'6	1471	0.22	1.53	2.10
Environmental	3	10	5		1	1		0.09	81.00	2.08	0.31	1.95	6.26
						5		accriptable	Sum	6,69	1.00		39.35
												A HEAN	6.56
				1000					104.00				
	Sate of project	or roject	Spin by Spin (SHS) Cast In-stu Precas	Precial	Continuous	Cast lo-situ Precast	Precast	RL	Matthew	nth root.	Multiply ain root Priorites Vertor Multiply Matrix Divide	stippy Matrix	Divide
51	Cast In-situ	t-sitti	5	1/5	-1		-	1/20	0.20	0.76	0.13	0.61	4.76
ØS	Freest	tel	*	-	M	40.		5	625.00	202	0.49	3.05	0.23
	Continuous	TUMB	-	1/5	1	1	~	0.01	0.20	0.76	0.13	0.61	4.76
69	Cast In-silu	-sthi		1/5	-	1.1	-	CR	0.20	0.76	0.13	0.61	4.76
BK	Precisel	ter l	_	1/2	-	-	4	0.01	0.20	0.76	0.13	0.61	4.76
								seceptable	Sum	5.98	1,00		25.20
												- X ITLAX -	5.06
	Factor Site Condition	tor diffion	Spaciby Span (SBS) Cast In-ettu. Precia	nn (SBS) Preciat	Continuous	Balance Cantilever (BC) Cant In-stru Precasi	Preciat	RI	Mahiphy	nth root	Multiply alli root Priorities Vertor Multiply Mairry. Divide	dtiply Matrix	Divide
58	Cast Desity	-aitu	-	103	-	1	1/3	1.20	0.07	0.61	0.11	0.50	4,67
1S	Freet	No.	-	-	5	5	-	D.	375.00	2.69	0.45	2.78	614
	Continuous	snam	1	1/5	-1	1	-	0.05	0.20	0.76	0.13	0.64	16 N
2	Cast In-stitu	1-stitu	1	1/5	I	1	113	CH	10.02	0.64	0.11	0.50	4.67
в	Prenast	list	275	1/3	1	8	_	0.04	3.00	1.20	0.20	1.13	5.56
								acceptable	Sum	5.92	1.00		25.98
											1	A nuex =	5,20
j	Factor	ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar an ar	Span by Span (SBS)	tan (SBS)	Continuous	Balance Cantilever (BC) Cost to dia Diserver	Phone	10	Multiply	nth root	Multiply allt root Priorities Vector Multiply Mains. Divide	dtiply Matrix	Divide
s	Cast In-site	-sini	I I	1/1	-	T	2/1	1.30	0.07	0.64	0.11	C5.07	12.1
HS	Precisel	X				*		5	225.00	140	0.43	95.0	6.06
	Continuous	1000B		1/3	-	-1	-	0:05	0.33	0,83	41.0	0.72	A.965
2	Cast In-situ	t-sitta		1/3	1	-	1/3	CR	0.07	0.64	011	0.52	111%
EI.	Freeast	Deft.	1	1/8	1	1	-	0.04	3.00	1.20	0.21	1.16	5,56
								accoputed	Sum	5772	1.60		26.00
							1					- A DIRK =	3/20

Divide	4.67	6.13	5.24	4.56	9	11	527	Divide	60'5			44)	5.81	26,60	5.32	6	Divide		0		54		5.66	25,79	\$15
iply Matrix	0.50	256	0.74	0.41	1.40		A HINK =	iply Matrix	0,66	2.58	0.71	0,33	THE		A ITEN =		iph Matrix		0.50	1.59	0.56	0.50	1.39		A TTEAV -
Multiply nth root Priorities Vectur Multiply Matrix Divide	11.0	0.42	0.14	60'0'	0.24	1.00		Multiply nth root Priorities Vector Multiply Matrix Divide	51.0	0.41	0.14	10.0	0.24	1,60			Multiply infitred Priorities Vector Multiply Matrix Divide		0,11	0.42	21.0	0.11	0.25	1.00	
thread Prior	0,64	247	0.83	0.53	1,44	16'5		th root Prio	0.76	141	0.83	044	141	565			firrout Prio		0.64	141	0.60	6910	1.44	5.88	
Multiply n	0.07	225.00	0.33	20:0	9.00	Sum		Multiply n	0.20	225.00	0.33	10.0	9:00	Sum			Multiply n		000	225.00	0.11	0.02	9.00	Sum	
RL	1.20	ы	0.07	CR	0.06	acceptable		81.	1,20	CI.	0.08	CR	0.07	acceptable				RI.	1,20	CI.	0.04	SR.	0.03	acceptable	
Precisi	1/3	-	1/3	13	1			ever (BC) Precast	1/3	÷	13	1/3	4		Ì	7	tiver (BC)	Precast	13	*	14	13	1		
Balance Cantilever (BC) Cast In-situ Precast	.1.	.5	F	ī	3			Ealance Cantilever (BC) Cast In-situ Precasi	3		NS	1	æ				Balance Cantilever (BC)	Cast hesitu	-	m		1	5		
Continuous	-1	10	1	1/5	3			Continuous	1	F	1	E/T	3				Continues		4	eri	1	-	1		
m (SBS) Precast	1/5	1	1/1	1/5	1/3			si (SBS) Precast	1/2	4	13	14	13				ai (SBS)	Precast	115	1	1/3	115	13		
Span by Span (SBS) Uast In-situ Preca	1	5	-	-	1			Span by Span (SBS) Cast Ineitu Preca	.1	5		1/3	3				Span by Span (SBS)	Cast In-situ	- 0	*		1.0	3		
Tinic	Cast In-situ	Precast	Continuous	Certheith	Processi			Factor	Cast Invetor	Proceed	Contributions	Cast Institu	Precisel				Factor	Environmental Impact.	Cast In-situ	Procast	Continuous	Cast Inveitu	Procasi		
	SE	15		n	a				S	as		2	H						SE	IS		0	9		

### Comparison of factors with respect to overall satisfaction with

Factor	Size or pro	Sile Condin.	lin 2	6	Health and	tions afer	Anuthy Internet	nis root	Priorities Vor	Mulipity Man	Dhide Tar
01 C - 1-2				Tuno		E.	Ma		200	200	õ
Size of project	1	3	1	1	1	÷.	3.00	1,20	0.19	1.15	6.10
Site Condition	1/3	1	1/5	1/5	1	1	0.01	0,49	0.08	0.54	7.0
Cost Time	1	5	1/3	3	÷.	T.	15.00	1.57	0.25	1.65	6.6
	i.		113		1	1		1.09			6.5
Health and Sufety Provincemental Immunt	1	4	1	1	1	1	1.00	1.00	0.16	1,00	6.3
Environmental Impact	4	£.	4	4	1	1		1.00	1.00	1.00	6.3 39.1
							Sum	6.35			
R.I Questionnaire No. <u>1</u>		C.I =		C.R. =	0.09 [4	accepti	able		•	max =	0.3
Questionnaire No.1	Action	by : Expe	rtise No		14	6					
Questionnaire No.1 Factor		by Expe	ertise No	Tune	Hould and	Earloom.	Maligny.	ath relat	Prioritor For	Muldary Mar	Divide
Questionnaire No.1 Factor Size of project	Action States	by Expe	stise No	w Time	14	a Earloun	Multiply Prints 123.00	2.50	Dionities Form	son Stoppy 226	Divide Var
Questionnaire No.1 Factor Size of project Site Condition	Action	by Expe	stise No	time time	Hould and	- ~ Earlonn	<sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup> <sup>10</sup>	2.50 0.58	Piones For	100 100 100 20 22	19 9 Dirds
Questionnaire No.1 Factor Size of project Site Condition Cost	Action	Loo allo	5 5 3 1/3 1	a Jame	w Hould and	~ Earloan	<sup>10</sup> hdun (hunor) 243.00 3.00	2.50 0.58 1.20	0.37 0.18	400-410 410 10 2.26 0.52 1.28	Pro Print 6 10 7.2
Questionnaire No.1 Factor Size of project Site Condition Cost Time	Action 2000 2010	by Expe	stise No 3 1/3 1/3	om <sub>1</sub> n 13 n 1	w w Reality and	w w Entime	<sup>10</sup> Noting Insurant 243.00 3.00	2.50 0.58 1.20 1.20	0.37 0.09 0.18	<sup>50</sup> 2.26 0.52 1.28 1.19	<sup>45</sup> 6.10 7.2 6.7
Questionnaire No.1 Factor Size of project Site Condition Cost Time Health and Safety	Action Action 1 1/3 1/3 1/3 1/3	Joon July 3	s 3 1/3 1 1/3 1	ong 3 13 3 1 1/3	1 to to Health and	$w = - w t_{a_1 t_{a_2}} w_{a_2}$	<sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup> hdun <sup>13</sup>	2.50 0.58 1.20 1.20 0.83	0.37 0.18 0.12	<sup>50</sup> 2.26 0.52 1.28 1.19 0.78	15 95-10 6,10 6,10 7,2 6,7 6,7 6,7 6,7 6,7 6,7 6,7 6,7 6,7 6,7
Questionnaire No.1 Factor Size of project Site Condition Cost Time	Action 2000 2010	by Expe	stise No 3 1/3 1/3	om <sub>1</sub> n 13 n 1	w w Reality and	w w Entime	<sup>10</sup> Noluti Insurant 243.00 3.00	2.50 0.58 1.20 1.20	0.37 0.09 0.18	<sup>50</sup> 2.26 0.52 1.28 1.19	6.55 6.10 6.10 7.2 6.11 7.2 6.3 6.11 38.70

#### Comparison of factors with respect to overall satisfaction with

Factor	Stin of Bar	Sile Coart	hage		Health and	ton.	Multiply	bor	Priorities Lon	"phy. Adar.	400. 170
	Suco	Sile	Gay	Timo	Heat	Enry	Aug	Inter Ant	Phio	Mul	Diride
Size of project	1	3	3	3	3	3	243.00	2.50	0.37	2.26	6.12
Site Condition	1/3	1	1/3	1/3	1	1	0,04	0.58	0.09	0.53	6.20
Cost	1/3	3	1	3	3	1	9.00	1,44	0.21	1.42	6,64
Time	1/3	3	1/3	1	1/3	3	0.33	0.83	0.12	0.87	7.07
Health and Safety	13	1	1/3	3	$\mathbf{r}$	1	0.33	0.83	0.12	0.86	0.96
Environmental Impa	ct 1/3	1	1/3	1/3	1	λ.	0.04	0.58	0.09	0.53	6.20
							Sum	6.76	1.00		39.19
		12.2	1.44	0.0							
1.56		C.I = by : Exp	0.11 ertise No	C.R. =	0.10	accept	iah le	_			
1.1.26	Action	by : Exp	ertise No	4	.12	2		au an	Priority Voc	Muliply Mar	Diride
<u>Questionnaire No. I</u> Factor		by : Exp	ertise No			2	able vandoh nibaci ala ta	1000 the 173	12 Priorition Von	25 Malapit Mar	29 Divide
Questionnaire No.1 Factor Size of project	Action	She Court	ertise No	Tique V	Health and	Eavinger Steer	Malifoly.	1000 Http 1.73 0.53	0.27 0.08	0.58 1 Muliphy Man	6.65
Questionnaire No. I Factor Size of project Site Condition	Action	w She Contr	ertise No	u line	- Reality and	- Environ	100 Wallings	1.73	0.27	1.82	6.69
Questionnaire No.1 Factor Size of project Site Condition Cost	Action	Bile Coart	ertise No	E time	Neally and	Entrinon	vanana hanar	1.73 0.53	0.27	1.82 0.58	6.65 6.90 6.7:
Questionnaire No.1	Action	to Contraction	ertise No Mo 3 1/5	1 2 2 12 1	Reality and	Entrinon	<sup>tonetlar</sup> <sup>tolog</sup> ing y 27,00 1,67	1.73 0.53 1.09	0.27 0.08 0.17	1.82 0.58 1.15	6.65 6.90 6.72 6.20
Questionnaire No.1 Factor Size of project Site Condition Cost Time	Action	by: Exp	trong 3 1/5 1	1 1 2 2 1 1 1	Reality and	Entition	<sup>tontun</sup> <sup>tontun</sup> <sup>tontun</sup> <sup>tontun</sup> <sup>tontun</sup> <sup>10</sup> 27.00 1,67 1,00	1.73 0.53 1.09 1.00	0.27 0.08 0.17 0.16	1.82 0.58 1.15 0.99	5 994 6.69 6.72 6.26 6.35 6.35

R.I. = 1.11 C.I. = 0.11 C.R. = 0.10 acceptable

 $\lambda \max = 6.55$ 

Comparison of factors with respect to overall satisfaction with

Factor	Size of Pro-	She Coader	bon		Health and	Tons and	Multiply.	m	Printing Par	Anulanty Ann	424 P
_		Site		Time	Heal	tan	Aun	nd tool			
Size of project	1	3	3	3	3	3	243.00	2,50	0.36	2,28	6.35
Site Condition	1/3	1	3	3	3	3	27.00	1,73	0.25	1,54	6.20
Cost	1/3	1/3	Ф	1/3	1	1	0.04	0.58	0.08	0.51	6.20
Time	1/3	1/3	3	1	1/3	3	0.33	0.83	0.12	0.82	6.8
Health and Safety	1/3	1/3	1	3	1	1	0.33	0.83	0.12	0.83	6.90
Environmental Impact	1/3	1/3	1/3	1/3	1	1	0.01	0.48	0.07	0.46	6.6
							Sum	6.95	1.00	max=	39.19 6.5
B.T.				A 10	0.00	neen	ash la				
R.L =	- 1.11	C.L=	0,11	C.R.=	0.10	accept	uione				-
K.L = Questionnaire No.1		C.L =			10	)					
	Action	by : Exp	ertise No	<u>).</u>	10	)		autroa	Priorities Ver	Multiply Man	Divide
Questionnaire No.1		by : Exp	ertise No			)	<sup>1) Bedding</sup> <sup>(fid)</sup> Im <sub>2</sub> y 243.00	1000 Hig 2.50	20 Palania Vec.	22 Maliphy Man	
<u>Questionnaire No.1</u> Factor	Action	Sile Condi:	Cost.	Time	Health and	Environ-	Malifiers.		0.09	401 401 100 2.26 0.56	6.1
Questionnaire No.1 Factor Size of project	Action Action	She Condition	ertise No	u Tiano	w Health and	w Environmenter	<sup>10</sup> eelley inuumer 243.00	2.50	0.37	2.26	6.1 6.5
<u>Questionnaire No.1</u> Factor Size of project Site Condition	Action 2010 1/3	by: Exp	ertise No 001 3 1/3	onitz 3 1/3	- w Health and	- ~ Entition	<sup>londing</sup> intuoring 243.00	2.50 0.58	0.37 0.09	2.26 0.56	6,1 6,5 6,5
Questionnaire No.1 Factor Size of project Site Condition Cost	Action 4 4 4 4 4 5 5 1 1/3 1/3	by: Exp	ertise No So 3 1/3 1	000 iz 3 1/3 1/3	W Health and	w Environ	<sup>10</sup> nuluy <sup>4</sup> idinty 243.00 0.33	2.50 0.58 0.83	0.37 0.09 0.12	2.26 0.56 0.81	6.1 6.5 6.5 6.7
Questionnaire No.1 Factor Size of project Site Condition Cost Time	Action <sup>104</sup> / <sub>10</sub> <sup>104</sup> / <sub>10</sub> <sup>105</sup> / <sub>10</sub>	by: Exp	ertise No 00 3 1/3 1 3	0 iz 1/3 1/3 1/3	10 Hould and 10	w w Environ	<sup>londing</sup> introduct 243.00 0.04 0.33 3.00	2.50 0.58 0.83 1.20	0.37 0.09 0.12 0.18	2.26 0.56 0.81 1.19	<sup>4</sup> brild 6.10 6.50 6.70 6.11
Questionnaire No.1 Factor Size of project Site Condition Cost Time Health and Safety	Action 4 4 5 5 5 5 1 1/3 1/3 1/3 1/3	by: Exp	ertise No 3 1/3 1 1	august 1/3 1/3 1/3 1/3 1/3	10 10 10 10 10 10	w w w Environ	<sup>kontun</sup> <sup>kidi</sup> lmuy 243.00 0.04 0.33 3.00 3.00	2.50 0.58 0.83 1.20 1.20	0.37 0.09 0.12 0.18 0.18	2.26 0.56 0.81 1.19 1.25	6.10 6.5 6.5 6.7 7.0

Comparison of factors with respect to overall satisfaction with

Factor	Stre or arou	Sine Condina		10	Health and	Eavingmonday.	Multiply - Jupice	ath roat	Printing Very	Muliply Man	Dinde
Size of project	1	Sin	1	- fime	140	2	1.00	1.00	0.16	1.00	6.18
Site Condition	1	ī	1/3	1/3	1/3	1/3	0.01	0.48	0.08	0.49	6.3
Cost	1	3	1	1/3	1/3	1/3	0.11	0.69	0.11	0,72	6.43
Time	1	3	3	1	1/3	3	9.00	1.44	0.23	1.46	6.27
Health and Safety	1	3	3	3	1	1.	27.00	1.73	0.28	1.85	6.59
Environmental Impact	I	3	1/3	1/3	1	1	0.33	0.83	0.13	0.93	6.87
							Sum	6.18	1.00		38.65
									λ	max =	6.45
R.I. =	1.11	C.1. =	0.09	C.R.=	0.08	acceptab	le				

Factor		5	5			areas	al Impace			tot	17
	Step of Prov	Site Contine	Cost	Time	Health and	Earingane	Anuliply.	nut root	Priorities Ver	Muliply Man	Diride
Size of project	1	1	1/3	1/3	1	1	0.11	0.69	0.11	0.69	6.38
Site Condition	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.08	0.46	6.05
Cost	3	3	1	1/3	1	1	3.00	1.20	0.19	1.19	6.31
Time	3	3	3	T	1/3	3	27,00	1.73	0.27	1.85	6.83
Health and Safety	1	3	г	3	1	1	9.00	1.44	0.23	1.69	7.49
Environmental Impact	1	3	1/3	1/3	1	1	0.33	0.83	0.13	0.84	6.47
							Sum	6.38	1,00		39.54
									7	max =	6.59
R.I. =	1.11	C.I.=	0.12	C.R. =	0.11	іткассер	nable				

#### Comparison of factors with respect to overall satisfaction with

Questionnaire No.1	Action	by : Expe	rtise No	<u>.</u>	5	Fr <sup>1</sup>	_	_			_
Factor.	Seconda.	Sile Condin	Court 18	Time	Health and	Eavidementary	Autory Autor	Indi raci	Priorities Van	Muliply Man	Dinde, Tay
Size of project	1	1	1	1	1	)	1.00	1.00	0.17	1.00	5.86
Site Condition	1	1	1/3	1/3	4	1	0.11	0.69	0.12	0.77	6.50
Cost	4	3	1	1	1/3	1/3	0.33	0.83	0.14	0.99	7,00
Time	Ĩ	3	ī	ī	1/3	3	3.00	1.20	0.20	1.31	6.39
Health and Safety	1	1	3	3	1	1	9.00	1.44	0.25	1.69	6.88
Environmental Impact	1	1	1/3	1/3	1	1	0.11	0.69	0.12	0.77	6.50
							Sum	5,86	1.00		39.13
									7	. max =	6.52
R.1.	- 1,11	C.L=	0.10	C.R. =	0.09	acceptabl	le.				

Questionnaire No.1 Action by : Expertise No.

Sile Court	180	ling	Health and	Earlinganger	Mahing.	ALL POOL	Pointing Ver	Multiply Man	
		~	3	49	5	TEP .	00	Tula	Divide
1	1	1	1	1	1.00	1.00	0.17	1.00	6.03
1	1/3	1/3	1	1	0.11	0.69	0.11	0.71	6.16
3	1	1	3	1	9.00	1.44	0.24	1.56	6.53
3	1	1	1/3	3	3.00	1.20	0.20	1.35	6.78
1	1/3	3	1	1	1.00	1.00	0.17	1.24	7,47
1	1/3	1/3	I.	1	0.11	0.69	0.11	0.71	6.16
					Sum	6.03	1.00		39.12
			1.0				2	max =	6.52
	1 3 1 1	1 1 1 1/3 3 1 3 1 1 1/3 1 1/3	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	1       1       1       1       1       1.00         1       1/3       1/3       1       1       0.11         3       1       1       3       1       9.00         3       1       1       1/3       3       3.00         1       1/3       3       1       1       1.00         1       1/3       3       1       1       0.11         1       1/3       3       1       1       1.00         1       1/3       1/3       1       1       0.11         Sum       Sum       Sum       Sum       Sum	1       1       1       1       1       1.00       1.00         1       1/3       1/3       1       1       0.11       0.69         3       1       1       3       1       9.00       1.44         3       1       1       1/3       3       3.00       1.20         1       1/3       3       1       1       1.00       1.00         1       1/3       3       1       1       0.01       0.00         1       1/3       1       1       0.11       0.69         1       1/3       1       1       0.01       0.00         1       1/3       1/3       1       1       0.11       0.69         Sum       6.03       Sum       6.03       Sum       6.03	1     1     1     1     1     1.00     0.07       1     1/3     1/3     1     1     0.11     0.69     0.11       3     1     1     3     1     9.00     1.44     0.24       3     1     1     1/3     3     3.00     1.20     0.20       1     1/3     3     1     1     1.00     1.00     0.17       1     1/3     3     1     1     1.00     1.00     0.20       1     1/3     3     1     1     0.69     0.11       1     1/3     1     1     0.01     0.00     0.17       1     1/3     1/3     1     1     0.01     0.00     0.17       1     1/3     1/3     1     1     0.11     0.69     0.11       Sumu     6.03     1.00     1.00     1.00     1.00     1.00	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

Comparison of factors with respect to overall satisfaction with

Factor	Ster at	Sile Co.	radinan t	a.	Health and	Eavingane.	Anutipers.	auf root	Progines Ver	Mauliply Man	ide tot
61 - A - 1 - 1				Tune		En .	100				
Size of project Site Condition	1	1	1/3	1/3	1/3	1/3 T	0.01	0.48	0.07	0.45	6.24 6.45
	3				3	1	81.00	2.08	0.10	2.01	6.45
Cost		3	1	3	3	1					
Time	3	3	1/3	1	1	9 - S	3,00	1,20	0.18	1.14	6.34
Health and Safety	3	1	1/3	1	1	1	1.00	1.00	0.15	0.94	6.23
Environmental Impact	3	1	1	I	i	1	3.00	1.20	0.18	1.14	6.3
							Sum	6.65	1.00		38.0
R.I.	1.11	C.1.	= 0.07	C.R.=	0.06	accepta	ble		λ	max =	6.34

Factor		100	<sup>tio</sup>			Safery.	al lapace		Lon	10.	N.G.
	Size of Dr.	Site Condin	Cost	Time	Health and	Eavingano	Auluply	toos que	Priorities V.	Mulaply Man	Divide
Size of project.	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.08	0.46	6.00
Site Condition	1	1	1/3	1/3	1	1	0.11	0.69	0.11	0.77	6.98
Cost	3	3	1	1	1/3	1/3	1.00	1.00	0.16	1.06	6.70
Time	3	3	1	1	1/3	1	3.00	1.20	0.19	1.19	6.25
Health and Safety	3	1	3	3	1	Ť.	27.00	1.73	0.27	1.85	6.74
Environmental Impact	3	4	1	1	1	1	3.00	1.20	0.19	1,15	6.05
							Sum	6.31	1.00		38,72
R.I.	1.11	C.L -	0.09	C.R.=	0.08	accepta	ble		3	max =	6,45

Comparison of factors with respect to overall satisfaction with

Factor		Slocy in:	100.			Environment.	uni fupuci		Lan.	Man.	ŧ,
ž.	Slice or De	Sile Candin	Cost	Timo	Health and	Environm	Atulapy.	aut rout	Printing Veen	Muloply Man	Divide
Size of project	1	L	1/3	1	1	1	0.33	0.83	0.13	0.77	6.12
Site Condition	ı	P.	1/5	1/5	1	1	0.04	0.58	0.09	0.59	6.70
Cost	3	5	1	3	3	1	135,00	2.26	0.34	2,19	6.38
Time	1	5	1/3	1	1	1	1.67	1.09	0.16	1,13	6.83
Health and Safety	1	1	1/3	1.	1	1	0.33	0.83	0,13	0.77	6.12
Environmental Impact	1	1	1	1	1	1	1.00	1.00	0.15	1.00	6.60
							Suni	6,60	1,00		38.75
									λ	max =	6.46
R.I.	- 1.11	C.I. =	0.09	C.R. =	0.08	accepta	ble				

Questionnaire No.1 Action by Expertise No. 2

Factor	Stee of Proc	Sile Condin.	Gr.		Hoalth and	Earlingunger	tonday a		Priorities Par	Arulopy Ala	*In.
	Steod	Sile Co	Cost	Time	Hoalth	Earling	Muluph	aut root	Priorie	Mulap	Divide
Size of project	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.26
Site Condition	1	1	1/3	1/3	1	1	0.11	0.69	0.11	0,71	6.40
Cost	Ĩ.	3	1	3	3	I	27.00	1.73	0.28	1.81	6.53
Time	1	3	1/3	1	1	a	1.00	1.00	0.16	1.04	6.49
Health and Safety	1.	1	1/3	1	ũ.	1	0.33	0.83	0.13	0.82	6.13
Environmental Impact	1	1	1	Ĩ.	1	1	1.00	1.00	0.16	1.00	6,26
							Sum	6.26	1.00		38.06
R.I.=	1.11	C.I. =	0.07	C.R. =	0.06	acceptab	le		λ	max =	6.34

Comparison of factors with respect to overall satisfaction with

Factor		101 1	day.			Earlingane	dal lapage	ċ	0	-10,- 10,-	Ko.
	See of pro	Sue Condin.	Case	Timo	Health and	Environme	Multiply	toos you	Priorities Von.	Malaps Man	Dirido
Size of project	1	3	3	3	3	3	243,00	2.50	0.36	2.28	6.36
Site Condition	1/3	1	1/5	1/5	1	1	0.01	0.49	0,07	0.45	6.50
Cost	1/3	5	1	1	1	1	1,67	1.09	0.16	1.04	6.65
Time	1/3	5	1	1	3	3	15.00	1.57	0.23	1.42	6.28
Health and Safety	1/3	1	1	1/3	1	è.	0.33	0,83	0.12	0.75	6.25
Environmental Impact	1/3	1	1/3	1/3	1/3	í.	0.01	0.48	0.07	0.43	6.17
							Sum	6.96	1.00		38.21
									2	max =	6.37
R.L.	1.11	CL =	0.07	C.R	0.07	accepta	1.16				

Briterity Vector of Factor		SBS: PRECAST		SBS :: CAST IN-SITU	IN-SITU
NAME TO DO DO DO DO DO	Under Shing	Crane Lifting	Overhead MSS.	Underslung MSS	Precast
4	620	0.25	0.08	0.14	0.14
2	0.41	0,26	0.07	0.13	0.14
8	0.24	0.41	20.0	11.0	0.17
	0.31	0.31	0.09	0.15	0.15
*	0.26	0.37	0.12	0.10	0.15
0	0.27	0.39	0.12	0.08	0.14
r> odx;	0.26	0.41	0.11	60.0	0.13
8	0.26	0,44	0.10	0.08	0.12
.6	0.25	0.39	0.09	0.10	0.17
10	0.26	0.38	0.07	0.12	0.17
10	0.30	0.33	0.00	0.10	0.17
12	0.25	66.0	0.09	0.10	0.17
61	0.26	0.38	0.07	0.12	0.17
14	0.30	0.33	0.08	0.15	0.15
15	0.25	0,39	0.11	0,10	0.14
Sum	4,27	5,43	1.35	1.66	2 29
Average	0.28	0.36	0,09	110	0.15
Weight	0.28	0.36	0.09	110	0.15
Ranking	2	1	\$	4	9
Factor		Time		Priority Vector	Ranking
Over Head				0.28	2
Crane Lithing				0.36	- 10
Coverhead MSS Undershing MSS				0.15	* "

Calculation Sheet

- And	Section Second		SBS : PRECAST		SBS CAST IN-SITU	IN-SITU
Sino	Phonity Vector of Pactor	Under Slung	Crane Lifting	Overhead MSS	Understung MSS	Precast
	-	0.07	0.37	0/10	0.18	61'0
	2	0.07	15.0	0.19	0.15	0.28
	m	0.08	0.37	0.19	0.15	0.21
	7	0.08	0.31	0.20	0.15	0.26
	5	0.08	0.40	0.19	0.16	0.18
	0	0.08	0.37	0.10	0.15	12.0
	٢	0.07	0.25	0.39	0.14	0.15
H JF	s	0.18	0.31	0.31	60'0	0.12
	6	0,25	0:37	0.18	0.10	0.10
	10	0.27	0.36	0.17	0.09	0.10
	100	0.29	0,42	0.08	0.00	0.11
	12	0.24	0.444	0.09	0.11	0.13
	13	0.24	0,44	0.07	61.0	0.13
	14	0,26	0.41	0.08	21.0	0.13
	15	0.24	0.44	0.11	0.11	0.11
	Sum	2.50	5.57	2.63	1.90	2.41
	Average	0.17	0.37	0.15	0.13	0.16
	Weight	0.15	0.32	0.15	0.73	0.16
	Ranking	3	1	2	5	+
	Pactor		Cost		Priority Vector	Ranking
	Over Hend				21:0	
SBS	Under Slung Crane Lifting				0.37	1
SBS	Overhead MSS Undershine MSS				0.13	v2 •

		SBS : PRECAST		SBS   CAST IN-SITU	IN-SITU
FIIOTILY VECTOR OF FACTOR	Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
1	0.15	0.26	0.41	0.08	01.0
9	0.15	0.26	0.41	01.0	0.08
m	0.18	0.18	0.45	.60.0	0.10
4	0.24	0.15	0.42	0.09	01.0
S	0.21	0.22	65'0	0.08	01.0
Q	0.18	0.20	0,44	0.07	01.0
7	0.15	0.31	0,37	0.07	0.10
∞	0.18	0.21	0.44	0.07	01.0
0.0] Ø	0.20	0.20	0,41	0.07	11.0
10	0.19	0.20	0.42	0.07	0.12
11	0.18	0.18	0.47	0.07	0.10
12	0.19	0.21	0,44	0.07	0'00
13	0.19	0.20	0.42	0.09	01.0
14	0.15	0.24	0.44	60.0	0.09
15	0.18	0.20	0,44	0.07	0.10
Sum	2.73	3.24	6,36	1.19	1.48
Average	0.18	0.22	0.42	0.05	0.10
Weight	0.18	0.22	0.42	0.05	0.10
Ranking	3	2	1	5	+
Factor		Site Condition		Priority Vector	Ranking
Over Head				0.18	5
Crane Lifting				0.22 0.42	2
Coverhead MSS Understung MSS				0.08	40 <del>+</del>

in a start of the second	Del selet Mantes of Dartas		SBS : PRECAST		SBS : CA	SBS : CAST IN SITU
nomy vec	IOI OI L SPICOL	Over Head	Under Shung	Crane Lifting	Overhead MSS	Understung MSS
_	1	0.33	0.26	0.07	0.16	0.18
	ы	0.32	0.32	0.06	0.15	0.14
	ę	0.32	0.32	20:0	0.14	0.14
	4	0.36	0.32	0.06	0.12	0.12
	s	0,34	0.31	0.06	0.15	0.14
112	9	0.36	0.36	0'00	0.11	0.11
dvs	4	0.32	0.32	0.07	0.14	0.14
1 10	80	0.27	0.38	20.07	0.14	0.14
0.01	6	0.32	0.32	0.07	0.12	0.17
J	10	0.31	0.31	0.09	0.15	0.15
	11	0.30	0.35	0.08	0.13	0.13
	12	0.31	0.37	20/0	0.10	0,15
	13	0.25	0.39	0.08	0.14	\$E.0
	14	0.30	0.33	60'0	0.10	21.0
_	15	0.24	0.42	0.09	0.11	0.14
Su	Sum	4.66	5.09	1.09	1:98	2.18
Ave	Average	0.31	0.34	0.07	0.13	0.15
We	Weight	0.31	0.34	0.02	0.13	0.15
Ran	Ranking	5	1	*	4	3
_	Factor		Size of Project		Weight	Ranting
-	Over Head				16.0	7
Prec Cran	Under Slung Crane Lifting				0.34	- Vî
utik-ni Under	Overhead MSS Understung MSS				0.13	4

Su	Local Pector of Factor	is of biolect	Condition	15	30	Man pur So	ההששטופן נשלאכו
1	-	013	000	CC 034		58 013	45 015
		0.16	11.0	0,28	0.16	0.13	0.16
	10	0.07	010	0.31	0.18	0.15	0.18
		0.08	0.11	0.16	610	0.27	0.19
	N.	0.17	21.0	4T.0.	0.20	0,25	0.12
	6	0.17	11:0	0.24	0.20	0.17	11.0
	5	0.16	0.08	0.11	0,23	0.28	0.13
	20	0.11	80/0	0.19	0.27	0.23	0.13
	.6	0.36	0.25	80.0	0,12	0,12	0.07
	10	0.37	60/0	0.12	0.18	0.18	0,07
	0.	0.37	60'0	0.21	0.12	0.12	0.09
	12	0.27	0,08	71.0	0.16	0.16	0.16
	13	61.0	80/0	0.25	6.17	0,16	0.16
	14	0.37	0.09	0.18	0.18	0.12	0.07
	15	0.36	0.07	0.16	6.23	0.12	0.07
	Sum	3.33	1 53	2.94	2.76	2.58	1.86
-	Average	0.22	0.10	0.20	0.18	0.17	0.12
	Weight	0.22	0.10	0.20	0.18	0.17	0.12
-	Ranking	-	9	2	3		10

<u>Calculation Sheet</u> Commuteon of factors with respect to overall satisfaction

The second second	Wanters of Desires		SES PRECASI		SBS: CAST IN-SITU	IN-SULO
Amon.4	FIDORY VOLUM OF FREIOL	Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
		0.26	10.01	0:00	0.13	0.15
	.61	0.25	0.39	0.07	0,14	0.15
	17	0.25	0.30	0.07	9.1.0	0.15
	4	0.24	14.0	0.07	0.14	0.13
	5	0.27	0.38	0.07	0.14	0.14
11:	.9	0.25	0.37	0.10	0.10	0.18
dx;	7	0.25	0.39	0.11	0.10	11.0
I.F	-90	0.27	0(30	0.10	01.0	11.0
5 '01	6	0.17	0(30	0.08	0.15	0.21
y	10	0.20	0.42	60.0	60'0	0.20
	11	0.26	0.37	0.10	0.12	0.15
	12	0.33	0.31	60'0	0.12	0,15
	13	0.26	0.38	0.07	0.12	0,17
	14	0.25	0.39	0.09	0.12	ALO.
	15	0.25	0.39	0.11	0.10	0.14.
	Sum	3.76	5.78	1.29	1.81	2.36
	Average	0.25	0.39	0.09	0.12	0.16
	Weight	0.25	0.30	0.09	0.12	0.16
	Ranking	2	1	S		Ð
	Factor		Safety		Priority Vector	Ranking
	Over Head				0.25	2
SBS	Under Slung				0.39	-
	Crane Lifting				0.09	\$
Sas	Overhead MSS Underslung MSS				0.12 0.16	* *
					1.00	

#### VITAE

Miss ThiparatThoothongEuapunpong was born on July 29, 1979 in Huasai district, Nakornsrithammarat Province, Thailand. She finished her elementary school and high school fromHuasaibumrungrat School. She spent 4.5 years to finish her bachelor degree in civil engineering in 2003, after that she worked in VSL (Thailand) Co.,Ltd.