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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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ทิภารัตน์ ถือทอง เอื้อพันธุ์พงศ์: การเลือกวิธีการก่อสร้างสะพานคอนกรีตแบบแยกส่วนในประเทศไทย: 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.ดร.นพดล จอกแก้ว, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ.ดร.ธนิต ธงทอง, 151 หน้า.

การออกแบบสะพานและเทคโนโลยีในการก่อสร้างได้ถูกพัฒนาอย่างรวดเร็วในทศวรรษที่ผ่านมา และถูกถ่ายทอดสู่วิศวกรอย่างแพร่หลาย แต่การตัดสินใจเลือกเทคนิคการก่อสร้างพื้นสะพานยังจำเป็นต้องใช้วิศวกรผู้ชำนาญการเฉพาะทางในด้านเทคนิคการก่อสร้างขั้นสูง ในการศึกษานี้ได้ประยุกต์วิธีการของกระบวนการลำดับชั้นเชิงวิเคราะห์ (Analytical Hierarchy Process: AHP) ในการพิจารณาปัจจัยที่ใช้ในการตัดสินใจเพื่อเลือกวิธีก่อสร้างพื้นสะพานประเภทชิ้นส่วนคอนกรีตสำเร็จรูปที่เหมาะสมสำหรับประเทศไทย โดยใช้โครงการก่อสร้างรถไฟฟ้าสายสีม่วง (สัญญาที่ 2) เป็นกรณีศึกษา โดยศึกษาการก่อสร้างพื้นสะพานและขั้นตอนของการเลือกเครื่องมือที่ใช้ยกอย่างเหมาะสม

จากผลการศึกษาพบว่าปัจจัยสำคัญที่ส่งผลต่อการตัดสินใจถึงการเลือกวิธีก่อสร้างที่เหมาะสมมี 6 ปัจจัย คือปัจจัยขนาดของโครงการ ปัจจัยเงื่อนไขของหน่วยงานก่อสร้าง ปัจจัยต้นทุน ปัจจัยด้านเวลา ปัจจัยทางด้านสุขภาพและความปลอดภัย และปัจจัยด้านผลกระทบต่อสิ่งแวดล้อมผลการประยุกต์ใช้ปัจจัยดังกล่าวในการเลือกระบบการก่อสร้างพื้นสะพาน 5 ระบบและเครื่องมือยก 12 วิธี กับโครงการกรณีศึกษาพบว่าระบบการก่อสร้างพื้นสะพานที่เหมาะสมคือ ระบบการก่อสร้าง Span-by-Span และเครื่องมือยกที่เหมาะสมคือ Under Slung Gantry

ภาควิชา วิศวกรรมโยธา ลายมือชื่อนิสิต……………………………………………….
สาขาวิชา วิศวกรรมโครงสร้างพื้นฐาน ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก……………………
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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.

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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.

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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, 2nd 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.

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

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 2.2: The Details of Each Project

Item	Projects	Total Distance (km.)	Number of (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

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.

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

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	

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

Table 2.4: Important Factors behind the Selection of the Suitable Construction Method by Youssef (1987)

Item	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

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.

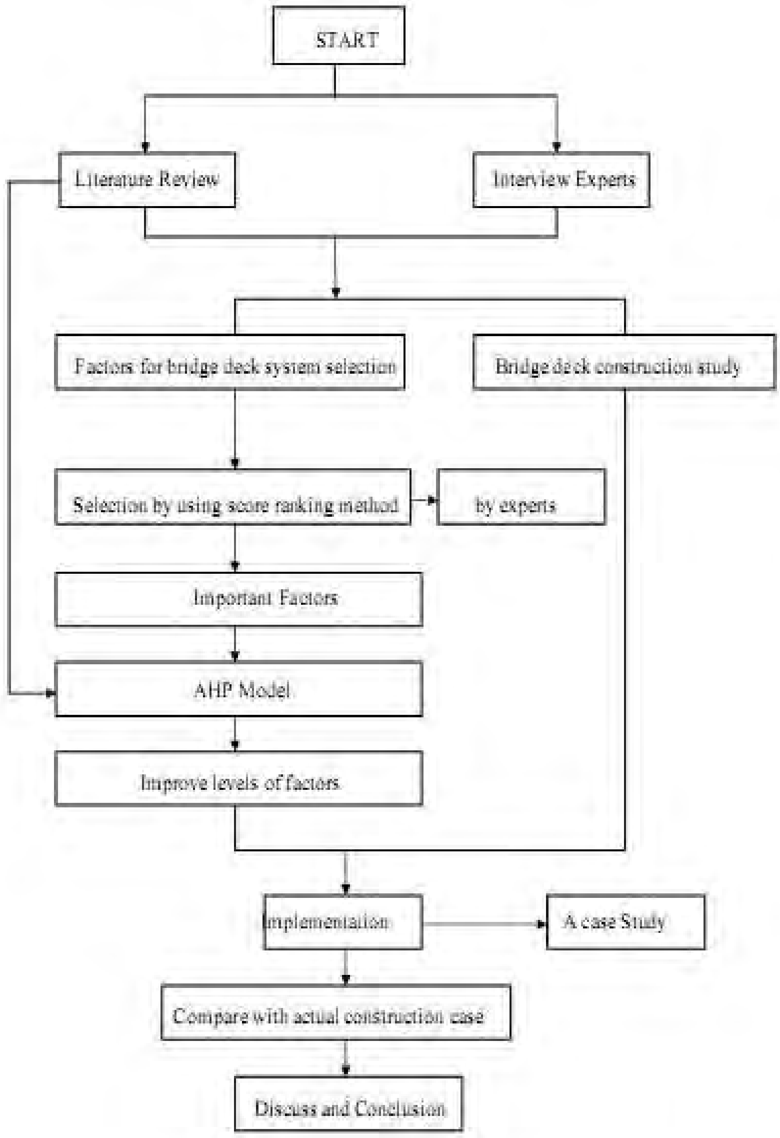

Figure 3.1: Research Methodology Flowchart

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 (person)	Main Contractor (person)	Sub Contractor (person)	Total (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;

Table 3.2: Example of Scoring Method

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	

Table 3.3: Example of Average Score of Factors

		A	B	C	D	E	F	G
	Factor	Very disagree	Disagree	Unprejudiced	Agree	Very agree	Total Experts (N)	Everage
		1	2	3	4	5		
1	Factor A	2	3	5	2	3	15	3.07
2	Factor B	4	5	1	1	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	B	C	D	E	F	G	
	Factor	Very disagree	Disagree	Unprejudiced	Agree	Very agree	Total Experts (N)	Everage	Result
		1	2	3	4	5			
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 decision-making 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.

$$\begin{bmatrix} 1 & \cdots & a1n \\ \vdots & \ddots & \vdots \\ 1/a1n & \cdots & 1 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots. (3.1)$$

Table 3.5: Pair-wise matrix

The objective of comparison	Factor			
	A1	A2	→	An
A1	1	3	-	-
A2	1/3	1	-	-
↓			-	-
Factors: An	-	-	-	1

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

$$\sum_{i=1}^{n} aij = 1.0 \text{...} \quad (3.3)$$

When;

W_i	=	Rating weight of factors
V_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.

$$\lambda \max = \sum_{i=1}^{n}\left[\sum_{j=1}^{n} aij\ Wj\right] \text{………………}(3.4)$$

a. This case means the matrix is corresponding.

λ max = number of principles that were compared (n)

b. This case means the matrix is not corresponding.

λ max >number of main criteria that were compared (n).

Consistency Index: CI

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

When n = the number of criteria

Consistency Ratio: CR

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

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-by-span 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)

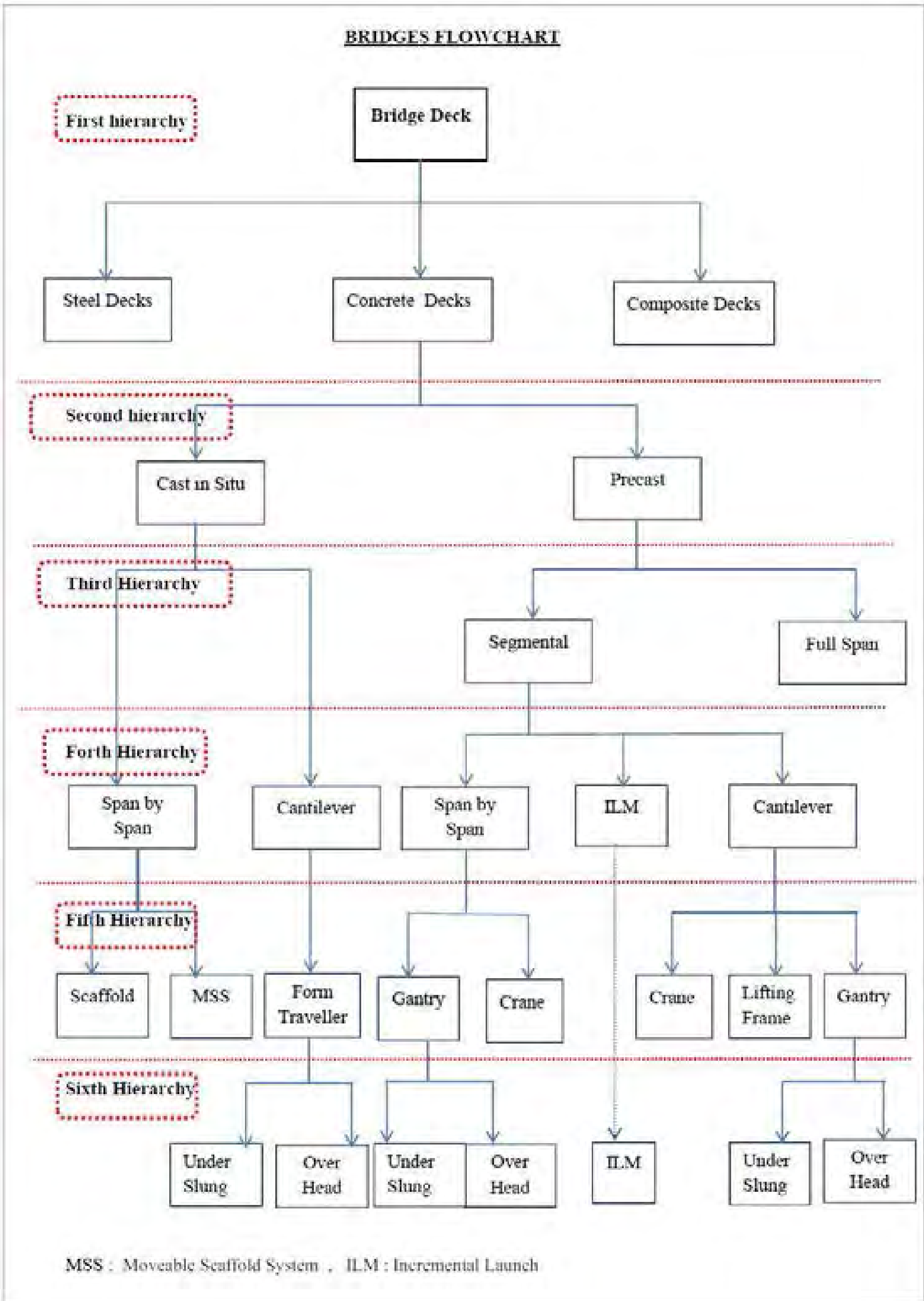

Figure 4.2: Bridge Type Category

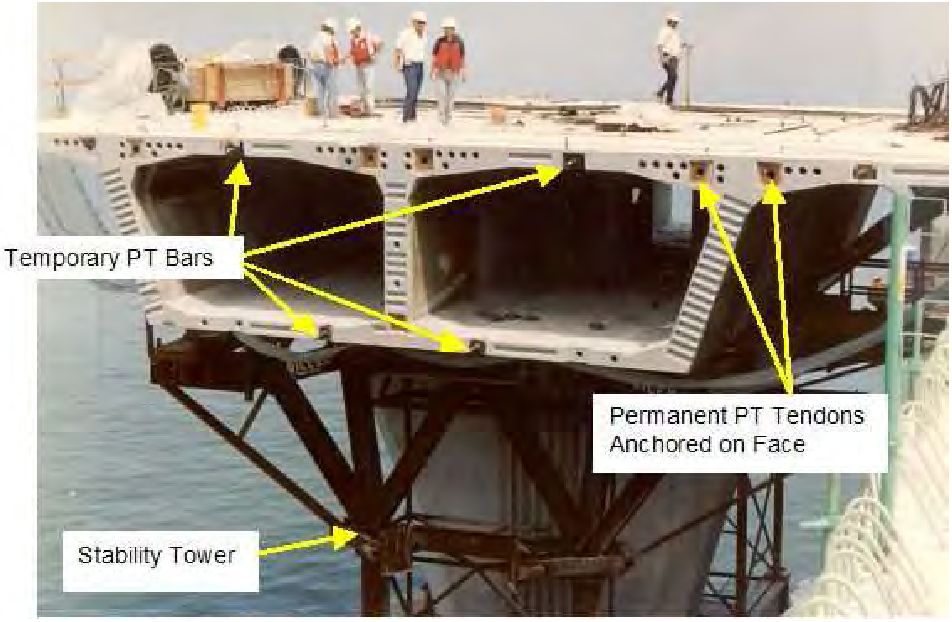

Figure 4.3: Concrete Segmental Details
Source: www.fhwa.dot.gov

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.

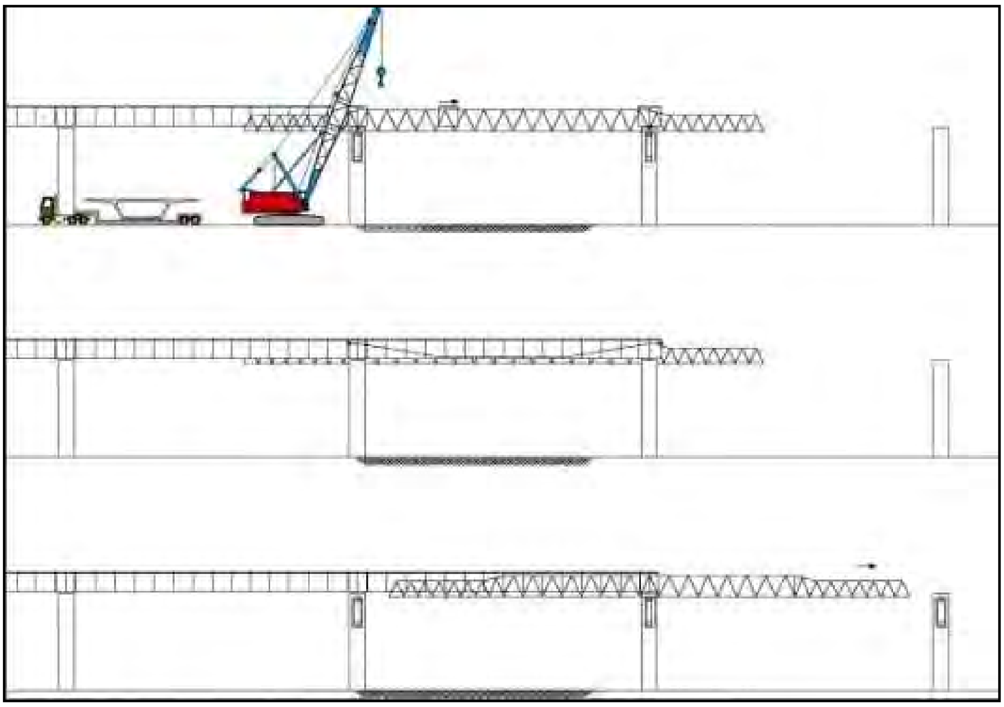

Figure 4.5: Span-by-Span Construction Sequence
Source: www.fhwa.dot.gov

Figure 4.6: The MSS Movable Formwork System
Source: www.Structurerae.com

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

The advantages and disadvantages of the span-by-span method using an erection-launching 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.

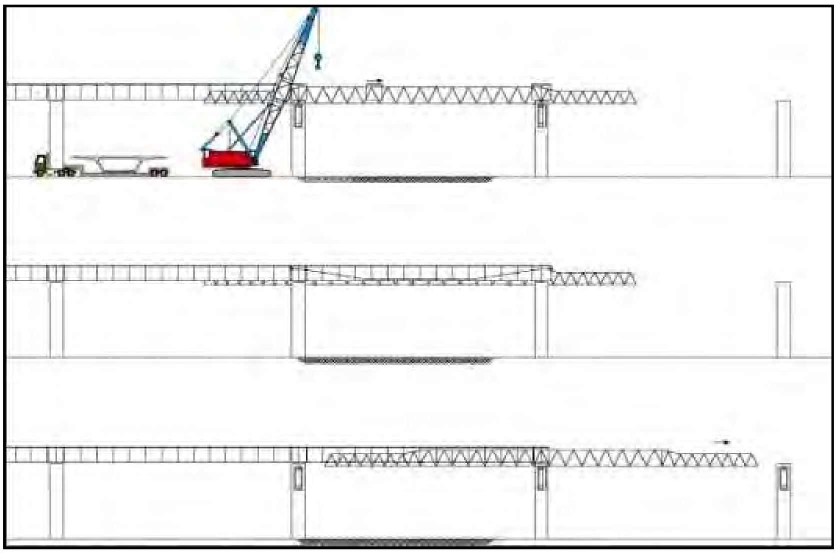

Figure 4.10: Balanced Cantilever Construction Process
Source: www.fhwa.dot.gov

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.

Table 5.1: Screening Factors for Bridge Deck Construction

Factors	Number of expert															Summary	Priorities Vecto:	Ranking
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
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	

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.

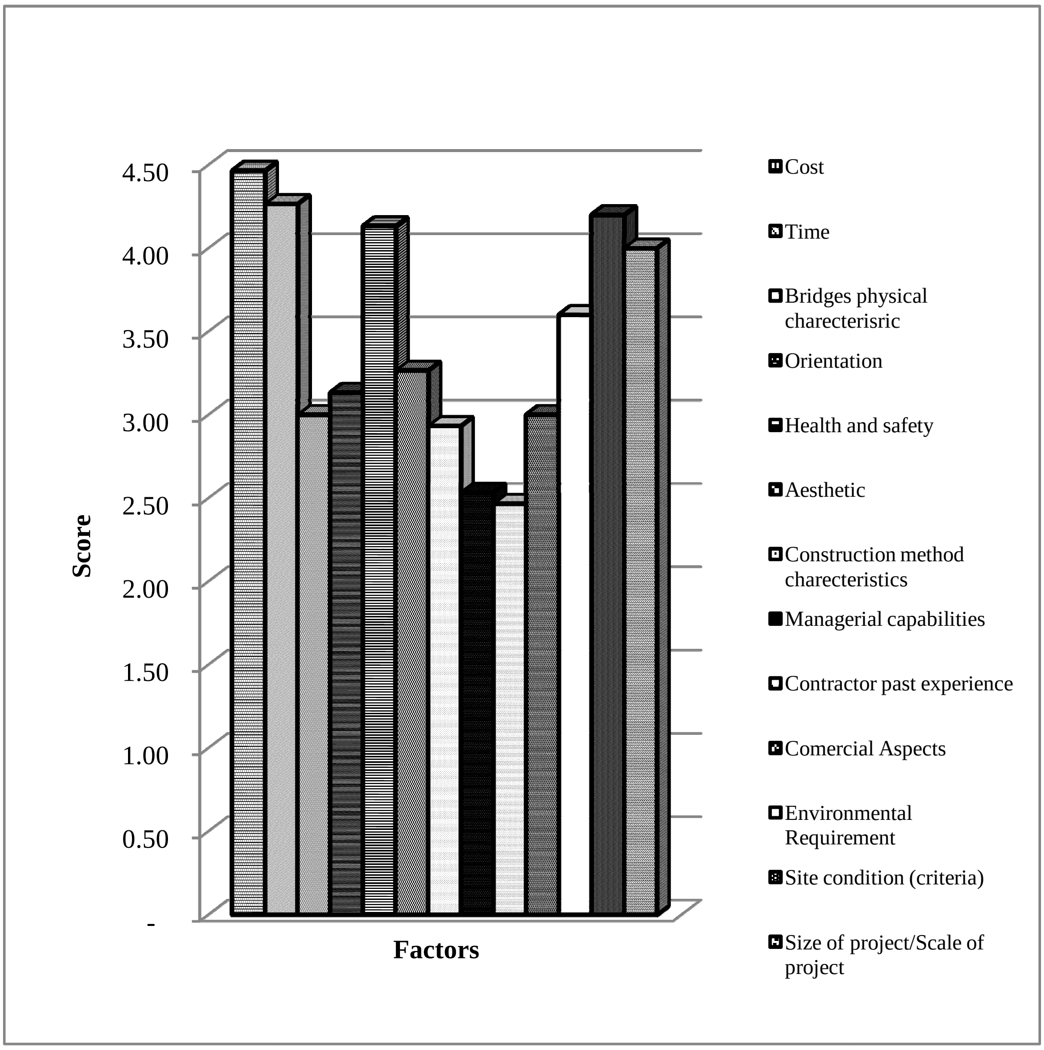

Figure 5.1: The Screening of Factors Scored 1-5

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.

Table 5.2: Weight of Important Factors for Selecting Superstructure

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	2
	1.00	

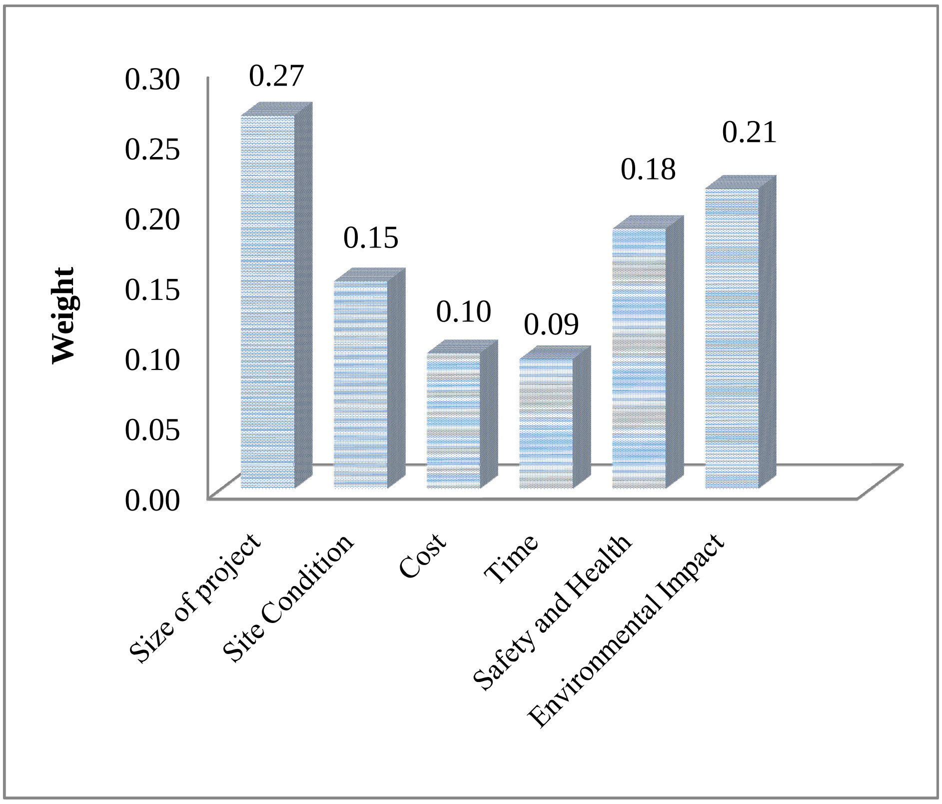

Figure 5.2: Weight of Important Factors for Selecting Superstructure

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

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	

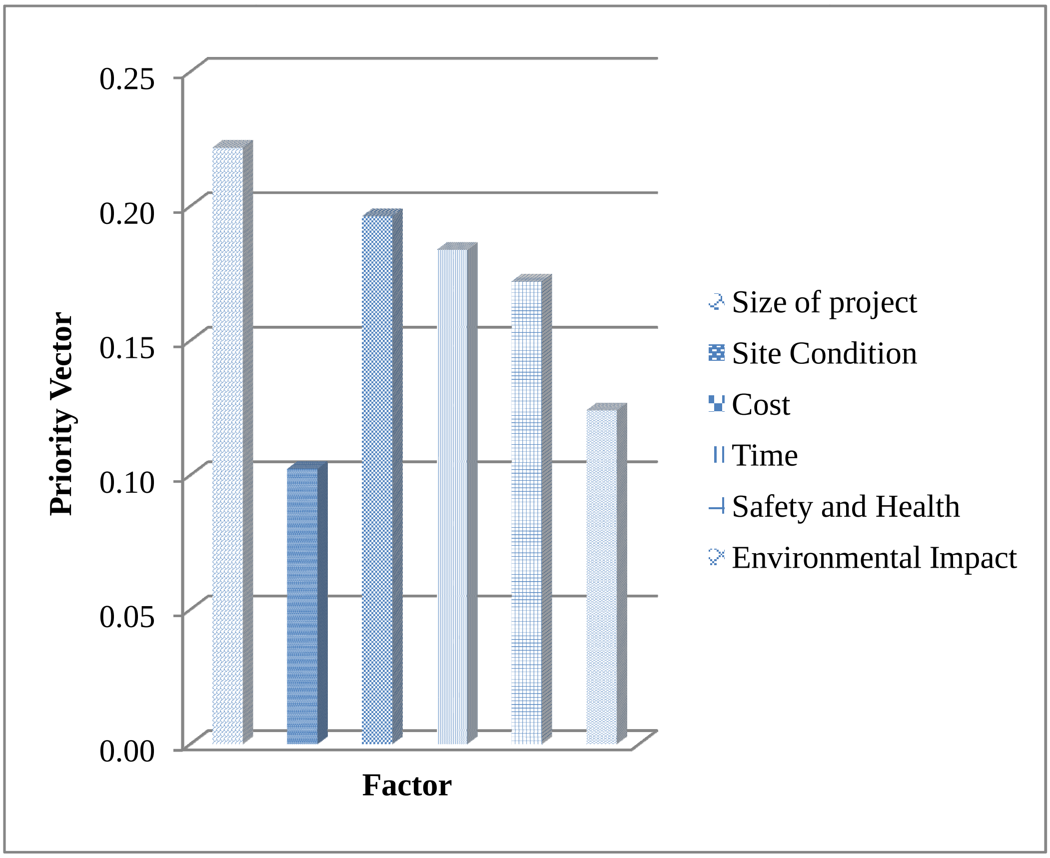

Figure 5.3: Weight of Important Factors for Selecting the Erection Equipment

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)).

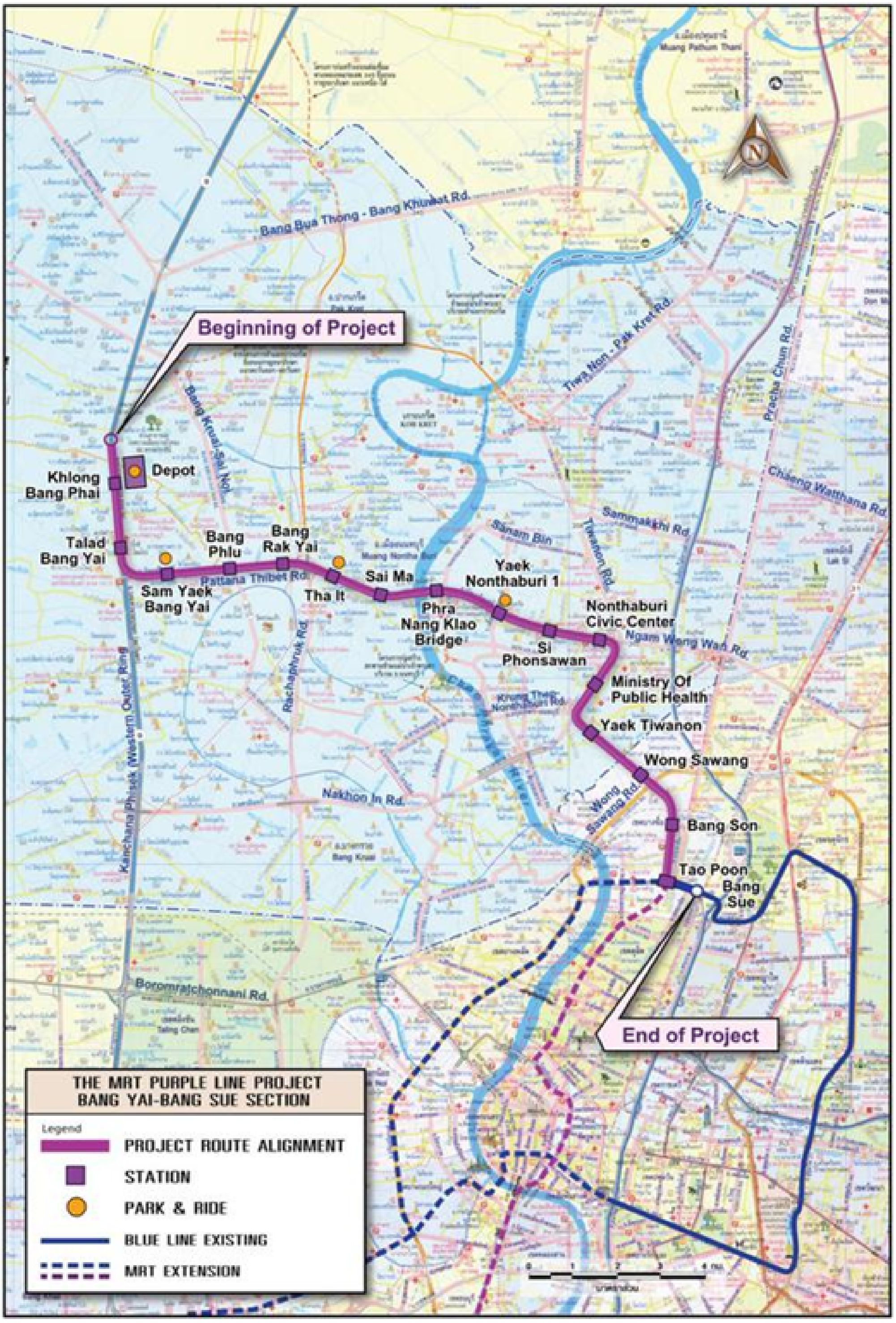

Figure 6.1: The MRT Purple Line Project, Bang Yai to Bang Sue Alignment

Source: MRT, (2011)

The above figure illustrates the MRT Purple Line Project, Bang Yai to Bang Sue Alignment comprising14 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.

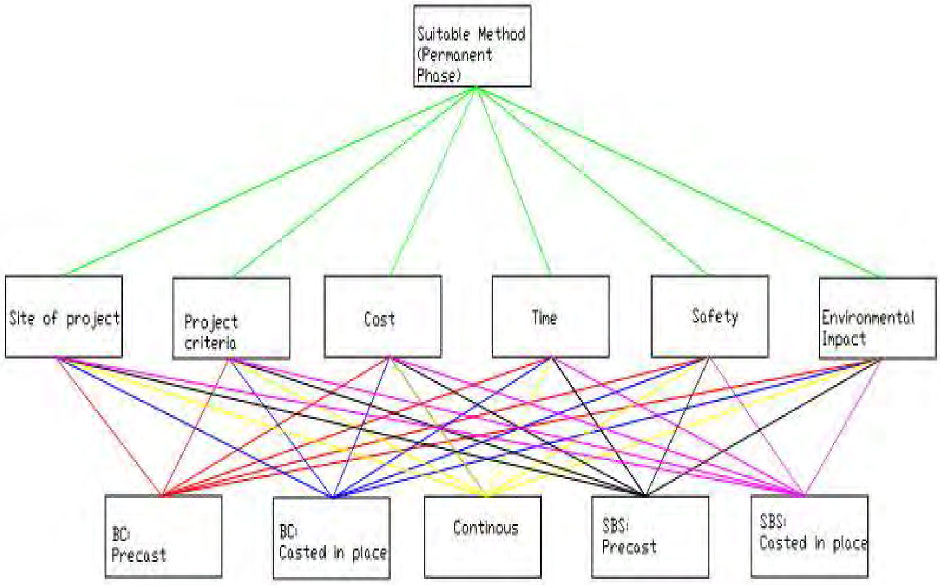

Figure 6. 2: Selection of Bridge Deck Construction Method

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.

Table 6.1: Weight of Factors for Selecting Superstructure System

Factor	Priorities Vector	Size of project	Project Criteria	Cost	Time	Safety	Environmental Impact	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	0.42	SBS: Precast	0.42	1
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								1.00	

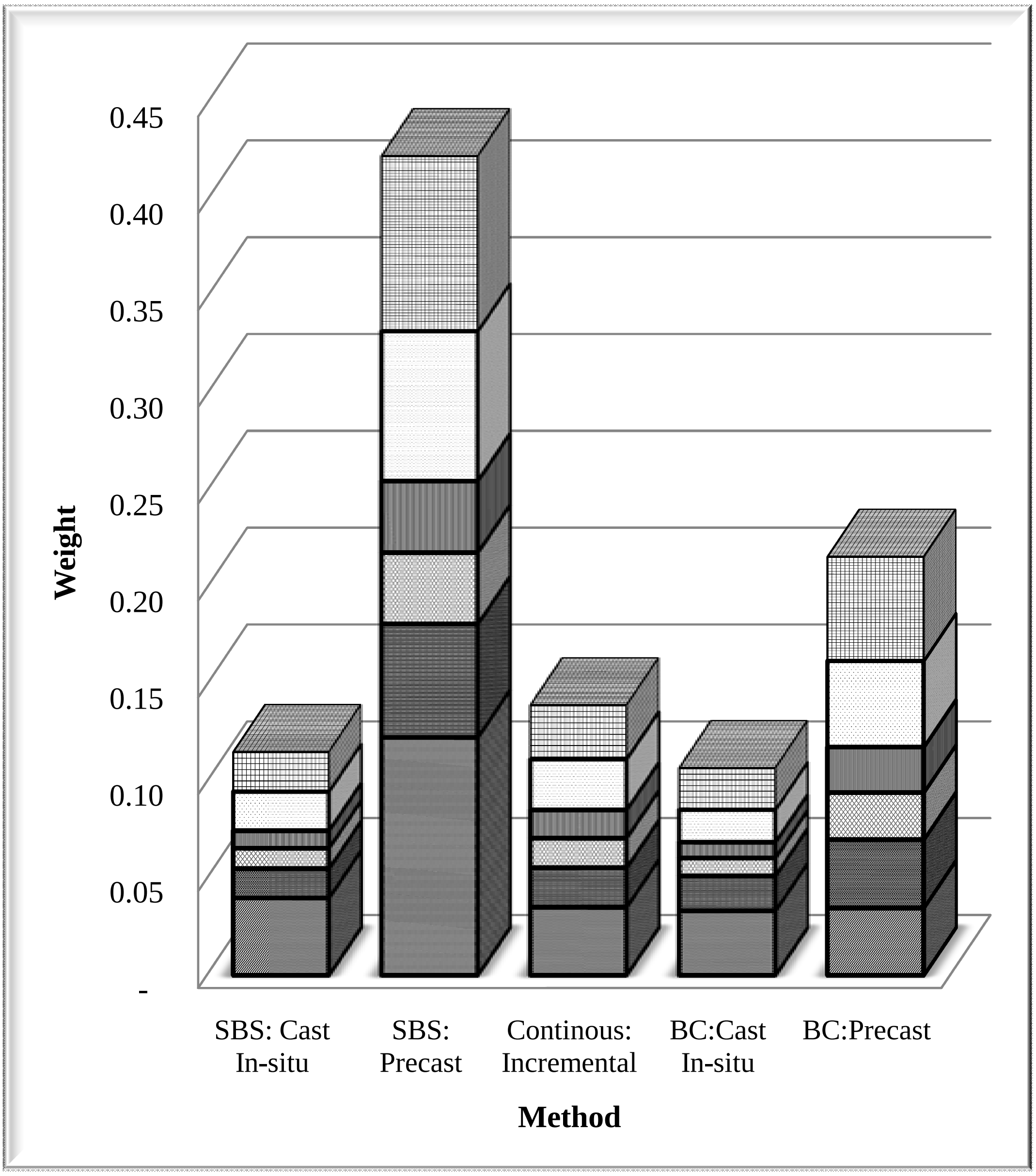

Figure 6.3: Weight of Factors for Selecting Superstructure System

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 6.1presentthe 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 pre-casting 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 pre-casting 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.

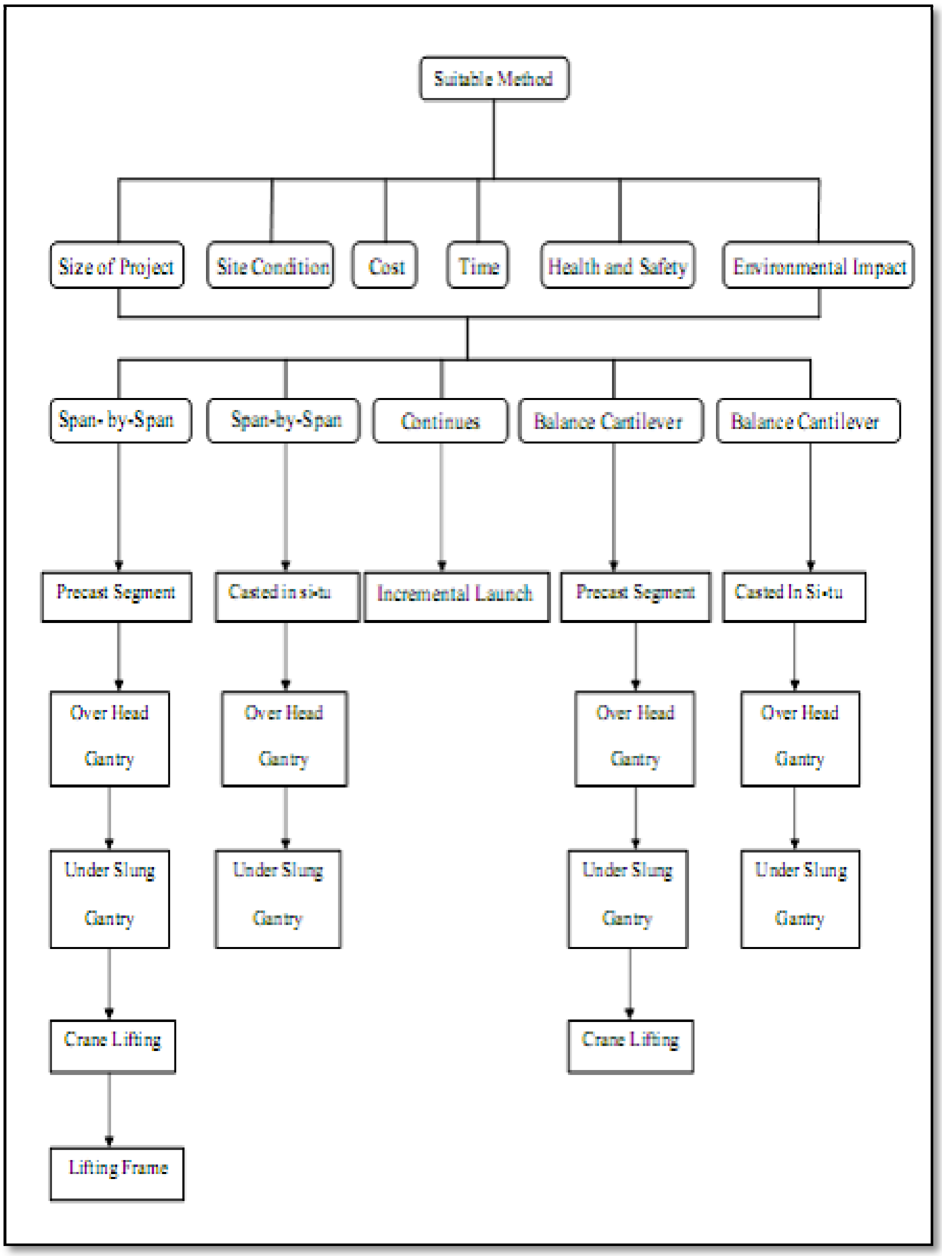

Figure 6.4: Bridge Deck Construction Framework.

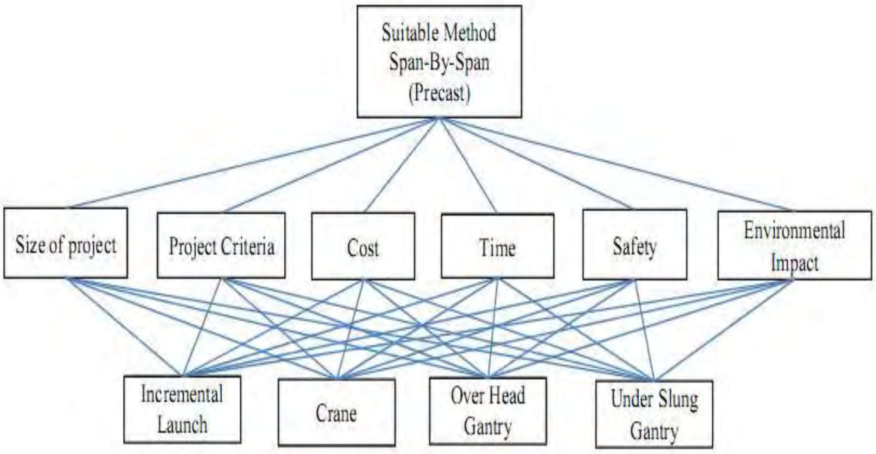

Figure 6.5: The Selection of Erection Equipment for Span-by-Span (precast) System

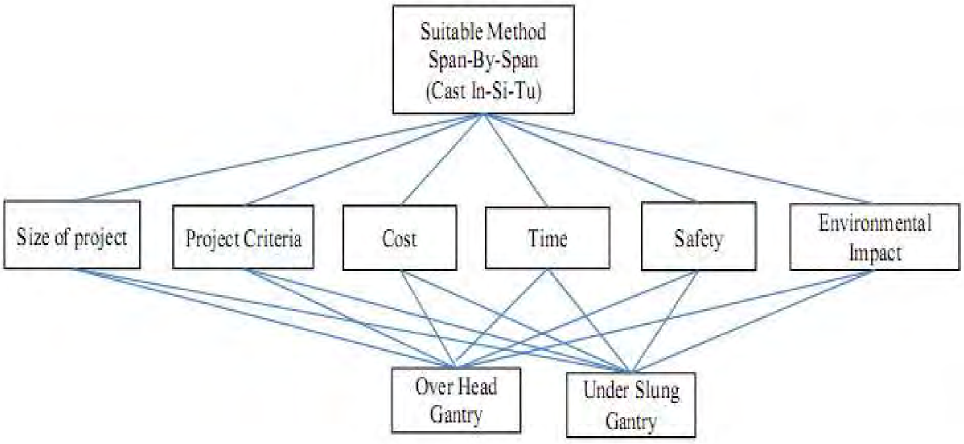

Figure 6.6: The Selection of Erection Equipment for Span-by-span (cast in-situ) System

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:
   - Erection using a lifting crane
   - Erection using a crane
   - Erection and launching using an overhead launching gantry
   - Erection and launching using an under slung launching gantry

2) Balanced cantilever method using cast in-situ system involves the following erection equipment:
   - Casting using an overhead formwork traveler
   - Casting using an under slung formwork traveler

3) Continuous method
   - Casting and pushing using an incremental launcher

4) Pre-cast segmental system using the span-by-span method involves the following erection equipment:
   - Erection with a crane
   - Erection and launching with an overhead launching gantry
   - 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)
   - 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

	Factor	Size of project	Site Condition	Cost	Time	Safety	Environmental Impact	Priorities Vector	Priorities Vector	Ranking
SBS	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	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
								0.12		
									1.00	

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.

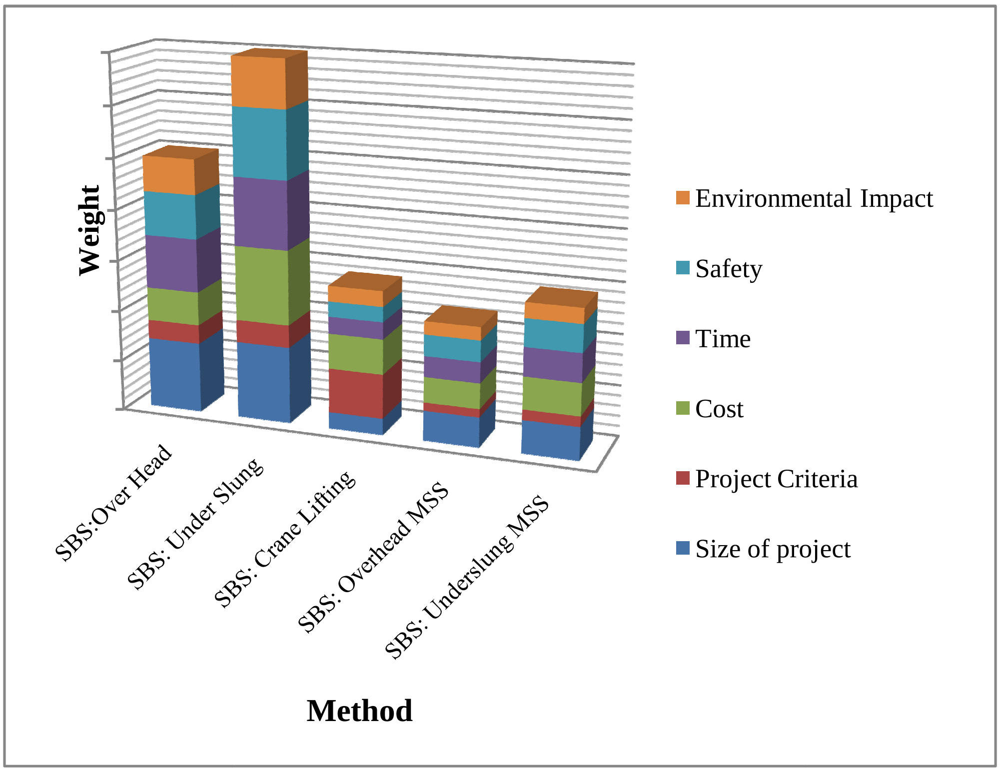

Figure 6.7: Weight of Factors for Selection of Erection Equipment Phase

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

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๖ กันยายน 2554

เรื่อง ขอความอนุเคราะห์ข้อมูลงานก่อสร้างสะพาน

เรียน ผู้จัดการ MAA Consultants Co., Ltd.

เนื่องด้วย นางสาวทิการัตน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปริญญามหาบัณฑิต สาขาวิชาโครงสร้างพื้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิด Segmental Concrete" โดยมี ผศ.ดร. นพดล จอกแก้ว เป็นอาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการกรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระดับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของการศึกษามีดังนี้

1. ปัจจัยที่นำมาวิเคราะห์ในการพิจารณาทางเลือกในการก่อสร้างสะพานประเภท segmental concrete
2. แบบสอบถามเกี่ยวกับการให้คะแนน และลำดับความสำคัญของแต่ละปัจจัยที่นำมาพิจารณา
3. ข้อมูลเกี่ยวกับการก่อสร้างโครงการรถไฟฟ้าสายสีม่วง

จึงเรียนมาเพื่อโปรดพิจารณาอนุมัติให้ข้อมูลดังกล่าวแก่นิสิต เพื่อเป็นประโยชน์แก่การศึกษา ขอขอบคุณล่วงหน้ามา ณ โอกาสนี้

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9 กันยายน 2554

เรื่อง ขอความอนุเคราะห์ข้อมูลงานก่อสร้างสะพาน

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

เนื่องด้วย นางสาวทิภารัตน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปริญญามหาบัณฑิต สาขาวิชาโครงสร้างพื้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิด Segmental Concrete" โดยมี ผศ.ดร. นพดล จอกแก้ว เป็นอาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการกรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระดับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของการศึกษามีดังนี้

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เรื่อง ขอความอนุเคราะห์ข้อมูลงานก่อสร้างสะพาน

เรียน ผู้จัดการ VSL(Thailand) Co., Ltd.

เนื่องด้วย นางสาวทิภารัตน์ ถือทอง เอื้อพันธุ์พงศ์ นิสิตปริญญามหาบัณฑิต สาขาวิชาโครงสร้างพื้นฐานทางวิศวกรรมโยธา คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย กำลังทำวิทยานิพนธ์เรื่อง "ทางเลือกในการก่อสร้างพื้นสะพานชนิด Segmental Concrete" โดยมี ผศ.ดร. นพดล จอกแก้ว เป็นอาจารย์ที่ปรึกษา มีความประสงค์จะขอสัมภาษณ์ผู้เชี่ยวชาญด้านงานสะพานและขอความอนุเคราะห์ในการกรอกแบบสอบถาม เพื่อใช้สำหรับการทำวิทยานิพนธ์ในระดับปริญญามหาบัณฑิต โดยวัตถุประสงค์ของการศึกษามีดังนี้

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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 : ....
Name of Respondent: ....
Position : ....
Date : ....

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

1) Project Criteria
1.1) Size of project
1.2) Structure type
1.3) Existing resource : Equipment and staff's experience

2) Site Condition and Requirement
2.1) Access for material delivery and construction
2.2) Location of Construction Site

3) Cost
3.1) Benefit of Cost Ratio
3.2) Economy of Scale
3.3) Available budget and Equipment

4) Time
4.1) Mobilization Time
4.2) Available Construction Time

5) Environmental Impact
5.1) Hazard to animals
5.2) Pollution such as air, water, and noise

6) Safety
6.1) Construction safety on site
6.2) Traffic disruption

Table 1: Fuzzy important scale

Vertical Judgement	Scale	Explanation
The best	5	Judgement strongly favour other criteria over another
Better	4	Judgement slightly favour other criteria over another
Equally	3	Two criterion contribute equally to the object
Worse	2	A criteria is slightly inferior to another
The worst	1	A criteria is strongly inferior to another

Table 2: Example of question

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Cost	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3	*1*	*4*	*4*	*3*
	Precast		3	5	5	4
	Continuous			3	3	2
BC	Cast In-situ				3	1
	Precast					3

Table 3: Questionnaire meaning

No.	Questionnaire with to access main criteria		Score
Q1	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Span by Span : Cast In-situ)	*3*
Q2	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Span by Span : Precast)	*5*
Q3	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Continuous)	*2*
Q4	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Cast In-situ)	*4*
Q5	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Precast)	*1*
Q6	How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Cast In-situ)	*4*
Q7	How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Precast)	*3*

Structural System Comparison

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Cost	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3				
	Precast		3			
	Continuous			3		
BC	Cast In-situ				3	
	Precast					3

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Time	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3				
	Precast		3			
	Continuous			3		
BC	Cast In-situ				3	
	Precast					3

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Safety	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3				
	Precast		3			
	Continuous			3		
BC	Cast In-situ				3	
	Precast					3

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Environmental Impact	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3				
	Precast		3			
	Continuous			3		
BC	Cast In-situ				3	
	Precast					3

Score	**5**	**4**	**3**	**2**	**1**
Meaning	**The best**	**Better**	**Equally**	**Worse**	**The worst**

Objective of Questionnaire

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

Temporary Structure Design

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 staff's experience

2) Site Condition and Requirement
2.1) Access for material delivery and construction
2.2) Location of Construction Site

3) Cost (Cost of Construction: sub structure, superstructure, equipment, precasting yard, transportation, personal, misc.)
3.1) Benefit of Cost Ratio
3.2) Economy of Scale
3.3) Available budget and Equipment

4) Time
4.1) Mobilization Time
4.2) Available Construction Time

5) Environmental Impact
5.1) Hazard to people and animals
5.2) Pollution such as air, water, and noise

6) Safety
6.1) Construction safety on site
6.2) Traffic disruption

Table 1: **Fuzzy important scale**

Vertical Judgement	Scale	Explanation
The best	5	Judgement strongly favour other criteria over another
Better	4	Judgement slightly favour other criteria over another
Equally	3	Two criterion contribute equally to the object
Worse	2	A criteria is slightly inferior to another
The worse	1	A criteria is strongly inferior to another

Table 2: **Example of question**

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
	Cost	Cast In-situ	Precast		Cast In-situ	Precast
SBS	Cast In-situ	3	5	2	4	1
	Precast	4	3			
	Continuous			3		
BC	Cast In-situ				3	
	Precast					3

Table 3: **Questionnaire meaning**

No.	Questionnaire with to access main criteria		Score
Q1	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Span by Span : Cast In-situ)	3
Q2	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Span by Span : Precast)	5
Q3	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Continuous)	2
Q4	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Cast In-situ)	4
Q5	How important is cost (Span by Span: Cast In-situ)	when it is compared to cost (Balance Cantilever: Precast)	1
Q6	How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Cast In-situ)	4
Q7	How important is cost (Span by Span: Precast)	when it is compared to cost (Span by Span : Precast)	3

Construction Method Comparison - Using ***Cost*** Criteria

	Factor	Span by Span (SBS)					Continuous	Balance Cantilever (BC)					
		Cast In-situ		Precast				Cast In-situ		Precast			
	Cost	Overhead Gantry	Under slung Gantry	Overhead Gantry	Under slung Gantry	Crane Lifting	Incremental	Under slung Gantry	Overhead Gantry	Crane Lifting	Lifting Frame	Under slung Gantry	Overhead Gantry
Cast In-situ	Overhead Gantry	3											
	Under slung Gantry		3										
Precast	Overhead Gantry			3									
	Under slung Gantry				3								
	Crane Lifting					3							
	Continuous						3						
Cast	Under slung Gantry							3					
	Overhead Gantry								3				
Precast	Crane Lifting									3			
	Lifting Frame										3		
	Under slung Gantry											3	
	Overhead Gantry												3

Construction Method Comparison - Using ***Time*** Criteria

	Factor	Span by Span (SBS)					Continuous	Balance Cantilever (BC)					
		Cast In-situ		Precast				Cast In-situ		Precast			
	Time	Overhead Gantry	Under slung Gantry	Overhead Gantry	Under slung Gantry	Crane Lifting	Incremental	Under slung Gantry	Overhead Gantry	Crane Lifting	Lifting Frame	Under slung Gantry	Overhead Gantry
Cast In-situ	Overhead Gantry	3											
	Under slung Gantry		3										
Precast	Overhead Gantry			3									
	Under slung Gantry				3								
	Crane Lifting					3							
	Continuous						3						
Cast	Under slung Gantry							3					
	Overhead Gantry								3				
Precast	Crane Lifting									3			
	Lifting Frame										3		
	Under slung Gantry											3	
	Overhead Gantry												3

Score	**5**	**4**	**3**	**2**	**1**
Meaning	**The best**	**Better**	**Equally**	**Worse**	**The worst**

Construction Method Comparison - Using ***Safety*** Criteria

	Factor	Span by Span (SBS)					Continuous	Balance Cantilever (BC)					
		Cast In-situ		Precast				Cast In-situ		Precast			
	Safety	Overhead Gantry	Under slung Gantry	Overhead Gantry	Under slung Gantry	Crane Lifting	Incremental	Under slung Gantry	Overhead Gantry	Crane Lifting	Lifting Frame	Under slung Gantry	Overhead Gantry
Cast In-situ	Overhead Gantry	3											
	Under slung Gantry		3										
Precast	Overhead Gantry			3									
	Under slung Gantry				3								
	Crane Lifting					3							
	Continuous						3						
Cast	Under slung Gantry							3					
	Overhead Gantry								3				
Precast	Crane Lifting									3			
	Lifting Frame										3		
	Under slung Gantry											3	
	Overhead Gantry												3

Construction Method Comparison - Using ***Environmental Impact*** Criteria

	Factor	Span by Span (SBS)					Continuous	Balance Cantilever (BC)					
		Cast In-situ		Precast				Cast In-situ		Precast			
	Environmental Impact	Overhead Gantry	Under slung Gantry	Overhead Gantry	Under slung Gantry	Crane Lifting	Incremental	Under slung Gantry	Overhead Gantry	Crane Lifting	Lifting Frame	Under slung Gantry	Overhead Gantry
Cast In-situ	Overhead Gantry	3											
	Under slung Gantry		3										
Precast	Overhead Gantry			3									
	Under slung Gantry				3								
	Crane Lifting					3							
	Continuous						3						
Cast	Under slung Gantry							3					
	Overhead Gantry								3				
Precast	Crane Lifting									3			
	Lifting Frame										3		
	Under slung Gantry											3	
	Overhead Gantry												3

Score	**5**	**4**	**3**	**2**	**1**
Meaning	**The best**	**Better**	**Equally**	**Worse**	**The worst**

APPENDIX B

DATA COLLECTION FOR FACTOR SCREENING

Name of Company	: NorCiv Engineering Co.,Ltd.
Name of Respondent	: Sophon Ritdumrongkul, Ph.D.
Position	: Structure Engineer
Date	: 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?

- [X] More than 8 years
- [ ] Between 8 years
- [ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		1	2	3	4	5
Cost	Cost of construction, Cost of repairing construction problem					5
Time	Time for normal operation, Time for erection and mobilization					5
Bridges physical charecterisric	Deck curvature,Deck up/down grade, Deck X-Section, Super			3		
Orientation	Machine intensive, Labour intensive			3		
Health and safety	Personal working in site, Third party					5
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			3		
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement					5
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,					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				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					5

Name of Company : NorCiv Engineering Co.,Ltd.
Name of Respondent : Worapatt Ritthichauy, Ph.D.
Position : Structure Engineer
Date : 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?

- [X] More than 8 years
- [ ] Between 8 years
- [ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		1	2	3	4	5
Cost	Cost of construction, Cost of repairing construction problem					5
Time	Time for normal operation, Time for erection and mobilization					5
Bridges physical charecterisric	Deck curvature,Deck up/down grade, Deck X-Section, Super				4	
Orientation	Machine intensive, Labour intensive		2			
Health and safety	Personal working in site, Third party				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			3		
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,				4	
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				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					5

Name of Company : NorCiv Engineering Co.,Ltd.
Name of Respondent : Piboon Tirasit, Ph.D.
Position : Structure Engineer
Date : 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?

- [X] More than 8 years
- [ ] Between 8 years
- [ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		1	2	3	4	5
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			3		
Health and safety	Personal working in site, Third party			3		
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			3		
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement				4	
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,				4	
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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium				4	

Name of Company	: NorCiv Engineering Co.,Ltd.
Name of Respondent	: Wanchai Chuenson
Position	: General Project Manager
Date	: 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?

- [X] More than 8 years
- [ ] Between 8 years
- [ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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					5
Bridges physical charecterisric	Deck curvature,Deck up/down grade, Deck X-Section, Super				4	
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					5
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application			3		
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,					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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3		

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
- [X] 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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				4	
Orientation	Machine intensive, Labour intensive			3		
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			3		
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					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
- [X] 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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				4	
Orientation	Machine intensive, Labour intensive			3		
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			3		
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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				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?

- [X] More than 8 years
- [ ] Between 8 years
- [ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		1	2	3	4	5
Cost	Cost of construction, Cost of repairing construction problem					5
Time	Time for normal operation, Time for erection and mobilization					5
Bridges physical charecterisric	Deck curvature,Deck up/down grade, Deck X-Section, Super			3		
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				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			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement					5
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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			3		
Size of project/Scale of project	Bridges construction were classified in maga project, medium					5

Name of Company	: VSL (Thailand) Co.,Ltd.
Name of Respondent	: Natthawut Cheencharoen
Position	: Satellite Manager
Date	: 23/10/2554

Part A: General Information

1)What kinds of your ***organization function***

- [ ] Contractor
- [ ] Owner
- [ ] Consultant
- [X] 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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 intensive				4	
Health and safety	Personal working in site, Third party			3		
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			3		
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,				4	
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				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
- [X] Sub-Contractor
- [ ] Others

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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score 1	2	3	4	5
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			3		
Health and safety	Personal working in site, Third party					5
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			3		
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,				4	
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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3		

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

Part A: General Information

1)What kinds of your ***organization function***

- [ ] Contractor
- [ ] Owner
- [ ] Consultant
- [X] Sub-Contractor
- [ ] Others

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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		1	2	3	4	5
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				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		2			
Managerial capabilities	Site control, Labour control, Equipment control		2			
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3		

Name of Company	: VSL (Thailand) Co.,Ltd.
Name of Respondent	: Mr. Rami
Position	: Erection Specialist
Date	: 23/10/2554

Part A: General Information

1)What kinds of your ***organization function***

- [ ] Contractor
- [ ] Owner
- [ ] Consultant
- [X] Sub-Contractor
- [ ] Others

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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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		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			3		
Construction method charecteristics	Available of system components, System complexity and Effective construction method on design, Method application		2			
Managerial capabilities	Site control, Labour control, Equipment control				4	
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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			3		
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3		

Name of Company : VSL (Thailand) Co.,Ltd.
Name of Respondent : Mr. Sakda
Position : Senior Project Manager
Date : 23/10/2554

Part A: General Information

1)What kinds of your ***organization function***

- [ ] Contractor
- [ ] Owner
- [ ] Consultant
- [X] Sub-Contractor
- [ ] Others

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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score 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		2			
Orientation	Machine intensive, Labour intensive			3		
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			3		
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement		2			
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium			3		

Name of Company	: Ch. karnchang Public Company Limited
Name of Respondent	: -
Position	: Structure Engineer (Bridge)
Date	: 25/10/2554

Part A: General Information

1)What kinds of your ***organization 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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 intensive			3		
Health and safety	Personal working in site, Third party					5
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			3		
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,			3		
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					5
Size of project/Scale of project	Bridges construction were classified in maga project, medium					5

Name of Company : Italian-Thai Development Public Company Limited.
Name of Respondent : -
Position : Structure Engineer
Date : 26/10/2554

Part A: General Information

1)What kinds of your ***organization 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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			3		
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					5
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			3		
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience			2			
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,			3		
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				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium					5

Name of Company : Unique Engineering and Construction Public Company Limited
Name of Respondent : -
Position : Structure Engineer (Bridge)
Date : 25/10/2554

Part A: General Information

1)What kinds of your ***organization 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

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score				
		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 intensive			3		
Health and safety	Personal working in site, Third party					5
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			3		
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,			3		
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					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***

[ ] 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?

[X] More than 8 years
[ ] Between 8 years
[ ] Lower 8 years

PART B: Identified factor for selection method of bridge deck construction

Factor	Description	Score 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					5
Bridges physical charecterisric	Deck curvature,Deck up/down grade, Deck X-Section, Super			3		
Orientation	Machine intensive, Labour intensive			3		
Health and safety	Personal working in site. Third party		2			
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			3		
Managerial capabilities	Site control, Labour control, Equipment control			3		
Contractor past experience				3		
Comercial Aspects	Contractor responsibilities, Contract Type, Procurement			3		
Environmental Requirement	Noise organization and cleaning, Emissions,Waters,				4	
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				4	
Size of project/Scale of project	Bridges construction were classified in maga project, medium				4	

Identified factor for selection method of bridge deck construction

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

Factor Ranking

Factors	Number of expert															Summary	Priorities Vector	Ranking
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
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 charecteristics	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	

APPENDIX C

CALCULATION SHEET

FOR ERECTION EQUIPMENT SELECTION

Structure System Designing Phase: Comparison of "Expert No.1"

Factors	Size of project	Site Condition	Cost	Time	Safety	Environmental		Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1/3	1/3	1/3	1/3	RI	0.01	0.48	0.07	0.42	6.39
Site Condition	1	1	1/3	1/3	1/3	1/3	1.25	0.01	0.48	0.07	0.42	6.39
Cost	3	3	1	1	3	5	CI	135.00	2.26	0.31	2.11	6.81
Time	3	3	1	1	1	3	0.12	27.00	1.73	0.24	1.47	6.20
Safety and Helth	3	3	1/3	1	1	5	CR	15.00	1.57	0.22	1.48	6.86
Environmental	3	3	1/3	1/3	1/5	1	0.10	0.20	0.76	0.10	0.73	6.92
							acceptable	Sum	7.29	1.00		39.57
											λ max =	6.60

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Size of project	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1	1.20	0.20	0.76	0.13	0.61	4.76
SBS	Precast	5	1	5	5	5	CI	625.00	2.92	0.49	3.05	6.23
	Continuous	1	1/5	1	1	1	0.01	0.20	0.76	0.13	0.61	4.76
BC	Cast In-situ	1	1/5	1	1	1	CR	0.20	0.76	0.13	0.61	4.76
BC	Precast	1	1/5	1	1	1	0.01	0.20	0.76	0.13	0.61	4.76
							acceptable	Sum	5.98	1.00		25.29
											λ max =	5.06

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Site Condition	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1	1.20	0.20	0.76	0.14	0.68	4.89
SBS	Precast	5	1	5	1	5	CI	125.00	2.24	0.40	2.06	6.58
	Continuous	1	1/5	1	1	1	0.09	0.20	0.76	0.14	0.68	4.89
BC	Cast In-situ	1	1	1	1	1	CR	1.00	1.00	0.18	1.00	5.53
BC	Precast	1	1/5	1	1	1	0.07	0.20	0.76	0.14	0.68	4.89
							acceptable	Sum	5.53	1.00		26.78
											λ max =	5.36

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Cost	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	3	1/3	1.20	0.20	0.76	0.13	0.76	5.67
SBS	Precast	5	1	3	5	3	CI	225.00	2.47	0.43	2.63	6.07
	Continuous	1	1/3	1	1	1	0.11	0.33	0.83	0.15	0.71	4.87
BC	Cast In-situ	1/3	1/5	1	1	1	CR	0.07	0.64	0.11	0.56	5.05
BC	Precast	3	1/3	1	1	1	0.09	1.00	1.00	0.18	0.98	5.59
							acceptable	Sum	5.70	1.00		27.25
											λ max =	5.45

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Time	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.62
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.59	6.18
	Continuous	1	1/3	1	1	1/3	0.04	0.11	0.69	0.12	0.56	4.72
BC	Cast In-situ	1	1/5	1	1	1/3	CR	0.07	0.64	0.11	0.50	4.62
	Precast	3	1/3	3	3	1	0.03	9.00	1.44	0.25	1.39	5.66
							acceptable	Sum	5.88	1.00		25.79
											λ max =	5.16

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Safety and Helth	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	3	1/3	1.20	0.20	0.76	0.13	0.66	5.24
	Precast	5	1	5	5	3	CI	375.00	2.69	0.44	2.75	6.21
	Continuous	1	1/5	1	1	1/3	0.07	0.07	0.64	0.11	0.49	4.63
BC	Cast In-situ	1/3	1/5	1	1	1/3	CR	0.02	0.53	0.09	0.40	4.60
	Precast	3	1/3	3	3	1	0.06	9.00	1.44	0.24	1.34	5.64
							acceptable	Sum	6.06	1.00		26.32
											λ max =	5.26

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Environmental Impact	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	3	1/3	1.20	0.20	0.76	0.13	0.68	5.26
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.60	6.22
	Continuous	1	1/3	1	1	1/3	0.08	0.11	0.69	0.12	0.56	4.75
BC	Cast In-situ	1/3	1/5	1	1	1/3	CR	0.02	0.53	0.09	0.42	4.63
	Precast	3	1/3	3	3	1	0.07	9.00	1.44	0.24	1.40	5.71
							acceptable	Sum	5.90	1.00		26.56
											λ max =	5.31

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 13

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	3	3	1	1	27.00	1.73	0.25	1.63	6.44
							Sum	6.83	1.00		39.00
										λ max =	6.50

R.I. = 1.25 C.I. = **0.10** C.R. = **0.08** *acceptable*

Questionnaire No.1 Action by : Expertise No. 14

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	5	5	5	5	5	3,125.00	3.82	0.48	3.09	6.48
Site Condition	1/5	1	3	3	1	1	1.80	1.10	0.14	0.84	6.10
Cost	1/5	1/3	1	1	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	1	1	1.80	1.10	0.14	0.84	6.10
Environmental Impact	1/5	1	3	3	1	1	1.80	1.10	0.14	0.84	6.10
							Sum	8.02	1.00		37.23
										λ max =	6.20

R.I. = 1.25 C.I. = **0.04** C.R. = **0.03** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 11

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	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	1	1	3.00	1.20	0.17	1.18	6.76
Cost	1/3	1/5	1	1	1/3	1/3	0.01	0.44	0.06	0.40	6.23
Time	1/3	1/3	1	1	1/3	1/3	0.01	0.48	0.07	0.42	6.06
Safety and Health	1	1	3	3	1	1	9.00	1.44	0.21	1.27	6.06
Environmental Impact	1	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*

Questionnaire No.1 Action by : Expertise No. 12

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	5	5	5	1	1	125.00	2.24	0.31	2.12	6.73
Site Condition	1/5	1	3	3	1	1	1.80	1.10	0.16	1.00	6.42
Cost	1/5	1/3	1	1	1/3	1/3	0.01	0.44	0.06	0.37	6.02
Time	1/5	1/3	1	1	1/3	1/3	0.01	0.44	0.06	0.37	6.02
Safety and Health	1	1	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	1.25	6.15
							Sum	7.11	1.00		37.50
										λ max =	6.25

R.I. = 1.13 C.I. = **0.05** C.R. = **0.04** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 | Action by : Expertise No. 9

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	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	1	1	1/3	1/3	0.01	0.48	0.07	0.42	6.32
Safety and Health	3	3	3	3	1	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
										λ max =	6.59

R.I. = 1.25 C.I. = **0.12** C.R. = **0.09** *acceptable*

Questionnaire No.1 | Action by : Expertise No. 10

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	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	1	1	3.00	1.20	0.17	1.18	6.76
Cost	1/3	1/5	1	1	1/3	1/3	0.01	0.44	0.06	0.40	6.23
Time	1/3	1/3	1	1	1/3	1/3	0.01	0.48	0.07	0.42	6.06
Safety and Health	1	1	3	3	1	1	9.00	1.44	0.21	1.27	6.06
Environmental Impact	1	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*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 7

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	3	3	243.00	2.50	0.35	2.29	6.50
Site Condition	1/3	1	3	3	3	3	27.00	1.73	0.24	1.57	6.41
Cost	1/3	1/3	1	1	1	1/3	0.04	0.58	0.08	0.51	6.22
Time	1/3	1/3	1	1	1	1/3	0.04	0.58	0.08	0.51	6.22
Safety and Health	1/3	1/3	1	1	1	1	0.11	0.69	0.10	0.60	6.14
Environmental Impact	1/3	1/3	3	3	1	1	1.00	1.00	0.14	0.93	6.57
							Sum	7.08	1.00		38.06
										λ max =	6.34

R.I. = 1.25 C.I. = **0.07** C.R. = **0.06** *acceptable*

Questionnaire No.1 Action by : Expertise No. 8

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	5	3	3	1	1	45.00	1.89	0.29	2.02	7.06
Site Condition	1/5	1	3	3	1	1	1.80	1.10	0.17	1.12	6.70
Cost	1/3	1/3	1	1	1	1/3	0.04	0.58	0.09	0.55	6.29
Time	1/3	1/3	1	1	1	1/3	0.04	0.58	0.09	0.55	6.29
Safety and Health	1	1	1	1	1	1	1.00	1.00	0.15	1.00	6.59
Environmental Impact	1	1	3	3	1	1	9.00	1.44	0.22	1.35	6.17
							Sum	6.59	1.00		39.09
										λ max =	6.51

R.I. = 1.25 C.I. = **0.10** C.R. = **0.08** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 5

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	1	1	27.00	1.73	0.26	1.59	6.10
Site Condition	1/3	1	1	1	1/3	1/3	0.04	0.58	0.09	0.53	6.10
Cost	1/3	1	1	1	1	1/3	0.11	0.69	0.10	0.65	6.23
Time	1/3	1	1	1	1	1/3	0.11	0.69	0.10	0.65	6.23
Safety and Health	1	3	1	1	1	1	3.00	1.20	0.18	1.17	6.48
Environmental Impact	1	3	3	3	1	1	27.00	1.73	0.26	1.59	6.10
							Sum	6.63	1.00		37.23
										λ max =	6.20

R.I. = 1.25 C.I. = **0.04** C.R. = **0.03** *acceptable*

Questionnaire No.1 Action by : Expertise No. 6

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	5	5	5	3	3	1,125.00	3.22	0.41	2.91	7.01
Site Condition	1/5	1	5	5	3	3	45.00	1.89	0.24	1.60	6.62
Cost	1/5	1/5	1	1	1	1/3	0.01	0.49	0.06	0.39	6.21
Time	1/5	1/5	1	1	1	1/3	0.01	0.49	0.06	0.39	6.21
Safety and Health	1/3	1/3	1	1	1	1	0.11	0.69	0.09	0.56	6.30
Environmental Impact	1/3	1/3	3	3	1	1	1.00	1.00	0.13	0.81	6.32
							Sum	7.78	1.00		38.66
										λ max =	6.44

R.I. = 1.25 C.I. = **0.09** C.R. = **0.07** *acceptable*

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	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	1	1/3	0.33	0.83	0.13	0.82	6.27
Time	1	1	1	1	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
										λ max =	6.27

R.I. = 1.25 C.I. = **0.05** C.R. = **0.04** *acceptable*

Questionnaire No.1 Action by : Expertise No. 4

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	1/3	1/3	0.11	0.69	0.10	0.63	6.10
Cost	1	1	1	1	1	1/3	0.33	0.83	0.12	0.77	6.24
Time	1	1	1	1	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	6.70	1.00		37.40
										λ max =	6.23

R.I. = 1.25 C.I. = **0.05** C.R. = **0.04** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 1

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.07	0.42	6.39
Site Condition	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.07	0.42	6.39
Cost	3	3	1	1	3	5	135.00	2.26	0.31	2.11	6.81
Time	3	3	1	1	1	3	27.00	1.73	0.24	1.47	6.20
Safety and Health	3	3	1/3	1	1	5	15.00	1.57	0.22	1.48	6.86
Environmental Impact	3	3	1/3	1/3	1/5	1	0.20	0.76	0.10	0.73	6.92
							Sum	7.29	1.00		39.57
										λ max =	6.60

R.I. = 1.25 C.I. = **0.12** C.R. = **0.10** *acceptable*

Questionnaire No.1 Action by : Expertise No. 2

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	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	6.26
							Sum	6.69	1.00		39.35
										λ max =	6.56

R.I. = [illegible] C.I. = **0.11** C.R. = **0.09** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 15

Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	5	5	5	5	3	1,875.00	3.51	0.44	2.97	6.68
Site Condition	1/5	1	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	1	1.00	1.00	0.13	0.79	6.27
							Sum	7.90	1.00		38.47
										λ max=	6.41

R.I.= 1.25 C.I.= **0.08** C.R.= **0.07** *acceptable*

Calculation Sheet

Case study: Structure System Designing Phase

Comparison of factors with respect to overall satisfaction.

No. of Expert	Priority Vector of Factor	Size of project	Site Condition	Cost	Time	Safety and Health	Environmental Impact
	1	0.07	0.07	0.31	0.24	0.22	0.10
	2	0.18	0.09	0.10	0.10	0.22	0.31
	3	0.19	0.09	0.13	0.13	0.19	0.27
	4	0.10	0.10	0.12	0.12	0.22	0.34
	5	0.26	0.09	0.10	0.10	0.18	0.26
	6	0.41	0.24	0.06	0.06	0.09	0.13
	7	0.35	0.24	0.08	0.08	0.10	0.14
	8	0.29	0.17	0.09	0.09	0.15	0.22
	9	0.18	0.11	0.07	0.07	0.29	0.29
	10	0.27	0.17	0.06	0.07	0.21	0.21
	11	0.27	0.17	0.06	0.07	0.21	0.21
	12	0.31	0.16	0.06	0.06	0.20	0.20
	13	0.18	0.18	0.07	0.07	0.25	0.25
	14	0.48	0.14	0.06	0.06	0.14	0.14
	15	0.44	0.20	0.06	0.06	0.12	0.13
	Sum	3.98	2.21	1.44	1.38	2.77	3.20
	Average	*0.27*	*0.15*	*0.10*	*0.09*	*0.18*	*0.21*
	Weight	*0.27*	*0.15*	*0.10*	*0.09*	*0.18*	*0.21*
	Ranking	**1**	**4**	**5**	**6**	**3**	**2**

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
		Cast In-situ	Precast		Cast In-situ	Precast
No. of Expert	1	0.11	0.42	0.12	0.11	0.25
	2	0.11	0.42	0.14	0.09	0.24
	3	0.11	0.42	0.14	0.09	0.24
	4	0.11	0.42	0.14	0.09	0.24
	5	0.11	0.45	0.14	0.09	0.22
	6	0.09	0.44	0.16	0.09	0.22
	7	0.09	0.41	0.17	0.09	0.24
	8	0.09	0.36	0.21	0.09	0.25
	9	0.11	0.41	0.17	0.07	0.24
	10	0.11	0.41	0.17	0.07	0.24
	11	0.11	0.35	0.17	0.08	0.30
	12	0.11	0.35	0.14	0.09	0.30
	13	0.10	0.34	0.17	0.07	0.32
	14	0.07	0.40	0.16	0.09	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		4	1	3	5	2

	Factor	Time	Priority Vector	Ranking
SBS	Cast In-situ		0.10	4
	Precast		0.40	1
Continous	Continuous		0.16	3
BC	Cast In-situ		0.09	5
	Precast		0.25	2
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Priority Vector of Factor		Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
		Cast In-situ	Precast		Cast In-situ	Precast
No. of Expert	1	0.13	0.43	0.15	0.11	0.18
	2	0.11	0.43	0.14	0.11	0.21
	3	0.11	0.36	0.12	0.11	0.30
	4	0.14	0.38	0.18	0.12	0.18
	5	0.11	0.35	0.17	0.08	0.30
	6	0.11	0.41	0.17	0.07	0.24
	7	0.11	0.35	0.13	0.09	0.32
	8	0.11	0.35	0.17	0.08	0.30
	9	0.11	0.41	0.17	0.07	0.24
	10	0.12	0.37	0.18	0.12	0.22
	11	0.11	0.41	0.17	0.07	0.24
	12	0.11	0.30	0.19	0.16	0.25
	13	0.09	0.37	0.12	0.11	0.31
	14	0.08	0.41	0.17	0.09	0.26
	15	0.11	0.41	0.17	0.07	0.24
Sum		1.64	5.74	2.39	1.45	3.78
Average		*0.11*	*0.38*	*0.16*	*0.10*	*0.25*
Weight		*0.11*	*0.38*	*0.16*	*0.10*	*0.25*
Ranking		4	1	3	5	2

	Factor	Cost	Priority Vector	Ranking
SBS	Cast In-situ		0.11	4
	Precast		0.38	1
Continous	Continuous		0.16	3
BC	Cast In-situ		0.10	5
	Precast		0.25	2
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Priority Vector of Factor		Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
		Cast In-situ	Precast		Cast In-situ	Precast
No. of Expert	1	0.14	0.40	0.14	0.18	0.14
	2	0.11	0.45	0.13	0.11	0.20
	3	0.11	0.42	0.12	0.11	0.25
	4	0.09	0.23	0.18	0.12	0.37
	5	0.09	0.48	0.13	0.13	0.18
	6	0.08	0.45	0.17	0.13	0.17
	7	0.09	0.36	0.15	0.13	0.28
	8	0.08	0.45	0.16	0.14	0.17
	9	0.09	0.46	0.16	0.14	0.16
	10	0.09	0.37	0.15	0.14	0.26
	11	0.11	0.37	0.12	0.14	0.26
	12	0.14	0.33	0.12	0.10	0.31
	13	0.08	0.41	0.14	0.10	0.28
	14	0.11	0.37	0.10	0.08	0.34
	15	0.13	0.42	0.12	0.09	0.24
Sum		1.54	5.97	2.07	1.83	3.59
Average		*0.10*	*0.40*	*0.14*	*0.12*	*0.24*
Weight		*0.10*	*0.40*	*0.14*	*0.12*	*0.24*
Ranking		5	1	3	4	2

	Factor	Site Condition	Priority Vector	Ranking
SBS	Cast In-situ		0.10	5
	Precast		0.40	1
Continous	Continuous		0.14	3
BC	Cast In-situ		0.12	4
	Precast		0.24	2
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
		Cast In-situ	Precast		Cast In-situ	Precast
No of Expert	1	0.13	0.42	0.12	0.09	0.24
	2	0.11	0.42	0.12	0.11	0.25
	3	0.11	0.42	0.12	0.11	0.25
	4	0.09	0.42	0.14	0.11	0.24
	5	0.11	0.42	0.12	0.11	0.25
	6	0.09	0.42	0.14	0.11	0.24
	7	0.07	0.41	0.14	0.13	0.26
	8	0.10	0.41	0.11	0.10	0.28
	9	0.09	0.46	0.10	0.09	0.25
	10	0.10	0.44	0.13	0.10	0.24
	11	0.11	0.45	0.13	0.10	0.22
	12	0.10	0.44	0.13	0.10	0.24
	13	0.08	0.41	0.14	0.11	0.26
	14	0.08	0.40	0.16	0.08	0.28
	15	0.08	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
Ranking		**5**	**1**	**3**	**4**	**2**

	Factor	**Environmental Impact**	Priority Vector	Ranking
SBS	Cast In-situ		0.10	**5**
	Precast		0.42	**1**
Continous	Continuous		0.13	**3**
BC	Cast In-situ		0.10	**4**
	Precast		0.25	**2**
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Priority Vector of Factor		Span by Span (SBS)		Continuous	Balance Cantilever (BC)	
		Cast In-situ	Precast		Cast In-situ	Precast
No. of Expert	1	0.13	0.44	0.11	0.09	0.24
	2	0.13	0.41	0.14	0.07	0.24
	3	0.12	0.42	0.14	0.09	0.23
	4	0.09	0.41	0.17	0.09	0.24
	5	0.11	0.42	0.14	0.09	0.24
	6	0.09	0.41	0.17	0.09	0.24
	7	0.11	0.42	0.14	0.09	0.24
	8	0.09	0.41	0.17	0.09	0.24
	9	0.12	0.41	0.14	0.07	0.26
	10	0.10	0.41	0.14	0.09	0.26
	11	0.11	0.42	0.14	0.09	0.24
	12	0.11	0.42	0.17	0.09	0.21
	13	0.11	0.43	0.14	0.11	0.21
	14	0.11	0.42	0.12	0.11	0.25
	15	0.13	0.41	0.10	0.10	0.26
Sum		1.63	6.28	2.12	1.36	3.61
Average		0.11	0.42	0.14	0.09	0.24
Weight		0.11	0.42	0.14	0.09	0.24
Ranking		4	1	3	5	2

	Factor	Safety	Priority Vector	Ranking
SBS	Cast In-situ		0.11	4
	Precast		0.42	1
Continous	Continuous		0.14	3
BC	Cast In-situ		0.09	5
	Precast		0.24	2
			1.00	

APPENDIX D

CALCULATION SHEET

FOR SUPER STRUCTURE SELECTION

Structural System Comparison of "Expert No.1"

Factors	Site of project	Site Condition	Cost	Time	Safety	Environmental			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Site of project	1	1	1/3	1	1	1	RI		0.33	0.83	0.13	0.77	6.12
Site Condition	1	1	1/5	1/5	1	1		1.25	0.04	0.58	0.09	0.59	6.70
Cost	3	5	1	3	3	1	CI		135.00	2.26	0.34	2.19	6.38
Time	1	5	1/3	1	1	1		0.09	1.67	1.09	0.16	1.13	6.93
Safety and Health	1	1	1/3	1	1	1	CR		0.33	0.83	0.13	0.77	6.12
Environmental	1	1	1	1	1	1		0.07	1.00	1.00	0.15	1.00	6.60
							acceptable		Sum	6.60	1.00		38.75
												λmax =	6.46

	Factor	Span by Span (SBS): Precast			Span by Span (SBS): Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Size of project	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	1	5	3	3		1.11	45.00	1.89	0.33	1.96	5.87
	Under Slung	1	1	3	3	1	CI		9.00	1.44	0.26	1.47	5.73
	Crane Lifting	1/4	1/3	1	1/4	1/3		0.00	0.00	0.41	0.07	0.32	4.39
SBS CAST IN-SITU	Overhead MSS	1/3	1/3	5	1	1	CR		0.56	0.91	0.16	0.89	5.56
	Underslung MSS	1/3	1	3	1	1		0.08	1.00	1.00	0.18	0.92	5.19
							acceptable		Sum	5.64	1.00		26.74
												λmax =	5.35

	Factor	Span by Span (SBS): Precast			Span by Span (SBS): Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Project Criteria	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	1/3	1/5	3	3		1.11	0.60	0.92	0.15	0.85	5.58
	Under Slung	3	1	1/3	5	3	CI		15.00	1.57	0.26	1.55	5.93
	Crane Lifting	5	3	1	5	3		0.11	225.00	2.47	0.41	2.65	6.46
SBS IN-SITU	Overhead MSS	1/3	1/5	1/5	1	1	CR		0.01	0.49	0.08	0.36	4.47
	Underslung MSS	1/3	1/3	1/3	1	1		0.10	0.04	0.38	0.10	0.45	4.70
							acceptable		Sum	6.02	1.00		27.35
												λmax =	5.43

	Factor	Span by Span (SBS): Precast			Span by Span (SBS): Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Cost	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	1/3	1/5	1/3	1/3		1.11	0.00	0.41	0.07	0.33	4.61
	Under Slung	3	1	3	3	3	CI		81.00	2.08	0.37	2.27	6.17
	Crane Lifting	5	1/3	1	1	1		0.08	1.67	1.09	0.19	1.04	5.42
SBS IN-SITU	Overhead MSS	3	1/3	1	1	1	CR		1.00	1.00	0.18	0.90	5.09
	Underslung MSS	5	1/3	1	1	1		0.08	1.67	1.09	0.19	1.04	5.42
							acceptable		Sum	5.66	1.00		26.70
												λmax =	5.34

	Factor	Span by Span (SBS); Precast			Span by Span (SBS); Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Time	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	3	5	3	3		1.11	135.00	2.26	0.39	2.37	6.09
	Under Slung	1/3	1	3	3	3	CI		9.00	1.44	0.25	1.47	5.91
	Crane Lifting	1/5	1/3	1	1/3	1/3		0.09	0.01	0.44	0.08	0.33	4.37
SBS IN-SITU	Overhead MSS	1/3	1/3	3	1	1	CR		0.33	0.83	0.14	0.73	5.07
	Underslung MSS	1/3	1/3	3	1	1		0.07	0.33	0.83	0.14	0.73	5.07
							acceptable		Sum	5.81	1.00		26.52
												λ max =	5.30

	Factor	Span by Span (SBS); Precast			Span by Span (SBS); Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Safety and Health	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	1/3	5	3	3		1.11	15.00	1.57	0.26	1.52	5.90
	Under Slung	3	1	5	5	3	CI		225.00	2.47	0.41	2.56	6.32
	Crane Lifting	1/5	1/5	1	1/5	1/5		0.10	0.00	0.37	0.06	0.27	4.34
SBS IN-SITU	Overhead MSS	1/3	1/5	3	1	1	CR		0.20	0.76	0.13	0.63	4.98
	Underslung MSS	1/3	1/3	5	1	1		0.09	0.56	0.91	0.15	0.80	5.38
							acceptable		Sum	6.08	1.00		26.92
												λ max =	5.38

	Factor	Span by Span (SBS)			Span by Span (SBS); Cast In Situ				Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Environmental Impact	Over Head	Under Slung	Crane Lifting	Overhead (MSS)	Underslung (MSS)	RI						
SBS PRECAST	Over Head	1	1/3	3	3	3		1.11	9.00	1.44	0.25	1.45	5.76
	Under Slung	3	1	3	5	3	CI		135.00	2.26	0.39	2.48	6.28
	Crane Lifting	1/3	1/3	1	1	1		0.10	0.11	0.69	0.12	0.57	4.72
SBS IN-SITU	Overhead MSS	1/3	1/5	1	1	3	CR		0.20	0.76	0.13	0.72	5.39
	Underslung MSS	1/3	1/3	1	1/3	1		0.09	0.04	0.58	0.10	0.48	4.78
							acceptable		Sum	5.74	1.00		26.93
												λ max =	5.39

Permanent Structure Phase: Comparison of "Expert No.2"

Factors	Size of project	Site Condition	Cost	Time	Safety	Environmental		Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	1/3	1/3	RI	3.00	1.20	0.18	1.24	6.88
Site Condition	1/3	1	1	1	1/3	1/3	1.25	0.04	0.58	0.09	0.53	6.13
Cost	1/3	1	1	1	1	1/3	CI	0.11	0.69	0.10	0.67	6.49
Time	1/3	1	1	1	1	1/3	0.11	0.11	0.69	0.10	0.67	6.49
Safety	3	3	1	1	1	1	CR	9.00	1.44	0.22	1.53	7.10
Environmental	3	3	3	3	1	1	0.09	81.00	2.08	0.31	1.95	6.26
							acceptable	Sum	6.69	1.00		39.35
											λ max =	6.56

	Factor Site of project	Span by Span (SBS) Cast In-situ	 Precast	Continuous	Balance Cantilever (BC) Cast In-situ	 Precast	RI	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
SBS	Cast In-situ	1	1/5	1	1	1	1.20	0.20	0.76	0.13	0.61	4.76
	Precast	5	1	5	5	5	CI	625.00	2.92	0.49	3.05	6.23
	Continuous	1	1/5	1	1	1	0.01	0.20	0.76	0.13	0.61	4.76
BC	Cast In-situ	1	1/5	1	1	1	CR	0.20	0.76	0.13	0.61	4.76
	Precast	1	1/5	1	1	1	0.01	0.20	0.76	0.13	0.61	4.76
							acceptable	Sum	5.98	1.00		25.29
											λ max =	5.06

	Factor Site Condition	Span by Span (SBS) Cast In-situ	 Precast	Continuous	Balance Cantilever (BC) Cast In-situ	 Precast	RI	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.67
	Precast	5	1	5	5	3	CI	375.00	2.69	0.45	2.78	6.14
	Continuous	1	1/5	1	1	1	0.05	0.20	0.76	0.13	0.64	4.94
BC	Cast In-situ	1	1/5	1	1	1/3	CR	0.07	0.64	0.11	0.50	4.67
	Precast	3	1/3	1	3	1	0.04	3.00	1.20	0.20	1.13	5.56
							acceptable	Sum	5.92	1.00		25.98
											λ max =	5.20

	Factor Cost	Span by Span (SBS) Cast In-situ	 Precast	Continuous	Balance Cantilever (BC) Cast In-situ	 Precast	RI	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.52	4.71
	Precast	5	1	3	5	3	CI	225.00	2.47	0.43	2.59	6.06
	Continuous	1	1/3	1	1	1	0.05	0.33	0.83	0.14	0.72	4.96
BC	Cast In-situ	1	1/5	1	1	1/3	CR	0.07	0.64	0.11	0.52	4.71
	Precast	3	1/3	1	3	1	0.04	3.00	1.20	0.21	1.16	5.56
							acceptable	Sum	5.77	1.00		26.00
											λ max =	5.20

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Time	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.67
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.56	6.13
	Continuous	1	1/3	1	3	1/3	0.07	0.33	0.83	0.14	0.74	5.24
BC	Cast In-situ	1	1/5	1/3	1	1/3	CR	0.02	0.53	0.09	0.41	4.56
	Precast	3	1/3	3	3	1	0.06	9.00	1.44	0.24	1.40	5.73
							acceptable	Sum	5.91	1.00		26.33
											λ max =	5.27

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Safety	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	3	1/3	1.20	0.20	0.76	0.13	0.66	5.09
	Precast	5	1	3	5	3	CI	225.00	2.47	0.41	2.58	6.21
	Continuous	1	1/3	1	3	1/3	0.08	0.33	0.83	0.14	0.71	5.07
BC	Cast In-situ	1/3	1/5	1/3	1	1/3	CR	0.01	0.44	0.07	0.33	4.41
	Precast	3	1/3	3	3	1	0.07	9.00	1.44	0.24	1.41	5.81
							acceptable	Sum	5.95	1.00		26.60
											λ max =	5.32

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Environmental Impact	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.62
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.59	6.18
	Continuous	1	1/3	1	1	1/3	0.04	0.11	0.69	0.12	0.56	4.72
BC	Cast In-situ	1	1/5	1	1	1/5	CR	0.07	0.64	0.11	0.50	4.62
	Precast	3	1/3	3	3	1	0.03	9.00	1.44	0.25	1.39	5.66
							acceptable	Sum	5.88	1.00		25.79
											λ max =	5.16

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Time	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.67
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.56	6.13
	Continuous	1	1/3	1	3	1/3	0.07	0.33	0.83	0.14	0.74	5.24
BC	Cast In-situ	1	1/5	1/3	1	1/3	CR	0.02	0.53	0.09	0.41	4.56
	Precast	3	1/3	3	3	1	0.06	9.00	1.44	0.24	1.40	5.73
							acceptable	Sum	5.91	1.00		26.33
											λ max =	5.27

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Safety	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	3	1/3	1.20	0.20	0.76	0.13	0.66	5.09
	Precast	5	1	3	5	3	CI	225.00	2.47	0.41	2.58	6.21
	Continuous	1	1/3	1	3	1/3	0.08	0.33	0.83	0.14	0.71	5.07
BC	Cast In-situ	1/3	1/5	1/3	1	1/3	CR	0.01	0.44	0.07	0.33	4.41
	Precast	3	1/3	3	3	1	0.07	9.00	1.44	0.24	1.41	5.81
							acceptable	Sum	5.95	1.00		26.60
											λ max =	5.32

	Factor	Span by Span (SBS)		Continuous	Balance Cantilever (BC)			Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
	Environmental Impact	Cast In-situ	Precast		Cast In-situ	Precast	RI					
SBS	Cast In-situ	1	1/5	1	1	1/3	1.20	0.07	0.64	0.11	0.50	4.62
	Precast	5	1	3	5	3	CI	225.00	2.47	0.42	2.59	6.18
	Continuous	1	1/3	1	1	1/3	0.04	0.11	0.69	0.12	0.56	4.72
BC	Cast In-situ	1	1/5	1	1	1/5	CR	0.07	0.64	0.11	0.50	4.62
	Precast	3	1/3	3	3	1	0.03	9.00	1.44	0.25	1.39	5.66
							acceptable	Sum	5.88	1.00		25.79
											λ max =	5.16

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 13

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	1	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	7.02
Cost	1	5	1	3	1	1	15.00	1.57	0.25	1.65	6.67
Time	1	5	1/3	1	1	1	1.67	1.09	0.17	1.14	6.66
Health and Safety	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.35
Environmental Impact	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.35
							Sum	6.35	1.00		39.14
										λ max =	6.52

R.I. = **1.11** C.I. = **0.10** C.R. = **0.09** *acceptable*

Questionnaire No.1 Action by : Expertise No. 14

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	3	3	243.00	2.50	0.37	2.26	6.16
Site Condition	1/3	1	1/3	1/3	1	1	0.04	0.58	0.09	0.52	6.10
Cost	1/3	3	1	3	1	1	3.00	1.20	0.18	1.28	7.23
Time	1/3	3	1/3	1	3	3	3.00	1.20	0.18	1.19	6.75
Health and Safety	1/3	1	1	1/3	1	3	0.33	0.83	0.12	0.78	6.35
Environmental Impact	1/3	1	1/3	1/3	1/3	1	0.01	0.48	0.07	0.44	6.18
							Sum	6.79	1.00		38.76
										λ max =	6.46

R.I. = **1.11** C.I. = **0.09** C.R. = **0.08** *acceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 11

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1/3	1	1/3	3	1	1	0.33	0.83	0.12	0.86	6.96
Environmental Impact	1/3	1	1/3	1/3	1	1	0.04	0.58	0.09	0.53	6.20
							Sum	6.76	1.00		39.19
										λ max =	6.53

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

Questionnaire No.1 Action by : Expertise No. 12

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	1	1	27.00	1.73	0.27	1.82	6.69
Site Condition	1/3	1	1/5	1/3	1	1	0.02	0.53	0.08	0.58	6.90
Cost	1/3	5	1	1	1	1	1.67	1.09	0.17	1.15	6.72
Time	1/3	3	1	1	1	1	1.00	1.00	0.16	0.99	6.26
Health and Safety	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.35
Environmental Impact	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.35
							Sum	6.35	1.00		39.27
										λ max =	6.55

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

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 9

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	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	6.84
Health and Safety	1/3	1/3	1	3	1	1	0.33	0.83	0.12	0.83	6.96
Environmental Impact	1/3	1/3	1/3	1/3	1	1	0.01	0.48	0.07	0.46	6.64
							Sum	6.95	1.00		39.19
										λ max =	6.53

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

Questionnaire No.1 Action by : Expertise No. 10

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	3	3	3	3	3	243.00	2.50	0.37	2.26	6.16
Site Condition	1/3	1	1/3	1/3	1	1	0.04	0.58	0.09	0.56	6.53
Cost	1/3	3	1	1/3	1	1	0.33	0.83	0.12	0.81	6.58
Time	1/3	3	3	1	1/3	3	3.00	1.20	0.18	1.19	6.75
Health and Safety	1/3	1	1	3	1	3	3.00	1.20	0.18	1.25	7.07
Environmental Impact	1/3	1	1/3	1/3	1/3	1	0.01	0.48	0.07	0.44	6.18
							Sum	6.79	1.00		39.26
										λ max =	6.54

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

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 7

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.18
Site Condition	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.08	0.49	6.34
Cost	1	3	1	1/3	1/3	1/3	0.11	0.69	0.11	0.72	6.45
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	1	3	1/3	1/3	1	1	0.33	0.83	0.13	0.93	6.87
							Sum	6.18	1.00		38.69
										λ max =	6.45

R.I. = **1.11** C.I. = **0.09** C.R. = **0.08** *acceptable*

Questionnaire No.1 Action by : Expertise No. 8

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	1	1/3	3	27.00	1.73	0.27	1.85	6.83
Health and Safety	1	3	1	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
										λ max =	6.59

R.I. = **1.11** C.I. = **0.12** C.R. = **0.11** *unacceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 5

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1	1	1	1	1.00	1.00	0.17	1.00	5.86
Site Condition	1	1	1/3	1/3	1	1	0.11	0.69	0.12	0.77	6.50
Cost	1	3	1	1	1/3	1/3	0.33	0.83	0.14	0.99	7.00
Time	1	3	1	1	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
										λ max =	6.52

R.I. = **1.11** C.I. = **0.10** C.R. = **0.09** *acceptable*

Questionnaire No.1 Action by : Expertise No. 6

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1	1	1	1	1.00	1.00	0.17	1.00	6.03
Site Condition	1	1	1/3	1/3	1	1	0.11	0.69	0.11	0.71	6.16
Cost	1	3	1	1	3	1	9.00	1.44	0.24	1.56	6.53
Time	1	3	1	1	1/3	3	3.00	1.20	0.20	1.35	6.78
Health and Safety	1	1	1/3	3	1	1	1.00	1.00	0.17	1.24	7.47
Environmental Impact	1	1	1/3	1/3	1	1	0.11	0.69	0.11	0.71	6.16
							Sum	6.03	1.00		39.12
										λ max =	6.52

R.I. = **1.11** C.I. = **0.10** C.R. = **0.09** *acceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 3

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1/3	1/3	1/3	1/3	0.01	0.48	0.07	0.45	6.24
Site Condition	1	1	1/3	1/3	1	1	0.11	0.69	0.10	0.67	6.45
Cost	3	3	1	3	3	1	81.00	2.08	0.31	2.01	6.45
Time	3	3	1/3	1	1	1	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	1	1	1	3.00	1.20	0.18	1.14	6.34
							Sum	6.66	1.00		38.05
										λ max =	6.34

R.I. = **1.11** C.I. = **0.07** C.R. = **0.06** *acceptable*

Questionnaire No.1 Action by : Expertise No. 4

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	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	1	27.00	1.73	0.27	1.85	6.74
Environmental Impact	3	1	1	1	1	1	3.00	1.20	0.19	1.15	6.05
							Sum	6.31	1.00		38.72
										λ max =	6.45

R.I. = **1.11** C.I. = **0.09** C.R. = **0.08** *acceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1 Action by : Expertise No. 1

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
Size of project	1	1	1/3	1	1	1	0.33	0.83	0.13	0.77	6.12
Site Condition	1	1	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
							Sum	6.60	1.00		38.75
										λ max =	6.46

R.I. = **1.11** C.I. = **0.09** C.R. = **0.08** *acceptable*

Questionnaire No.1 Action by : Expertise No. 2

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	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	1	3	1	3	3	1	27.00	1.73	0.28	1.81	6.53
Time	1	3	1/3	1	1	1	1.00	1.00	0.16	1.04	6.49
Health and Safety	1	1	1/3	1	1	1	0.33	0.83	0.13	0.82	6.13
Environmental Impact	1	1	1	1	1	1	1.00	1.00	0.16	1.00	6.26
							Sum	6.26	1.00		38.06
										λ max =	6.34

R.I. = **1.11** C.I. = **0.07** C.R. = **0.06** *acceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction with

Questionnaire No.1   Action by : Expertise No.   15

Factor	Size of project	Site Condition	Cost	Time	Health and Safety	Environmental Impact	Multiply	nth root	Priorities Vector	Multiply Matrix	Divide
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	3	0.33	0.83	0.12	0.75	6.25
Environmental Impact	1/3	1	1/3	1/3	1/3	1	0.01	0.48	0.07	0.43	6.17
							Sum	6.96	1.00		38.21
										λ max =	6.37

R.I. = **1.11** C.I. = **0.07** C.R. = **0.07** *acceptable*

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		SBS : PRECAST			SBS : CAST IN-SITU	
		Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
No. of Expert	1	0.39	0.25	0.08	0.14	0.14
	2	0.41	0.26	0.07	0.13	0.14
	3	0.24	0.41	0.07	0.11	0.17
	4	0.31	0.31	0.09	0.15	0.15
	5	0.26	0.37	0.12	0.10	0.15
	6	0.27	0.39	0.12	0.08	0.14
	7	0.26	0.41	0.11	0.09	0.13
	8	0.26	0.44	0.10	0.08	0.12
	9	0.25	0.39	0.09	0.10	0.17
	10	0.26	0.38	0.07	0.12	0.17
	11	0.30	0.33	0.09	0.10	0.17
	12	0.25	0.39	0.09	0.10	0.17
	13	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*	*0.11*	*0.15*
Weight		*0.28*	*0.36*	*0.09*	*0.11*	*0.15*
Ranking		**2**	**1**	**5**	**4**	**3**

	Factor	**Time**	Priority Vector	Ranking
SBS	Over Head		0.28	**2**
	Under Slung		0.36	**1**
	Crane Lifting		0.09	**5**
SBS	Overhead MSS		0.11	**4**
	Underslung MSS		0.15	**3**
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		SBS : PRECAST			SBS : CAST IN-SITU	
		Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
No of Expert	1	0.07	0.37	0.19	0.18	0.19
	2	0.07	0.31	0.19	0.15	0.28
	3	0.08	0.37	0.19	0.15	0.21
	4	0.08	0.31	0.20	0.15	0.26
	5	0.08	0.40	0.19	0.16	0.18
	6	0.08	0.37	0.19	0.15	0.21
	7	0.07	0.25	0.39	0.14	0.15
	8	0.18	0.31	0.31	0.09	0.12
	9	0.25	0.37	0.18	0.10	0.10
	10	0.27	0.36	0.17	0.09	0.10
	11	0.29	0.42	0.08	0.09	0.11
	12	0.24	0.44	0.09	0.11	0.13
	13	0.24	0.44	0.07	0.13	0.13
	14	0.26	0.41	0.08	0.12	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*	*0.18*	*0.13*	*0.16*
Weight		*0.17*	*0.37*	*0.18*	*0.13*	*0.16*
Ranking		**3**	**1**	**2**	**5**	**4**

	Factor	Cost	Priority Vector	Ranking
SBS	Over Head		0.17	**3**
	Under Slung		0.37	**1**
	Crane Lifting		0.18	**2**
SBS	Overhead MSS		0.13	**5**
	Underslung MSS		0.16	**4**
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		SBS : PRECAST			SBS : CAST IN-SITU	
		Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
No. of Expert	1	0.15	0.26	0.41	0.08	0.10
	2	0.15	0.26	0.41	0.10	0.08
	3	0.18	0.18	0.45	0.09	0.10
	4	0.24	0.15	0.42	0.09	0.10
	5	0.21	0.22	0.39	0.08	0.10
	6	0.18	0.20	0.44	0.07	0.10
	7	0.15	0.31	0.37	0.07	0.10
	8	0.18	0.21	0.44	0.07	0.10
	9	0.20	0.20	0.41	0.07	0.11
	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	0.09
	13	0.19	0.20	0.42	0.09	0.10
	14	0.15	0.24	0.44	0.09	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*	*0.08*	*0.10*
Weight		*0.18*	*0.22*	*0.42*	*0.08*	*0.10*
Ranking		**3**	**2**	**1**	**5**	**4**

Factor		**Site Condition**	Priority Vector	Ranking
SBS	Over Head		0.18	3
	Under Slung		0.22	2
	Crane Lifting		0.42	1
SBS	Overhead MSS		0.08	5
	Underslung MSS		0.10	4
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		SBS : PRECAST			SBS : CAST IN-SITU	
		Over Head	Under Slung	Crane Lifting	Overhead MSS	Underslung MSS
No. of Expert	1	0.33	0.26	0.07	0.16	0.18
	2	0.32	0.32	0.06	0.15	0.14
	3	0.32	0.32	0.07	0.14	0.14
	4	0.36	0.32	0.06	0.12	0.12
	5	0.34	0.31	0.06	0.15	0.14
	6	0.36	0.36	0.06	0.11	0.11
	7	0.32	0.32	0.07	0.14	0.14
	8	0.27	0.38	0.07	0.14	0.14
	9	0.32	0.32	0.07	0.12	0.17
	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	0.07	0.10	0.15
	13	0.25	0.39	0.08	0.14	0.14
	14	0.30	0.33	0.09	0.10	0.17
	15	0.24	0.42	0.09	0.11	0.14
Sum		4.66	5.09	1.09	1.98	2.18
Average		*0.31*	*0.34*	*0.07*	*0.13*	*0.15*
Weight		*0.31*	*0.34*	*0.07*	*0.13*	*0.15*
Ranking		**2**	**1**	**5**	**4**	**3**

	Factor	Size of Project	Weight	Ranking
SBS Precast	Over Head		0.31	2
	Under Slung		0.34	1
	Crane Lifting		0.07	5
SBS Cast In-Situ	Overhead MSS		0.13	4
	Underslung MSS		0.15	3
			1.00	

Calculation Sheet

Comparison of factors with respect to overall satisfaction

	Priority Vector of Factor	Size of project	Site Condition	Cost	Time	Safety and Helth	Environmental Impact
No. of Expert	1	0.13	0.09	0.34	0.16	0.13	0.15
	2	0.16	0.11	0.28	0.16	0.13	0.16
	3	0.07	0.10	0.31	0.18	0.15	0.18
	4	0.08	0.14	0.16	0.19	0.27	0.19
	5	0.17	0.12	0.14	0.20	0.25	0.12
	6	0.17	0.11	0.24	0.20	0.17	0.11
	7	0.16	0.08	0.11	0.23	0.28	0.13
	8	0.11	0.08	0.19	0.27	0.23	0.13
	9	0.36	0.25	0.08	0.12	0.12	0.07
	10	0.37	0.09	0.12	0.18	0.18	0.07
	11	0.37	0.09	0.21	0.12	0.12	0.09
	12	0.27	0.08	0.17	0.16	0.16	0.16
	13	0.19	0.08	0.25	0.17	0.16	0.16
	14	0.37	0.09	0.18	0.18	0.12	0.07
	15	0.36	0.07	0.16	0.23	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	**1**	**6**	**2**	**3**	**4**	**5**

Calculation Sheet

Comparison of factors with respect to overall satisfaction

Priority Vector of Factor		SBS : PRECAST			SBS : CAST IN-SITU	
		Under Slung	Crane Lifting	Overhead MSS	Underslung MSS	Precast
No. of Expert	1	0.26	0.41	0.06	0.13	0.15
	2	0.25	0.39	0.07	0.14	0.15
	3	0.25	0.39	0.07	0.14	0.15
	4	0.24	0.41	0.07	0.14	0.13
	5	0.27	0.38	0.07	0.14	0.14
	6	0.25	0.37	0.10	0.10	0.18
	7	0.25	0.39	0.11	0.10	0.14
	8	0.27	0.39	0.10	0.10	0.14
	9	0.17	0.39	0.08	0.15	0.21
	10	0.20	0.42	0.09	0.09	0.20
	11	0.26	0.37	0.10	0.12	0.15
	12	0.33	0.31	0.09	0.12	0.15
	13	0.26	0.38	0.07	0.12	0.17
	14	0.25	0.39	0.09	0.12	0.14
	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	0.39	0.09	0.12	0.16
Ranking		**2**	**1**	**5**	**4**	**3**

	Factor	Safety	Priority Vector	Ranking
SBS	Over Head		0.25	**2**
	Under Slung		0.39	**1**
	Crane Lifting		0.09	**5**
SBS	Overhead MSS		0.12	**4**
	Underslung MSS		0.16	**3**
			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.