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An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects

Miss Su Lae Yee Zaw

จุฬาลงกรณ์มหาวิทยาลัย
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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Civil Engineering
Department of Civil Engineering
FACULTY OF ENGINEERING
Chulalongkorn University
Academic Year 2022
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แบบจำลองกระบวนการโครงข่ายเชิงวิเคราะห์ (ANP) สำหรับเลือกประเภทสัญญาร่วมลงทุนรัฐและเอกชน (PPP) ซึ่งเหมาะที่สุดสำหรับโครงการโครงสร้างพื้นฐาน

น.ส.ซู เลย ยี ซอ

จุฬาลงกรณ์มหาวิทยาลัย
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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมโยธา ภาควิชาวิศวกรรมโยธา
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ปีการศึกษา 2565
ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

Thesis Title	An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects
By	Miss Su Lae Yee Zaw
Field of Study	Civil Engineering
Thesis Advisor	Associate Professor VEERASAK LIKHITRUANGSILP, Ph.D.

Accepted by the FACULTY OF ENGINEERING, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Engineering

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ซู เลย ยี ซอ : แบบจำลองกระบวนการโครงข่ายเชิงวิเคราะห์ (ANP)
สำหรับเลือกประเภทสัญญาร่วมลงทุนรัฐและเอกชน (PPP)
ซึ่งเหมาะที่สุดสำหรับโครงการโครงสร้างพื้นฐาน. (An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects) อ.ที่ปรึกษาหลัก : รศ. ดร.วีระศักดิ์ ลิขิตเรืองศิลป์

งบประมาณมีความสำคัญต่อการพัฒนาโครงสร้างพื้นฐานของประเทศในด้านสังคมและเศรษฐกิจ อย่างไรก็ตาม รัฐบาลของหลายๆประเทศกำลังประสบปัญหาด้านงบประมาณและความสามารถทางเทคนิคที่จำกัดในการหาโครงสร้างพื้นฐานสาธารณะให้มีประสิทธิภาพ การร่วมลงทุนระหว่างพัฒนารัฐและเอกชน (Public-Private Partnership PPP) เป็นข้อตกลงความร่วมมือทางเลือกระหว่างรัฐบาลและเอกชนในหลายประเทศเพื่อช่วยในการแก้ปัญหาในส่วนนี้ รูปแบบสัญญา PPP ถูกกำหนดให้เป็นสัญญาระยะยาวระหว่างรัฐและเอกชนตั้งแต่กระบวนการออกแบบ การก่อสร้าง การเงิน การดำเนินการและการบริหารจัดการโครงการ รูปแบบสัญญา PPP นั้นมีหลากหลายรูปแบบ ซึ่งสามารถจำแนกโดยหลากหลายปัจจัย รูปแบบของ PPP ที่แตกต่างจะบ่งบอกถึงระดับความรับผิดชอบและความเสี่ยงที่เอกชนต้องแบกรับที่แตกต่างกันด้วย โดยทั่วไปรัฐบาลจะเป็นผู้ตัดสินใจเลือกรูปแบบ PPP ที่เหมาะสม ซึ่งขึ้นอยู่กับหลายปัจจัยที่มีผลโดยตรงต่อความสำเร็จของโครงการ วิทยานิพนธ์นี้นำเสนอแบบจำลองการตัดสินใจเลือกรูปแบบสัญญา PPP โดยใช้กระบวนการวิเคราะห์แบบโครงข่าย Analytical Network Process (ANP) จุดประสงค์ของแบบจำลองคือการเลือกรูปแบบสัญญา PPP ที่เหมาะสมโดยพิจารณาปัจจัยที่สำคัญ การจัดลำดับความสำคัญของปัจจัยอาศัยผลจากแบบสอบถาม แบบจำลองถูกประยุกต์ใช้กับกรณีศึกษาทั้งหมด 4 โครงการ โดยอาศัยการสัมภาษณ์เชิงลึกจากผู้เชี่ยวชาญด้าน PPP และการสัมภาษณ์ออนไลน์ ผลของวิทยานิพนธ์คือแบบจำลองการวิเคราะห์การตัดสินใจที่ประกอบด้วยกระบวนการวิเคราะห์โครงข่าย (Analytical Network Process) ซึ่งสามารถพัฒนารูปแบบสัญญา PPP ที่เหมาะสมโดยขึ้นอยู่กับปัจจัยที่ผู้ตัดสินใจเลือก วิทยานิพนธ์นี้สามารถช่วยผู้ที่เกี่ยวข้อง เช่น ผู้มีอำนาจตัดสินใจทางการเมือง นักลงทุนเอกชน และที่ปรึกษาโครงการ ซึ่งเป็นผู้ที่มีบทบาทหน้าที่รับผิดชอบในการเลือกรูปแบบสัญญา PPP ที่เหมาะสมกับโครงการ ดังนั้นวิทยานิพนธ์ฉบับนี้จะเป็นการนำเสนอแบบจำลองรูปแบบใหม่ที่สามารถลดระยะเวลาในการตัดสินหรือการปรับรูปแบบสัญญา PPP ที่ช่วยให้โครงการประสบความเร็จ แต่เนื่องจากข้อจำกัดของกฎหมายในประเทศไทย จึงทำให้แบบจำลองนี้ยังไม่สามารถนำไปประยุกต์ใช้ในชีวิตจริงได้

สาขาวิชา วิศวกรรมโยธา ลายมือชื่อนิสิต .....
ปีการศึกษา 2565 ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

6370427321 : MAJOR CIVIL ENGINEERING
KEYWORD:

Su Lae Yee Zaw : An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects. Advisor: Assoc. Prof. VEERASAK LIKHITRUANGSILP, Ph.D.

With the rapid social and economic development, a great deal of expenditure is crucial for the nation's infrastructure development. Nevertheless, the governments of many developing nations have been experienced with the limited budget and technical inability to deliver effective public infrastructures. Public-private partnership (PPP) has been adopted as an alternative collaboration arrangement between the government and the private sector in many nations to overcome these challenges. PPP can be defined as a long-term contract between a public agency and a private entity for rendering public facilities, including design, construct, finance, operate, and manage the project. The PPP contract types can be classified by various factors. Different PPP options imply different levels of responsibility and risks to be assumed by the private operator. Deciding an appropriate PPP contact type is always a risk-taking task for the government. This decision-making depends upon several criteria, which directly contribute to project success. This thesis proposes a multi-criteria decision-making model based on analytical network process (ANP). The proposed model can be employed to choose a PPP contract type that optimizes important criteria. The main input of the model is the priorities (weights) of the PPP contracts selection criteria, which are obtained from a series of questionnaire surveys. The model is applied to four case studies. One case study is an ongoing project and in-depth interview with a group of PPP experts. The three case studies are done via online interviews. The outcome of this research is a decision-analysis model that is structured by an analytical network process, which can determine the best type of PPP contract depending on decision-maker’s objectives. This research can assist the stakeholders such as political decision-makers, private investors, and strategic consultants who are responsible for proposing and selecting the various types of available PPP options that will suit their PPP projects. Moreover, using this supported optimal decision model can minimize the time-consuming of adopting the best form of PPP contract type, and it leads to project success. Although this proposed model is an innovative approach, due to the limitation of the legal system in Thailand, the proposed model needs to be modified to apply in practice.

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Field of Study:	Civil Engineering	Student's Signature .....
Academic Year:	2022	Advisor's Signature .....

ACKNOWLEDGEMENTS

Firstly, I would like to thank all persons who help, advised, encourage, and support me throughout my study period in Thailand.

I would like to special thanks to my advisor Associate Professor Veerasak Likhitrungsilp for his continuous support and advice. This research could not be done without his interesting ideas, guidance, and expertise.

I really appreciate all professors in Construction Engineering and Management field who support and teach me at Chulalongkorn University.

I am deeply grateful to the ASEAN and Non-AEAN scholarship program, Chulalongkorn University, Thailand. Without awarding this scholarship to me, I have no chance to continue my master's degree successfully.

Moreover, I really appreciate the respondents who participated in my data-collecting process. Without their cooperation, it would not be possible to finish my research.

Furthermore, I am thankful for the physical and mental support of my family, friends, and seniors who always trust and advice, and encourage me, especially during the study period in Thailand, when I needed them a lot.

Su Lae Yee Zaw

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CHAPTER 1
INTRODUCTION

1.1 Background

With the rapid growth of the country's social and economic development, expenditures on infrastructure would be necessary (Izaguirre and Mirzagalyamova 2008). However, developing-nation governments have been encountered with the lack of budget and technical inability to deliver effective infrastructure and facilities for the public (Babatunde et al. 2015). Worldwide, the process of project implementation is currently experiencing major change. Numerous research and practical experience have suggested that selecting the ideal project delivery strategy may lead to a reduction in the project's length and cost of up to 30%. Consequently, an important strategic choice is the project delivery system, which is made at the conclusion of the practical study and matches the choice of the project's financial requirements strategy. It's crucial to investigate and categorize different project delivery systems in order to choose the one that best meets the needs of the project manager (Thomas 2003).

Theoretically, public-private partnership (PPP) has been adopted as an alternative collaboration arrangement between the government and the private sector in most of the developed countries to overcome the above issues. A long-term agreement for the provision of public infrastructure or services between a private corporation and a public agency to plan, construct, finance, run, and oversee the project is known as a public-private partnership (PPP). The private-sector collaborator is accountable for risk management, and the compensation is related to its performance. The World Bank (2017) suggested that under the PPP policy and scope, it is necessary to consider how PPP projects are carried out to meet their objectives and standards. There have been numerous research works examining whether PPP initiatives are appropriate for meeting the infrastructure needs in different countries, including Eaton et al. (2007), Farquharson et al. (2011), Henjewele et al. (2014), Kakabadse et al. (2007), Kwak et al. (2009), Mubin and Ghaffar (2008), Shen et al. (1996), Tawiah and Russell (2008), and Zangoueinezhad and Azar (2014).

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Firstly, the government must examine whether or not a PPP project can be sufficiently supported politically or socially. Secondly, the government institutions should consider institutional, legal, and regulatory contexts. After considering these facts, policymakers must determine the most appropriate PPP contract types commercially and financially. Moreover, cost-benefit, value for money, funding sources, contractual arrangements, investor and government characteristics, among other factors, must be taken into account while designing a PPP framework (Delmon 2010).

The types of PPP contracts can be classified by various factors such as project characteristics, the degree of risk sharing between the public and private sectors, the involvement of the private sector, countries' policies, or laws population density and demographic conditions (World Bank 2017). The conventional approach for categorizing PPP options is based on the risk-sharing scheme between the government and the private sector as well as the ownership of assets (Roehrich et al. 2014). The World Bank (2017) stated that there are five types of PPP contracts:

1. Design-Build-Finance-Operate (DBFO), Design-Build-Finance-Operate-Maintain (DBFOM), and Design-Construct-Manage-Finance (DCFM)
2. Build-Operate-Transfer (BOT) and Build-Own-Operate-Transfer (BOOT)
3. Build-Transfer-Operate (BTO)
4. Rehabilitate-Operate-Transfer (ROT), and
5. Concession

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Yescombe (2017) divided PPP contracts into four main types per the responsibilities of the private sector and the ownership of the facility:

1. Build-Operate-Transfer (BOT) and Build-Own-Operate-Transfer (BOOT)
2. Design-Build-Finance-Operate (DBFO), Design-Construct-Manage-Finance (DCMF), and Design-Build-Finance-Maintain (DBFM)

3. Build-Transfer-Operate (BTO), Build-Transfer-Lease (BTL), Build-Lease-Operate-Transfer (BLOT), and Build-Lease-Transfer (BLT), and
4. Build-Own-Operate (BOO)

Moreover, there are many other terms such as lease, affermage, turnkey, operation, and maintain contract, which have been widely used by different institutions around the world. But these terms are not well defined (World Bank 2017).

Some contract types include the same typical functions and characteristics as those of PPP such as the partnership between the public and commercial sectors, performance-related, output-based, and long-term projects. On the other hand, these types of arrangements are not recognized as PPP because they do not involve significant capital investment from the private sectors, risk sharing between the public and the private sectors. They also do not entail long-term responsibilities for performance and do not include operation and management functions (World Bank 2017).

Per various reliable sources, the common forms of PPP options are designated, as shown in Table 1.1.

Options	Ownership	Design	Build	Operation and maintenance	Financial responsibility	Source of revenue	References
PPP							
DBFO DBFM DCMF DBFOM	Public	Private	Private	Private	Public, Public / Private, Private	Government or user pays	Asian Development Bank (2005), World Bank (2017), Yescombe and Farquharson (2018)
BOT BOOT	Public (owns until contract finished)	Private	Private	Private	Public	Government or user pays	Asian Development Bank (2005), World Bank (2017), Yescombe and Farquharson (2018)
BTO BTL BLOT BLT	Public (owns during construction)	Private	Private	Private	Public	Government or user pays	World Bank (2017), Yescombe and Farquharson (2018)
BOO	Private	Private	Private	Private	Private	Private, off-taker, public, users	Asian Development Bank (2005), World Bank (2017), Yescombe and Farquharson (2018)
Non-PPP							
DB Turnkey	Public	Private (by fee contract)	Private	Public	Public	Government pays	Asian Development Bank (2005), World Bank (2017)
DBB	Public	Private	Private	Public	Public	Government pays	Asian Development Bank (2005)

		(by fee contract)					
O and M	Public	Public or (contracted to private)	Public	Private	Public	Government pays	Delmon (2010), World Bank (2017)
Affermage	Public	Public	Private	Private	Private	User pays	Asian Development Bank (2005), Delmon (2010), World Bank (2017)
Lease	Public	Public	Private	Private	Private	Government pays	Asian Development Bank (2005), Delmon (2010), World Bank (2017)

Notes:

DBFO = Design-Build-Finance-Operate

DBFM = Design-Build-Finance-Manage

DCMF = Design-Construct-Maintain-Finance

DCFOM = Design-Construct-Finance-Operate-Maintain

BOT = Build-Operate-Transfer

BOOT = Build-Own-Operate-Transfer

DBB = Design Bid Build

BTO = Build-Transfer-Operate

BTL = Build-Transfer-Lease

BLOT = Build-Lease-Operate-Transfer

BLT = Build-Lease-Transfer

BOO = Build-Own-Operate

DB = Design Build

O and M = Operations and Maintenance

1.2 Problem Statement

The critical success factors of PPP projects are the key area of study related to the success of PPP procurement. The appropriate procedures and arrangements for PPP contracts is one of the critical success factors for PPP infrastructure projects (e.g., Abdel Aziz (2007), Chou and Pramudawardhani (2015), Jefferies et al. (2002), Natalia et al. (2021), Wibowo and Alfen (2014)). There are several PPP definitions and various PPP contract types. Table 1.1 displays the PPP contract types, which are widely used worldwide. Different PPP options imply varying degrees of risk and accountability that the private operator must accept. Various PPP options are associated with differences in their structures and contract forms. Presently, PPP projects have increasingly adopted hybrid contracts, which adopt a variety of contracts' qualities to mirror the most ideal regional requirements. Additionally, every contract type has pros and cons as well as varying efficacy and fit for various project and sectoral contents (Commission of the European Communities 2003).

A crucial task of the government is choosing an appropriate PPP option for an infrastructure project. This decision must be made in accordance with project objectives and many other criteria, leading to project success. This method always depends on a number of variables, such as the project objectives, the financial requirements, the market conditions, the supervision and management of government, the political and legal framework, and the risk factors (Mundial 2017).

Different PPP projects have their unique characteristics. Thus, it is necessary to evaluate PPP projects meticulously to derive their best contract types. Important questions are as follow. How do we choose an appropriate PPP contract type for a specific PPP project? Which methodology should we adopt for selecting the suitable type of PPP procurement? What criteria do we need to examine to choose relevant PPP arrangements? In Vietnam, the PPP arrangements have been developed and widely used for several years. Yet, they still do not have a single definite framework that acts as a guideline to help decide on the most relevant PPP type suitable for the type of infrastructure projects (Sy and Likhitruangsilp 2013). In order to implement more complex choices, decision-makers need carefully assess the local capabilities available. An important question for any government is which PPP structure is optimal for the given situations and can achieve the best results for governments.

Several past studies have examined specific types of infrastructure projects. Dabarera et al. (2019) proposed that for PPP road development projects in Sri Lanka, the Build-Own-Operate-Transfer (BOOT) contract is ideal. Yaseen and Naji (2021) concluded that the Build-Own-Operate (BOO) contract is the best PPP option for the abandoned construction projects in Iraq. In addition, Mohammed and Harputlugil (2017) developed a decision-making model that is structured with Analytical Hierarchy Process (AHP) and sensitivity analysis to select best PPP contracts for airport projects in developing countries. According to Liang and Jia (2018), the Build-Operate-Transfer (BOT) contract and the Design-Build-Operate-Transfer (DBOT) contract are the most appropriate PPP options for the transportation sector. However, previous studies do not address which PPP contract type is the most suitable for a certain infrastructure project.

Choosing a suitable PPP contract type is a crucial and complex process for governments and stakeholders because multiple criteria must be considered. Stakeholders (e.g., political decision-makers, investors, and strategic consultants) are usually responsible for nominating PPP options. Political decision markers to approve decision criteria for selecting preferred and recommended PPP options and investors to provide feedback on contributions to various PPP options. It is the duty of strategic consultants to provide a fair assessment of PPP options, to examine the current system, and to suggest changes (Asian Development Bank 2005). It was reported that 70% of the termination of PPP contracts resulted from the fact that the government did not have enough experience to choose the proper PPP contract type (Noorzai et al. 2016). During the selection process, decision-makers should notice the use of a particular PPP contract type for a particular sector (Asian Development Bank 2005).

Similar projects with different contract types and different projects with similar PPP options were observed in previous PPP projects. Even though it is quite complicated, the decision-makers have spent much time on debating the related merits of different PPP options through specific legal systems historically and nationally. Nonetheless, there is no common methodology for selecting the best PPP solutions. (Delmon 2010). The lack of a universal categorized methodology can lead to confusion and limitation to the success of PPP projects.

For choosing a feasible PPP contract type for an infrastructure project, the simultaneous consideration of all pertinent factors should be followed by their integration into a decision model. In order to evaluate pertinent PPP possibilities, an appropriate multi-criteria decision-making (MCDM) model is required. In past studies, several decision-analysis methods have been applied to select appropriate PPP contract types such as analytical hierarchy method (AHP), outranking method (OR), analytical network process (ANP), simple weighted sum approach (WS), fuzzy set theory (FST), and multi-attribute utility analysis (MAUA). Mohammed and Harputlugil (2017) developed an AHP model and sensitivity analysis to select the best form of PPP contracts for airport projects in developing countries. Yaseen and Naji (2021) implemented an ANP model as a tool to define the most reasonable PPP option to solve the problems of abandoned construction projects in Iraq. By using both AHP and ANP

techniques. El Chanati et al. (2016) created a multi-criteria evaluation methodology. to achieve the optimal solution of the maintenance plan for plumbing service.

The previous MCDM-based models were effectively employed in deciding the PPP contract types for infrastructure projects and construction industries. However, the proposed models did not cover all assessment criteria. Moreover, the interdependent relationships between the criteria and alternatives were not included. The validity of these results can be improved by considering all relevant criteria and their interdependent relationship as an input means in the decision-analysis model.

The analytical network process (ANP) can be applied to not only the significance of criteria and alternatives hierarchically but also the significance of the alternatives themselves as well as to solve the problems as mentioned above. An expansion of the analytical hierarchy process (AHP) is the ANP. The interdependence of criteria and alternatives provides a more systematical approach in the decision-making process. Its network process includes clusters (component, criteria, node) and elements (sub-criteria) in the cluster (Saaty and Vargas 2006). This research proposes an ANP decision-analysis model by considering all relevant criteria that significantly affect the selection of PPP contract types. The ideal contract type can be determined based on the weight assessment provided by the established ANP model. The suggested approach enables decision-makers to choose the appropriate PPP contract type for their infrastructure projects and evaluate the significance of various variables.

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1.3 Research Objective

The objective of this research is to develop an analytical network process-based decision-making model (ANP). The proposed model can assist in choosing a PPP contract type that optimizes important criteria such as project characteristics, objectives, and risk factors.

1.4 Scope of Research

This research mainly focuses on developing an ANP model for choosing an optimal PPP contract type. The main input of the model is the priority of the PPP contract selection criteria, which will be obtained from a series of questionnaire surveys. The surveys were conducted in Thailand. All research participants must be experienced in PPP infrastructure projects. A group of seven experts will opine in finalizing the PPP contract selection criteria during a pilot survey. Subsequent questionnaire surveys invited four respondents from both public sector and private entities such as government officers, contractors, subcontractors, sponsors, and consultants with over five years of experience in PPP projects. After that, a case study was done on a real project with four groups of experts. Since this research primarily investigates the PPP contract types widely used in Thailand, we focus on the BOT, BTO, BOO, and DBFO contracts only.

1.5 Research Steps

This research consists of seven steps.

Step 1: Review relevant theory and literature to identify major criteria while selecting appropriate PPP contract types and explore existing decision-supporting methods.

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Step 2: Compile and analyze major PPP contract types, which are widely used in developing countries.

Step 3: Finalize the list of criteria from Step1. Conduct interviews with seven PPP experts by providing a list of criteria and ask them to specify the criteria that affect the selection process of PPP arrangement.

Step 4: Assess the weight of the finalized criteria and their priorities by interviewing seven PPP professionals. The respondents rank the priorities of the criteria based on the fundamental scale of an absolute number (1 to 9).

Step 5: Rank the best fit PPP contract type based on the priorities of the weight of the criteria with the use of analytical network process (ANP).

Step 6: Verify the proposed decision-analysis model by applying it to a case study.

Step 7: Identify the limitation of the proposed decision-analysis model.

Conclude the research.

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CHAPTER 2
LITERATURE REVIEW

2.1 Overview of Public-Private Partnership (PPP)

2.1.1 Definition of PPP

Over the past few years, PPP has become more popular because of its advantages and is widely used all over the world. From the perspective of the government, PPP is expected to provide financial value and transfer operational risk to the private sector, which has the necessary knowledge and technical know-how in a given industry or technological discipline. Additionally, it enables the private sector to teach and provide the government with specialized technologies. According to the private sector, PPP can foster economic prospects since the private sector can provide guidance to the government on efficient procedures and the government can reduce some urgent risks, such as certain legal processes. Better value-for-money services, in the view of the general public, can result from private agency knowledge and government-subsidized prices that are reasonable (National Science Technology and Innovative Policy Office 2015).

Through public-private partnerships (PPP), the public and private sectors can collaborate on infrastructure projects and other services. While engaging the private sector, PPP provides a system that met the guarantee of the social requirement. Thus, it led to the successful reformation of the sectors and public investments have been reached (Asian Development Bank 2005). The government is using a relatively new strategy to boost the private sector's involvement in the delivery of public services. As a result, the PPP model has emerged as a prominent strategy for delivering public amenities and services in many nations around the globe.

Although PPP is a popular and widely used strategy in supplying public amenities and services in numerous developed and developing nations, there is no clear definition of PPP. There are various PPP goals and definitions depending on the organizations, authors, and experts. Therefore, in Table 2.1 listing of PPP's

characteristics, the perspective on one particular component should be highlighted. The three main goals of using PPPs to improve state performance are:

(1) attracting capital investment from the private sector;

(2) increasing efficiency and making better use of resources; and

(3) reforming the public sector through the distribution of responsibilities, rewards, and accountability.

Table 2.1 Definitions of PPP

No	"Definitions of PPP"
1	"PPP is a long-term contract between a private party and a government agency for the creation of public assets or the provision of services, in which the private party assumes significant risks and management responsibility" (World Bank 2017)
2	"The term PPP refers to the scope of all possible relationships between public and private organizations in terms of infrastructure or other services" (Asian Development Bank 2005)
3	"PPP is a contractual agreement that allows a private partner to participate more in relations with the state than traditional participation, which usually involves the modernization, construction, operation, maintenance, or management of a particular object, system between a government and a private company." (Kweun et al. 2018)
4	"Long-term public-private partnership agreement", "design, construction, financing, and commissioning of social infrastructure by the private party", "PPP payment to a private party or state or users", "state ownership of the object, or PPP" "Transfer to state ownership upon expiration of the contract".

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	(Yescombe and Farquharson 2018)
5	“The transfer of investment projects, traditionally implemented and financed by the public sector, to the private sector.” (European Union Commission 2003)

As a result, the community has not established what the precise meaning of "PPP" is. Generally speaking, the word refers to partnership between business and government in funding, building, modernizing, managing, or maintaining infrastructure or providing services (Garvin 2010). The same time, “PPP is a contractual relationship between government agencies and the private sector aimed at increasing the participation of the private sector in transport projects” (Soomro and Zhang 2015). The World Bank (2017) noted that the lack of precise terms and criteria for PPPs restricted their growth and confounded the decision-makers.

2.1.2 Types of PPP contract

Depending on how much private participation there is in PPP initiatives, various PPP models may be established. A new type of PPP addressing funding and asset ownership emerges as the degree of human involvement in the project changes.Some of the contract types have the same characteristics as PPP. Because they lack the long-term nature of PPPs, substantial private capital investment, and the high degree of long-term performance accountability that comes with investing in infrastructure assets, they are not PPP contract types like management contracts or service contracts (World Bank 2017).

According to (Kwak et al. 2009), there are five varieties of PPP agreements:

- Build-Operate-Transfer (BOT)
- Design-Build-Finance-Operate (DBFO)
- Design-Build-Operate (DBO)

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- Operation-Maintenance(OM)
- Build-Own-Operate (BOO) .

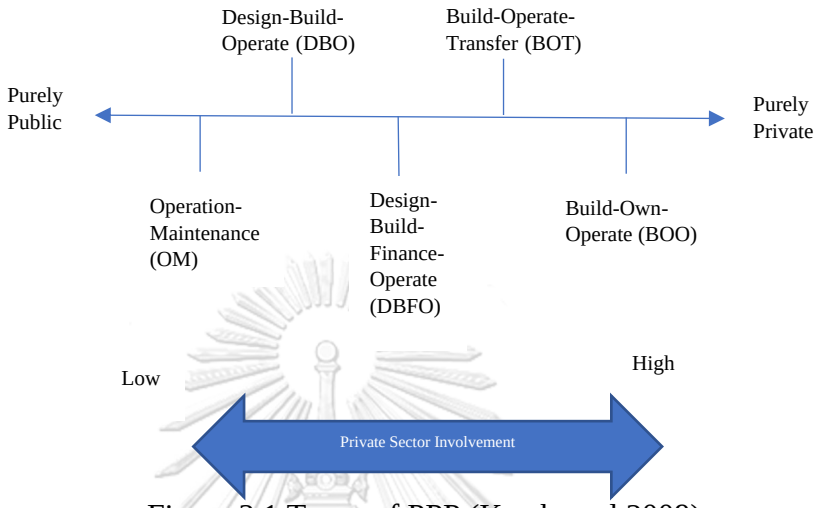

Figure 2.1 Types of PPP (Kwak et al.2009)

Moreover, (Asian Development Bank 2005) described those five types of PPP contracts which are widely used in Asia. They are:

1. Concessions
2. Management contracts
3. Service contracts
4. Lease contracts
5. BOT and similar arrangements

Furthermore, Karim and Alkaf (2001) stated that PPP agreements can be categorized into five main groups, including;

1. Supply and management contract
2. Turnkey
3. Affermage / Lease
4. Concessions

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5. Private ownership of assets and PFI type

2.2 PPP Projects in Thailand

The legal, administrative, cultural, and social foundation for PPP agreements differs from nation to nation. Some nations pass general PPP laws to encourage PPP agreements and establish private investment in infrastructure. Instead of being subject to general or sector-specific PPP laws, government policy, and supplementary arrangements like the creation of PPP units or other governing organizations helping public and private negotiation, PPP plans are controlled in other countries (such assistance is based on the guiding principles of government effectiveness, stability, and consistency in promoting PPP delivery and procurement.)

Since the ’90s PPP has been developed in different infrastructure projects, consisting of power and electricity, ports, toll highways and expressways, public transit, water and sanitation, and telecom in Thailand. The most active sectors with the PPP scheme are transportation and energy (Kokkaew and Likhitruangsilp 2018). The Thai government also considers PPP as a substitute for the traditional procurement strategy for developing prospective infrastructure projects. However, the Thai Government is facing several challenges in arranging the PPP framework. There are some limitations and difficulties in using PPP arrangements such as lack of clarity in terms of interpretation and definition, failure to cover all types of PPP, do not have clear methodologies for risk allocation, evaluation and procurement method, and time-consuming procedure (Susangarn 2007).

To meet the Government’s aim of managing successful PPP infrastructure projects, the research will cover the evaluation and choosing the suitable procurement, will propose a decision-analysis model to reduce time-consuming procedures for decision-makers.

Thailand’s PPP infrastructure projects in previous years used BOT contract type for BTS projects, DBOM for Blue Line, BOO contract for power and electricity projects, and for telecom they applied BTO contract type.

2.3 Concern Criteria for Selecting Appropriate Types of PPP Contracts

A sourcing strategy is a procurement system for completing projects that allots particular roles and powers to individuals and groups. In order to generate forms of power within a coalition of opposing or cooperating interest groups that are more than just contractual relationships, the process of choosing a procurement system necessitates the development of a distinctive set of social interactions (Love et al. 2012). As a result, the project's chosen procurement system will specify how closely or distantly the parties will cooperate.

In particular, when public procurement systems are weak, it is unclear ways to use public resources, such as foreign aid, more efficiently. However, the price of purchasing infrastructure might not be as low at this time as it could be. As a result, before selecting the procurement method, it is crucial to reevaluate the budgetary requirements for infrastructure development as well as the procurement effectiveness of that process. According to Ratnasabapathy and Rameezdeen (2010), finding the criteria for procurement selection is necessary for the project's efficient and effective completion and the creation of a model appropriate for an actual selection procedure when it is not possible to select a procurement system that is suitable for a building project in a systematic or practical manner.

As stated by (Asian Development Bank 2005) choosing a suitable PPP option is dependent on a diagnosis of:

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- Technical limitations and industry objectives (determined by the diagnostic)
- Legislative and regulatory restrictions (determined by the diagnostic)
- Institutional problems (determined by the diagnostic)
- Financial limitations (determined by the diagnostic)
- The market's interest (both domestically and internationally, as will be discussed below); and
- The sector's unique requirements, which are based on the system or population's features.

Moreover, the decision-makers need to compare the available PPP options with specific project requirements. In addition, the developers also need to consider the below criteria.

1. Government objectives for the PPP process: such as
    - To reduce the costs of service
    - To improve billing and collection
    - To expend coverage
2. Government's preference in the PPP option

"Option	Political Commitment	Cost Recovery Tariffs	Regulatory Framework	Information Base	Government Capacity for Contracting, Management, and Analysis
Service Contract	Low	Low	Low	Low	Moderate
Management Contract	Moderate	Moderate	Moderate	Low	Moderate
Lease	Moderate	High	High	High	High
Concession	High	High	High	High	High
Build-Operate-Transfer and variations	High	Variable	High	High	High"

Figure 2.2 Prerequisites of PPP options (Asian Development Bank 2008)

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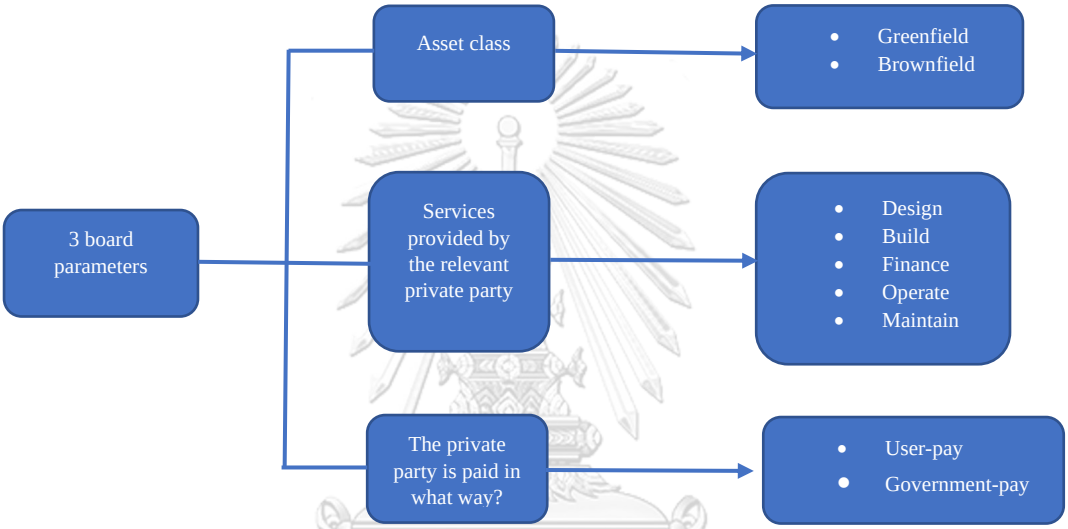
3. The private sector's interest in the option

Analysis of prior investments in the area, nation, and sector, as well as an evaluation of market interest, can be used to determine the likely degree of interest (Asian Development Bank 2005).

Moreover, based on (World Bank 2017) three factors are taken into account while describing PPP contracts.:



2.4 Decision-Supporting Methods (DSMs)

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PPPs are mostly driven by the desire to save money. Therefore, by enhancing service quality and innovating, the government, the private sector, and decision-makers must increase operational, construction, and procurement efficiencies. Experience has shown that the widely accepted PPP framework is essential for the success of PPP initiatives(World Bank 2017). The relevance of how DSMs work to achieve an objective has been recognized by academics and industry (Cheung et al. 2001; Love et al. 1998). Indecision supporting methods (DSMs), to aid decision-makers in making well-informed decisions, mathematical models involving tools and techniques, as well as judgments, have been constructed (Luu et al. 2003).

Furthermore, how these DSMs work and how they are different from one another must be investigated. Some DSMs are conditional on customers using them,

and most of the models take a long time to complete due to the need for skill and knowledge to employ complicated mathematical approaches (Alhazmi and McCaffer 2000). Each DSM, of course, has its own set of pros and cons, and suitability for use in a specific project.

DSMs are divided into four types based on the features of the tools and processes employed in the decision-making process:

- Analysis of economic and organizational aspects (EO)
- Artificial intelligence (AI)
- Predicting techniques (PT) and
- Multi-criteria decision making (MCDM).

2.4.1 Artificial intelligence (AI)

Zhao and Ying (2018) classified the DSMs of artificial intelligence into three groups. They are case-based reasoning (CBR), interaction matrix (IM), and artificial neural network (ANN), these methods are mainly dependent on the users' experience.

Table 2.2 Description of artificial intelligence (AI) models

DSMs	Diagnostic	Benefits/Limitations	Authors
CBR	CBR studies the intricate fundamental interrelationships of procurement system requirements and involves fuzzy qualities. It is based on clients' personal experiences and their priorities are heavily weighted in the selection of criteria. However, it is not extensively	The acquired data is extremely accurate (Benefit). User-unfriendly (Limitation). The CBR system's performance may be subjective and	Chen et al. (2011) Luu et al. (2003,2005, 2006),

	employed in procurement selection decision-supporting approaches. Besides, it is mostly used to determine whether the system is properly established. The framework can be built using the information gathered from specialists.	insufficient (Limitation).	
ANN	Chen et al. (2011) used the ANN approach to determine which route was optimum for the intended project. They described that ANN required a large amount of data information since data gathering was particularly difficult if there were just previous PPPs, ANN was ignored when examining the PPP context.	Data collecting is difficult and is ignored when examining the PPP context (Limitation).	Chen et al. (2011)
IM	To meet the project context, reassess, priorities of clients' needs and project parameters, the pros and cons of each procurement technique clearly will be presented by this method.	It describes the advantages and disadvantages of every procurement strategy. (Benefit) The respondents' experience strongly influences the findings and is user-unfriendly (Limitation).	Tucker and Ambrose (1998)

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2.4.2 Predicting techniques (PT)

The regression model (RM) is developed as a performance prediction model that can give project owners information about their chances of achievement. It can be employed if evidence exists that one aspect has an effect on another. The disadvantages of using this model are complicated, arduous, and inaccessible. Moreover, the outcome must be supported by relevant experiential judgments.

2.4.3 Analysis of economic and organizational aspects (EO)

In addition to examining the compatibility of various procurement methods and addressing institutional forms, outlined key perspectives of strategic management organization at the project level Chong and Preece (2014). Rajeh et al. (2015) assessed and selected procurement strategies. Both of these studies were conducted from an economic perspective. EO can be divided into two categories: the McKinsey 7 S model and the transaction cost-based approach (TCBA) (MC).

Table 2.3 Description of economic and organizational aspects models

DSMs	Diagnostic	Benefits/Limitations	Authors
TCBA	The transaction cost is used to determine including the pre- and post-contract costs for each procurement technique.	This strategy can improve financial sufficiency and can identify the most advantageous contractual options.	Chang and Ive (2002), Ive and Chang (2007), Rajeh et al. (2015)
MC	The McKinsey 7S Model is an institutional tool that evaluates the economy and the future well-being of the company. It	This method can specify various organizational	Chong and Preece (2014)

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	evaluates a company's compliance with seven internal organizational criteria to see whether it has the structural backing required to succeed.	forms and procurement approach.	

2.4.4 Multi-criteria decision making (MCDM)

Mathematical simulation techniques are used in multi-criteria decision-making analysis to make a comparison and compare competing options depending on several factors. In this approach, the possibilities are ranged from most desirable to least preferred. Apart from the necessities, the weight and preference functions are considered (Ozsahin et al. 2021). Decision-makers in the environmental studies and civil engineering occasionally encounter issues requiring numerous criteria, hence these fields tend to employ this method the most. Decision-making is vital of importance to the success of any projects of the civil engineering. Any bad decision can have a negative impact on people's lives as well as the cost and effectiveness of the time put into a project. When it comes to implementing a project, civil engineers are frequently battling with options. These options include things like the type, length, strength, and durability of the material to be used. Moreover, Likhitruangsilp et al. (2017a) stated that the most serious threat to PPP highway development projects in China was a stagnant government decision-making process and a feasible solution need to be figured out in advance.

The problem mentioned above can be assisted by multi-criteria decision methods (MCDC) and it recently has been used. There are numeral types of MCDMs, and some approaches are commonly and frequently used such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), a simple weighted sum approach (WS), fuzzy set theory (FST), outranking method (OR) and multi-attribute utility analysis (MAUA).

Table 2.4 Description of multi-criteria decision making (MCDM) models

MCDM	Diagnostic	Benefits / Limitation	Author
AHP	The three steps of AHP are (1) establishing the goal, (2) defining the criteria, sub-criteria, and alternatives in relation to the goal, and (3) rating the alternatives using a pairwise comparison of the weight of the criteria.	The outcome is accurate and acceptable. Comparison is a kind of synthetic way.	Roy (2004)
ANP	The analytical hierarchy approach is expanded upon by the ANP, and it is much more systematic than (AHP). It includes a network that consists of the cluster (component, criteria, node) and elements as well (sub-criteria) in the cluster (Saaty and Vargas, 2006).	Concept explanation and process management are extremely challenging. A standard tool to solve complex decision problems.	Saaty and Vargas (2006)
FST	The linguistic fuzzy membership functions' degree of fuzziness • Using a horizontal perspective • Those functions can explain the selection criteria to be used in procurement. We must	This strategy can help qualified consultants to reduce some confusion. Users must have some amount of expertise with fuzzy approaches, though.	Cheung et al. (2001), Luu et al. (2006)

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	set up four phases in order to construct a vertical strategy. • Comparing two options • Using probabilistic characteristics to estimate the membership function		
OR	This method includes pairwise comparison and ranks the alternatives.	Can help with the difficult decision-making process. Complex process and user inconvenience.	OJO and IKPO (2013)
MAUA	Quantitative decision approach. Begin with calculating mean utility value of each criterion and based on the priority, need to weigh. And then rank and sum the utility score. The option with the highest score is deemed to be the best procurement strategy.	Strongly rely on the respondents' experience and the accuracy is not reliable.	Chang and Ive (2002), Love et al. (1998), OJO and IKPO (2013)

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2.4.5 Summary of DSMs review

Among the various decision-supporting methods, the multi-criteria decision method is the most suitable method to apply in civil engineering and environmental engineering (Marović et al. 2021). The most popular MCDM in procurement selection method is AHP and 25% of papers are used in their research (Zhao and Ying 2018).

Over the past few years, there were numerous studies that used AHP technology to find solutions for issues in various industries. For example, (Arukala et al. 2019) suggested a framework for the assessment of sustainable performance in the construction industry; (Kokangül et al. 2017) examined risk management; (Lee and Chan 2008) adopted AHP to develop the most sustainable design for the evaluation of urban renewal proposals; and (Darko et al. 2019) investigated the use of AHP in construction management. To choose the best private partners for housing projects, (Abdullah and Alshibani, 2021) used the analytical hierarchy process (AHP) and the multi-attribute utility theory (MAUT). In addition, the outranking method (OR) and the simple weighted score approach (WS) are also employed to determine the optimal procurement strategy.

Despite similar ranking methods, the outcomes can vary when it comes to solving the same problem. Furthermore, fuzzy set technique (FST) and regression model (RM) were also used to be able to identify the critical success factors of PPP projects. However, the published papers with these two methods are infrequent (lower than 20%) and the application process is time-consuming and user-unfriendly techniques (Chan et al. 2002; Ling and Liu 2004; Zhao and Ying 2018). Jin et al. (2018) used ANP technology with the purpose of developing a framework that can provide several optimum temporary facility layout planning. Furthermore, (Chanati et al. 2016) proposed a multi-criteria assessment model to maximize the service schedule for water planning by using ANP and AHP approaches.

2.5 Research Gaps

To choose the best PPP contract type using the Analytic Network Process, we want to create a decision-supporting model in this study. Despite the fact that the earlier MCDM-based decision models are useful for selecting the optimum PPP contract type, the developed models did not examine the weight of the alternatives, and the optimum contract type was selected based on the highest score of the weight of the criteria. Therefore, there has been a research gap to develop a decision-supporting model that will consider the interrelationship between the criteria and the alternatives to attain a more accurate outcome. Moreover, past studies and reports performed the most suitable contract type for the sector by sector and none of them investigated the standard forms of the decision-supporting model which is the main tool to assist the decision-makers for PPP infrastructure projects and has a research gap as well.

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CHAPTER 3
RESEARCH METHODOLOGY

This chapter presents the research framework and the methodology used in this research to achieve the objective of selecting the appropriate PPP contract type for infrastructure projects. The steps of the research are discussed in the sections below and the data analysis process for the identification and ranking of criteria that need to contemplate when nominating the most suitable type of PPP arrangement. It will be proposed and validated by super decision software. In addition, in-depth interviews, questionnaire survey methods, and document analysis are applied for data collection.

3.1 Research Framework

The research's framework is shown in Figure 3.1, which consists of seven steps.

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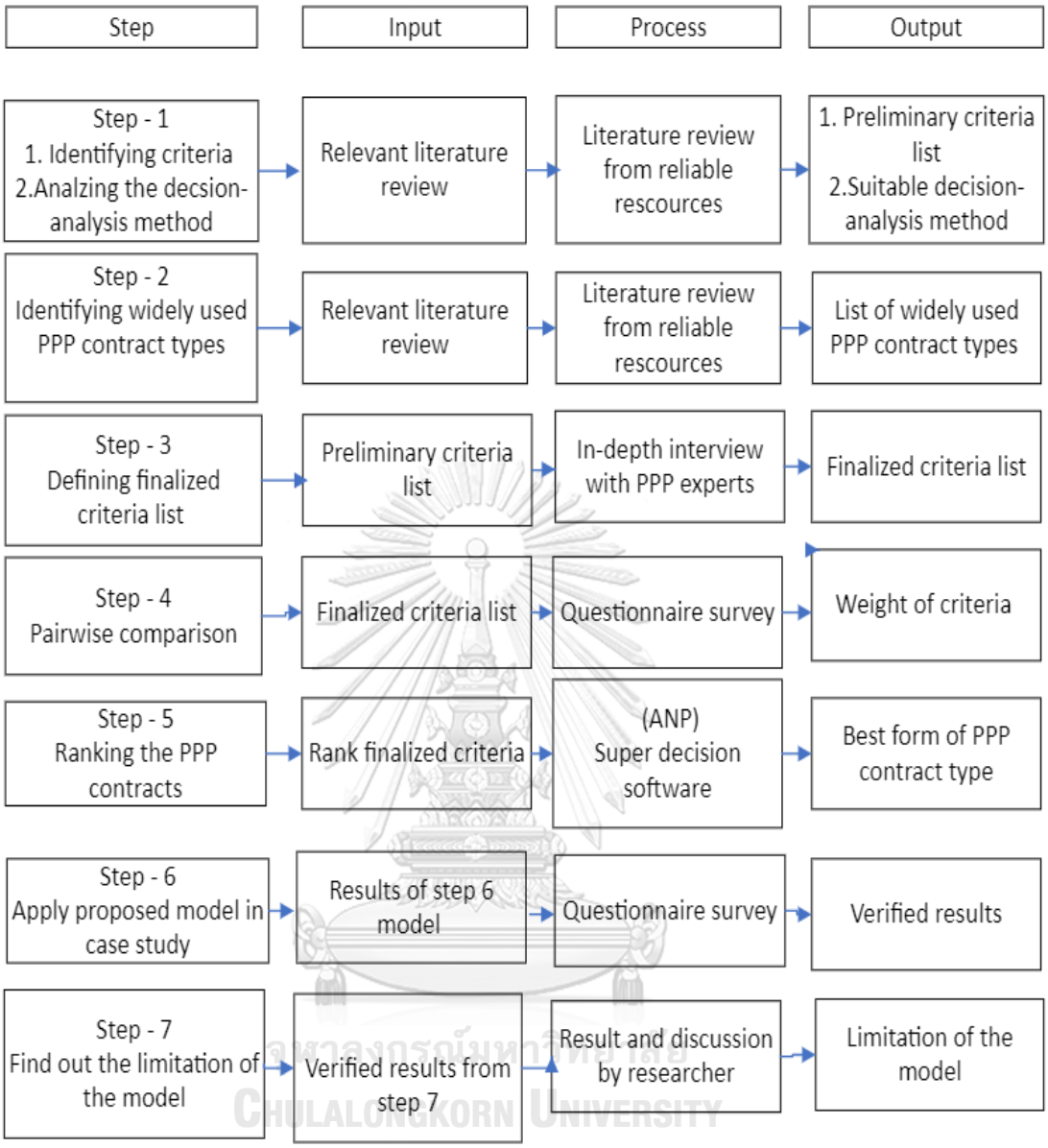

Conclude the research.

Figure 3.1 Research framework

Step 1: Review theory and literature to identify the effective criteria while selecting the appropriate type of PPP contract and explore the decision-supporting methods.

A variety of resources are explored to gain insight into Public-Private Partnership projects and their practices in different countries. Theories and literature are searched and reviewed on various topics such as definitions and types of Public-Private Partnership (PPP) contracts, available PPP contracts, the criteria to select the

appropriate type of PPP options, and various decision-supporting methods that are used in the procurement selecting approach. The identification of criteria that need to inspect the selection of suitable PPP arrangements are obtained through literature review. Relevant literature contributes to develop a set of criteria that makes it easier to implement a pilot survey.

No PPP alternative, it may be argued, could be used without being tailored to the local circumstances. The choices offer a selection of PPP contract options that can be altered to meet specific requirements of the project. Additional changes might be required to facilitate the financial transaction, address concerns of potential partners, improve the supply of services for the underprivileged, and categorize labor difficulties. The country background, the project's specifications, the government agency's nature and functions may all influence the leading procurement process. In this research, twenty-eight selected criteria are mentioned based on the literature review as a pilot outcome. They are:

1. Risk allocation and sharing
2. Government’s preference in the option
3. The private sector’s interest in the option
4. Types of project nature
5. Strong private consortium
6. Available financial market,
7. Payment mechanism (the source of revenue stream)
8. The level of private finance involved
9. Political support
10. Technical constraints and goals of the sector
11. Legal and regulatory constraints
12. Institutional issues,
13. Finance constraints
14. Based on system or population features, the sector has certain requirements
15. Type of asset
16. What functions the private party is responsible for?

17. Transparent procurement
18. Commitment made by partners
19. Favorable legal framework
20. Efficiency in cost and time management
21. Land ownership
22. The economic framework developed
23. Financial return
24. Integrated delivery of projects
25. Efficiency of safety management at work
26. Transfer sustainable technologies and methods
27. Percent of completion and
28. Environmental conservation.

Step 2: Compile and analyze major PPP contract types, which are widely used in developing countries.

Since the foundation of the widely used PPP is the provision of a service, the contracting authority states its requirements in terms of "outputs," which are a list of the public services that the facility is intended to provide but do not specify how these services are to be provided. The facility must be designed, financed, constructed, and run by the private sector to achieve these long-term output requirements. Based on the literature review, there are four types of PPP contract types available in most developing countries. They are:

- Design-Build-Finance-Operate (DBFO).
- Build-Operate-Transfer (BOT)
- Build-Transfer-Operate (BTO)
- Build-Own-Operate (BOO) and

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Build-Operate-Transfer (BOT)

In the BOT agreement, the private partner contributes the capital expenditure needed to develop a new facility. The private operator will be the legal owner of the

assets for the duration specified in the contract, which will be long enough for the developer to recoup its investment costs through user fees (e.g., collect the revenue from users). Thus, the private sector's transfer period must be long enough to cover its investment. In some PPP projects, the operator receives commitments from the public sector to buy a minimum amount of production, which is enough to pay operating expenses.

Build-Transfer-Operate (BTO)

In Build-Transfer-Operate (BTO) projects, the government pays the capital investment. Thus, the private company needs to transfer the ownership of assets to the public owner immediately rather than at the completion of the contract once construction is finished.

Build-Own-Operate (BOO)

Build-Own-Operate (BOO) projects are ones in which the developer builds and runs facilities without giving the government ownership. This type of PPP arrangement is similar to privatization, but in BOO projects the government is still involved.

Design-Build-Finance-Operate (DBFO)

The duties of planning, building, funding, and operating are combined in the Design-Build-Finance-Operate (DBFO) strategy. However, the asset ownership is always with the public entity. The degree of financial duties, which are often delegated to the private partner, varies substantially between DBFO agreements. The primary basis for the private sector's interest in the project is its contractual right to manage the facility and receive payment from the off-taker, not on ownership of the physical assets, as long as the contracting authority retains legal possession of the facility.

Step 3: Finalize the list of criteria from step:1, conduct an interview with seven PPP specialists, giving them a list of criteria and asking them to describe the factors that influence the PPP arrangement selection process.]

In-depth interviews conducted to collect and discuss the data about the influenced criteria while selecting PPP options by the practitioners in administration PPP contracts of the infrastructure project who have over five years of working

experience in PPP infrastructure projects. Meeting and interviewing the engineers and specialists who are working in PPP infrastructure projects can provide more detailed and comprehensible information.We will provide a list of selected criteria based on a review of the literature and will ask to specify and evaluate the factors that influence how PPP contract types are chosen in infrastructure projects.

Step 4: Assess the weight of the finalized criteria and their priorities, fifteen PPP professionals will be interviewed. The respondents can rank the priorities of the criteria with the fundamental scale of an absolute number (1 to 9).

The next step in the framework aims to explain how the priorities of criteria will be selected by using pairwise comparisons with a suitable MCDC method called analytical network process (ANP). This decision-making model will be used as a tool to choose the PPP model that best fits the requirements for projects involving public-private partnerships in developing nations. This approach is intended to assist decision-makers who are presented with various and competing alternatives in reaching the best choice. The literature review and expert consultation in the preceding step served as the basis for the essential characteristics and criteria. To accomplish this, it is necessary to determine the relative importance of each criterion as well as the decision-makers' preference hierarchies.

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Step 5: Rank the best fit PPP contract type based on the priorities of the weight of the criteria with the use of analytical network process (ANP).

Based on the priority of the criteria, the decision analysis model will be developed. The workflow of the ANP technique adopted in this study to deal with the problems of selecting PPP option decisions is shown in figure 3.2. The Super Decisions software (v.3.2) is used based on the analytical network process (ANP) for building the decision model which has a goal, criteria, and alternatives. This model can make judgments (paired comparisons), and the feedback system between the criteria and alternatives and finally compute the results to find out the best alternative. Figure 3.3 shows the interface of the super-decision software.

The proposed methodology process of the Analytical Network Process tool can be summarized in five main steps in figure 3.2 as follow:

Step 1: Determination of the goal of decision-making.

Step 2: Selection and identification of the criteria and alternatives concerning the goal of the decision making and then constructing a hierarchy system for its evaluation. When it comes to criteria, the comparison must be made for the decisive goal. Similar to the alternatives, criteria must be assumed as alternatives.

Step 3: Selection and identification of independent alternatives which can be weighted as a suitable solution to the goal of the decision-making problem.

The ratio of significance for each alternative is averaged (geometric mean) to find the overall significance of the alternative concerning the criteria. Similarly, each criterion will have its weight of significance. This weight of significance of each criterion will be multiplied with the weight of significance of the alternatives for that criterion and the arithmetic mean of this product will yield the final significance of the alternatives. After that, all such products will be divided by the product with maximum magnitude to find the weight of significance of the respective alternatives.

Step 4: Estimating the weight of the decision elements and check for consistency ratio:

As a result, each criterion will have another weightage of significance. This becomes an interactive process where the weight of significance of alternatives is updated with each new weight of criteria until the difference between the new and old weight of alternatives does not exceed 0.1.

Step 5: Ranking the alternatives

Based on the priority of the weight, the ranking procedure can continue

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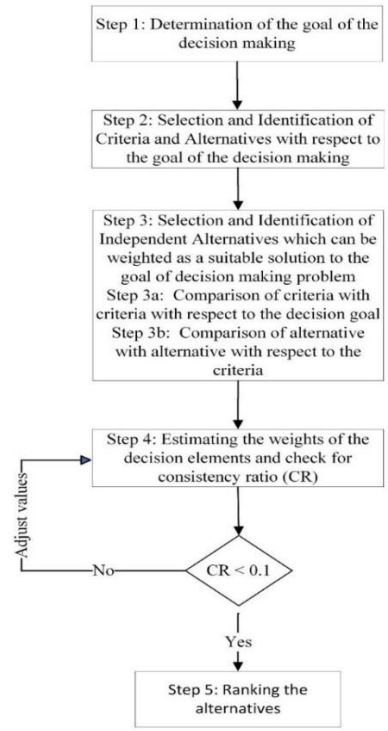

Figure 3.2 Structure of analytical network process (ANP)

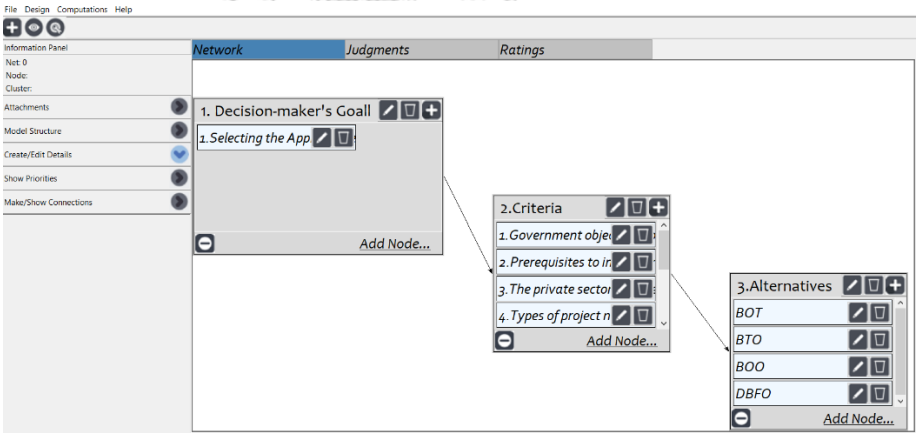

Figure 3.3 Structure of ANP decision-analysis tool in the super decision software

Step 6: Validate the proposed decision-analysis model on a case study.

In this step, we will validate the decision analysis model on the real infrastructure project to evaluate the model by interviewing fifteen PPP professionals with the questionnaire.

Step 7: Identify the limitation of the proposed decision-analysis model.

The limitation will be prepared after validating a decision model and verification by the experts in a case study. The final recommendation will be concluded to support the decision-makers to consider the optimal solution of PPP options that leads to the success PPP infrastructure projects.

3.2 Data collection

Data collection is a process that calls to carry out the communique among the researcher and the focused respondents. Moreover, this process helps the researcher to decide and deal simultaneously with critical content and social manner. In this research to fulfill the objectives and aims of the research, a literature review, in-depth interview, and questionnaire survey will be used.

3.2.1 Literature review

In this research, the literature review was carried out from different resources such as textbooks, thesis, journals, articles, as well as websites to obtain relevant data and to explore the real-world problem in public-private partnership infrastructure projects in order to develop the decision-analysis model. Moreover, (Randolph 2009) revealed that "A literature review is a tool used to show an author's understanding of a specific topic of research, including terminology, theories, important variables and phenomena, as well as its methodology and history."

3.2.2 In-depth interview

Easwaramoorthy and Zarinpoush, (2006) described that "When it's necessary to gather in-depth data on people's opinions, beliefs, experiences, and feelings, interviews are a suitable way". In this research, face-to-face and online in-depth interviews will be adopted. To fulfill the research objectives, the interview will be semi-structured. The respondents include government's agencies, private investors,

contractors, sub-contractors, consultants, and specialists in managing PPP projects. In this study, three PPP experts are selected for a preliminary survey to finalize the criteria while selecting the appropriate PPP contract type in total. The respondents from the government's organizations, private investors, and PPP consultants with a minimum experience of five years in PPP infrastructure projects and their position should be at least senior management level and above.

The respondents will be contacted via telephone and email to participate and answer the questionnaire developed. After they confirm, the interview will be arranged either face to face or online depending on the interviewee's convenience. The length of the interview will take a minimum of thirty minutes to one hour based on the interviewees' speed for a response.

In the second stage, at least ten respondents need to participate in an in-depth interview by providing a questionnaire to assess the weight of each criterion and the performance of each alternative. Moreover, the author needs to spend enough time explaining the use of scale for pairwise comparisons to participants who do not have experience with the Analytical Network Process (ANP). The most challenging part of using ANP is an explanation of the concept and the management of the process. Moreover, the comparison technique is quite complicated. The author needs to spend enough time before the respondent's feedback is given. Table 3.4 provides the pairwise comparison scale to calculate the weight of each criterion.

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After receiving the feedback from the respondents, a validation survey will be used to check the consistency ratio of the questionnaires. If the consistency ratio is greater than 10%, the author needs to contact the respondents to calculate the criteria again until the researcher attains the recommended limit.

In the third stage, after developing the decision-analysis model with (ANP), the proposed model will be applied in the case study project in Thailand. And then, the researcher will finalize the result and find out the limitation of the proposed model.

Table 3.1 The fundamental scale of an absolute number (Saaty, T. L., and Vargas, L. G. 2006)

Scale	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values
Use reciprocals for inverse comparisons	

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CHAPTER 4
DEVELOPMENT OF ANALYTICAL NETWORK PROCESS (ANP) MODEL

This chapter explains the development of an analytical network process (ANP) model for the selection of an appropriate PPP contract type for a specific infrastructure project. The proposed model can be used by modifying the criteria that can be suited to their specific infrastructure project.

First, in-depth interviews were conducted to explore the PPP contract selection criteria which need to consider before choosing a suitable contract type for an infrastructure project. After the analysis, the priority level of these identified criteria was determined using pairwise comparison. Finally, based on the result of the pairwise comparison, the optimal contract type for a specific infrastructure project can generate by using the analytical network process (ANP).

4.1 Identification of the PPP contract selection criteria

4.1.1 Exploring the common factors of PPP contract selection criteria associated with successful PPP infrastructure project

In-depth interview with experts in PPP projects was conducted to explore the common criteria that affect the selection process to obtain the optimal PPP contract type for the infrastructure project. To identify the PPP contract selection criteria, relevant past studies, research works, journals, articles, and textbooks were examined. Traditional way of selecting the suitable PPP contract type is based on these criteria.

PPP contract types	Risk allocation for private sector	Legal ownership and control of project assets	Technical constraints	Financial involvement by private sector	Type of project nature
DBFO	High	Public	High	Moderate	
BTO	High	Private owns during construction	Low	Moderate	
BOT	High	Private owns until contract finished	Low	High	
BOO	High	Private	Low	High	

Table 4.1 Typical PPP contract selecting criteria

Typically, there are five main criteria that need to consider while selecting the suitable PPP contract type. They are

(1) Risk allocation between the public and private sector

(2) Legal ownership and control of project assets

(3) Technical constraints

(4) Financial involvement by private sector

(5) Type of project

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In this research, we listed a total of twenty-eight contract criteria, which are considered while choosing appropriate PPP contract types from past studies, literature reviews, document analysis, thesis, journals, articles, and website. Appendix A contains a sample of the questionnaire used for this purpose. They included:

1. Risk allocation and sharing
2. Government's preference in the option
3. The private sector's interest in the option
4. Types of project nature
5. Strong private consortium

6. Available financial market,
7. Payment mechanism (the source of revenue stream)
8. The level of private finance involved
9. Political support
10. Technical constraints and goals of the sector
11. Legal and regulatory constraints
12. Institutional issues,
13. Finance constraints
14. Based on system or population features, the sector has certain requirements
15. Type of asset
16. What functions the private party is responsible for?
17. Transparent procurement
18. Commitment made by partners
19. Favorable legal framework
20. Efficiency in cost and time management
21. Land ownership
22. The economic framework developed
23. Financial return
24. Integrated delivery of projects
25. Efficiency of safety management at work
26. Transfer sustainable technologies and methods
27. Percent of completion and
28. Environmental conservation.

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These criteria were reviewed by seven PPP professionals experienced in PPP infrastructure projects through in-depth interviews. The experts who participated in these interviews entail one director from the private consulting firm and one director from government side, one senior executive vice president, and four engineers. Table. 4.2 displays their profile. As can be seen, among the seven respondents, three participants have ten years of experience or more in PPP infrastructure projects. Four respondents have five to ten years of PPP experience. Each participant was provided with a list of PPP contract selection criteria and was asked to identify the criteria that affect the contract selection process in infrastructure projects. The input criteria should have less than ten to use effectively the proposed analytical network process (ANP) model. Therefore, we made a depth interview to identify the most influence PPP contract selection criteria. According to the expert opinions, twenty-one criteria were removed that have less significant important while choosing suitable PPP contract type. Table.3 lists the seven criteria considered in this research.

The final criteria and the alternative PPP options became the inputs of the ANP model to evaluate the pairwise comparison. The ANP model can rank the most appropriate PPP contract type for a specific infrastructure project.

4.1.2 Demographic profile of respondents of in-depth interview

Seven specialists in total consented to take part in our interview.

Table 4.2 Details of the participants of the in-depth interview

No	Designation	Organization	Experience	Sector
1	Director	Construction supervision	≥10 years	Private
2	Director	Consultant	≥10 years	Public
3	Senior executive vice president	Consultant	≥10 years	Private
4	Engineer	Consultant	5-10 years	Private
5	Engineer	Department of highway	5-10 years	Public
6	Engineer	Consultant	5-10 years	Private
7	Engineer	Consultant	5-10 years	Private

4.2 In-depth interview result of the contract selection criteria

In this research, we focus only on the factors that can be addressed by the standard form of PPP contract and are associated with PPP transportation projects. The original twenty-eight criteria that were derived through the in-depth interview were reduced to seven criteria, as tabulated in Table 4.3. These seven criteria were subsequently analyzed. It should be noted that most of the identified criteria are like the other PPP contract selection criteria in most of the developing countries identified in past literature. However, we found several unique criteria in transportation projects such as technical issues and land ownership that were rarely mentioned in past studies.

From the in-depth interview, a total of seven criteria contributing to the contract selection process of the optimal contract type for a specific infrastructure were compiled as shown in Table 4.3. All these criteria affect the overall process of choosing the suitable PPP contract type directly or indirectly.

Table 4.3 Results of the in-depth interview

No	Contract selection criteria
1	Risk allocation and sharing
2	Government's preference in the option
3	The private sector's interest in the option
4	Finance constraints
5	Technical issues
6	Efficiency in cost and time management
7	Land ownership

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4.2.1 Description of the contract selection criteria identified by in-depth interview with experts

The contract selection criteria are briefly described here to obtain the optimal contract for the decision-makers who are from both government agencies and private sectors.

1. Risk allocation and sharing

In every PPP project, the related risks are essential to be considered. Depending on the contract type, the consideration must be measured whether the governments or investors enable to perform key functions to allocate risk as to the crucial factors. The inclination for low-risk contracts increased during the global downturn in PPPs in the 1990s (Asian Development Bank 2005). Moreover, (Likhitruangsilp et al. 2017) stated that using BOT contract for infrastructure projects were not recommendable due to several risks in Vietnam. Therefore, foreign firms had no passion to invest with this type of PPP option. For the DBFO contract type, revenue risk is the challenge for the private sector. Therefore, if the government does not want to take revenue risk, the suitable contract type will become DBFO option. For the BOO option, the government does not want to take entire risk. Therefore, this criterion strongly influences in the contract selection process.

2. Government's preference in the PPP option

Under this criterion, government should consider how can affect each type of contract arrangement in political commitment, cost recovery tariffs, the legal system, the data base, and the government's ability to monitor and analyze contracts are all factors. Moreover, in some cases, government does not have capital investment to build the infrastructure project. Therefore, DBFO option cannot be considered for this project. For these reasons, all the respondents agreed to consider this criterion.

3. The private sector's interest in the option

Even though electing the best appropriate PPP option by government, in some cases the risk that will transfer to the private sector may be unacceptable. After surveying the demands and market interests of the private sector, some measurements should be taken by government to meet its objectives and the requirements of the private sector (Asian Development Bank 2005). Therefore, this criterion includes in this survey.

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4. Finance constraints

To attract private financing, the government mostly uses the BOT contract type. However, the private sectors have the willingness to run partially or completely into debt by investigating the possibility of long-term income based on the country's inflation rate, political risks, legal risks, and government experience with PPP projects (Likhitruangsilp et al. 2017a), the option will be DBFO in general (Asian Development Bank 2005). As a result, this criterion should consider strongly in the contract selection process.

5. Technical issues

To the extent that they are known, the government should evaluate the current technological restrictions in the sector that needs reforming, including client responsiveness, utility services, and system efficiency. It ought to establish the extent to which operational problems are brought on by underinvestment, inadequate investment planning, upkeep, inefficient management, a deficiency in operational expertise, or other issues (Asian Development Bank 2005). Insofar as this knowledge is important for the reform and is accessible in a way that is economical, it should be cataloged along with current and projected investments as well as existing assets.

Connectivity, links, and interdependencies between various infrastructure components must be considered during the analysis (e.g., electricity production versus distribution, connectivity between means of transportation, the validity of tickets and billing when used with different modes of transportation, adherence to technical standards, etc.).

6. Efficiency in cost and time management

According to (Ozdogan and Birgoniil 2000), the government's main goal in putting the BOT model into practice is to complete urgent infrastructure projects with the least amount of financial stress and without reducing its minimum borrowing

capacity. Because of the BOO project's financing structure, lenders can only determine the project's viability based on predicted cash flows (Woodward 1995).

Value for money (VfM) has been achieved through DBFO contracts. Cost savings relative to the public sector comparator, PSC, have ranged from negligible to significant, with an average cost saving of 15%. Bidders can spend less time preparing their offers when this contract is used as the foundation for negotiations for each DBFO contract, and the agency gains significant operational and negotiation efficiencies. As a result, every responder enthusiastically agreed to take this factor into account while making a decision about the contract.

7. Ownership of project assets

Different PPP options have different forms of legal possession and management of project resources. In BOT agreements, the project assets are owned by the private sector until the contract is completed to recover the capital investment in the PPP project. For the BTO contract type, once development is complete, the private sector must transfer ownership of project assets. In DBFO contract type, the project asset is never owned by the private sector. whereas, in the BOO option, the project asset ownership is private the sector. Therefore, ownership of project assets is the critical criterion in order to select a suitable PPP option.

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4.3 Analytical network process (ANP)

The Analytical Hierarchy Process (AHP) served as the foundation for Saaty's development of ANP (Saaty and Vargas 2006). ANP can solve both the network's qualitative and quantitative information. Moreover, it can handle the linkages of interaction and feedback between the criteria, sub-criteria, and options. For a variety of decisions, including choosing a project or component, the ANP model has been utilized as a multi-criteria decision-making tool. The next paragraphs cover the generalized ANP steps:

Step 1: By distinctly defining the objective, the criteria/sub-criteria, and the alternatives, as shown in Figure, the main problem is separated into sub-problems (4.3). What we wish to achieve is the goal, the criteria are the norms used to make decisions., and the alternatives are the factors that must be taken into consideration.

Step 2: The Saaty qualitative scale of importance is used to rank criteria and alternatives, and this quantitative scale range of 1 to 9 is then transformed as indicated in Table.

Step 3: After scaling, a pairwise comparison is conducted. By comparing the ith row and jth column, the matrix of criteria is produced. (i,j) is used to indicate if the ith row criterion is superior or not, and otherwise (j, i). Scores between 1 to 9 indicate the great importance of one element relative to another. Score of 1 denotes equal importance.

Step 4: The comparison matrix's Eigenvalues and Eigenvector are used to calculate relative relevance. As the items are normalized, weights for the criteria or sub-criteria are determined.

Unweighted and weighted supermatrix

The unweighted supermatrix of the ANP model is depicted in Figure (4.6). It includes the nodes' local priorities as determined by pairwise comparison matrices (1) to (9). Combining the eigenvectors from each individual matrix results in the unweighted supermatrix depicted in the picture (4.7). In order to make this unweighted matrix column stochastic (such that the total of each column equals 1), it is then converted into a weighted supermatrix, as shown in Fig (4.8). The combination of an unweighted supermatrix and a cluster matrix results in a weighted supermatrix.

Limit supermatrix

Getting reliable weights out of a weighted supermatrix, a limit supermatrix is used. In a weighted supermatrix, all values are multiplied by 2k, where k is a chosen number at random. Until the same and steady values are attained, the process is

repeated. The limit supermatrix contains a summary of the outcomes of all pairwise comparisons. It includes all unintended consequences between parts. The limit supermatrix is depicted in Figure, where the standing alternative and criterion are clearly visible.

Step 5: It is crucial to make sure that the comparisons done are consistent in order to guarantee the accuracy of the conclusions. Satty defines the Consistency Index (CI) and Consistency Ratio (CR). The random reciprocal matrix created from the quantitative 9-point scale's consistency ratio and consistency index are denoted by the letters CR and RI, respectively. The pairwise comparison must be updated if the value of CR is more than 10%.

The outcomes of pairwise comparisons are used to determine the element weights. It is crucial to achieve consistency between comparisons in order to guarantee the accuracy of the conclusions. The consistency ratio, or CR, has a desirable value of under 10%. The consistency index (CI) to random index (CR) ratio (RI). The consistency index of a matrix is given by

$$CI = (\lambda_{max} - n)(n-1)$$

where λ_{max} is the ratio of the total weight of the criteria and the total number of criteria. For the number of criteria which is less than ten, the appropriate random index can be used as shown in Table. III, where n is the number of criteria.

Table 4.4 Random index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	.25	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Step 6: An unweighted super matrix was produced by the local priority values (Eigenvectors) from the comparison matrix. If the total of each column is 1, it is transformed into a weighted super matrix; otherwise, there is interdependence between

the clusters in a network. The result of an unweighted super matrix and cluster matrix is a weighted super matrix.

Step 7: To the power of 2k, the weighted super matrix is raised until it converges to a more stable set of weights to produce the limit matrix, where k is an arbitrary high number. By normalizing each block of the limit matrix, it is possible to determine the ultimate priorities of each element in the network. With the highest priority, the best option should be chosen.

The ANP model can be analyzed by using spreadsheet software or commercial software (e.g., super decision software). Fig. 2 displays the user interface of the ANP model in super decision software. In this research, the mathematical calculation was performed by user friendly super decision software. The concept is same as explained in above procedure.

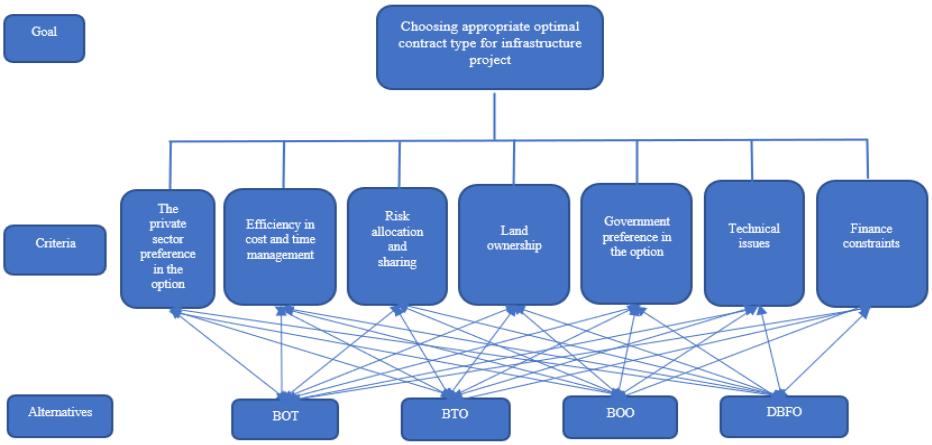

Figure 4.1 ANP model for optimal PPP contract selection

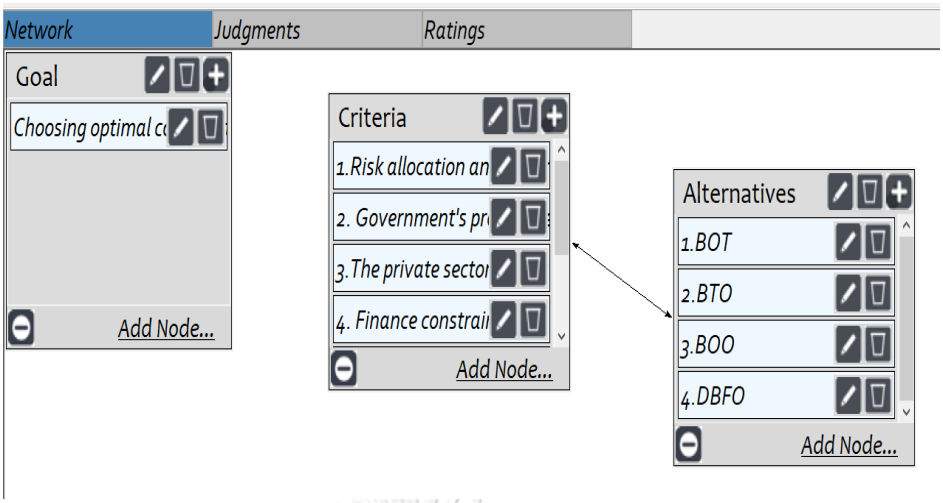

Figure 4.2 Analytical network process (ANP) model in super decision software

4.4 Discussion

Choosing the appropriate PPP contract type is a vital process for the PPP infrastructure process. The proposed analytical network process (ANP) can be applied to transportation sectors such as road projects, mass transit projects, seaport projects, express-way projects, etc. and the decision-makers should involve both sides of the public sector and private sectors. By applying this model, the decision-makers will more focus on the main objective of developing a PPP project such as which criteria will be more concentrated for this project. Therefore, the application of this model provides more important and less important criteria regarding the objective of the project. This model and its associated criteria are specifically tailored to meet the need of specific infrastructure projects. When another PPP project is adopted, this model can also be used by revising the criteria to new criteria suited to the new context. Application of the analytical network process (ANP) model to choose the suitable PPP contract will provide the guidelines to achieve successful adoption. In order to obtain the data for the contract selection criteria and alternatives, the survey could be conducted by structured interview form or by electronic questionnaire form alternatively. After the input criteria got, there still remains the process of pairwise comparison process that decision-makers should strongly and carefully be involved in

this process that needs some time to meet the consistency ratio, but the team might have struggled in the adoption.

4.5 Conclusion

This chapter presented the development of the analytical network process (ANP) model and explained the detailed process. At first, the input of contract selection criteria and alternatives were constructed in order to develop the decision analysis analytical network process (ANP) model. After that, a pairwise comparison survey was performed to choose the most suitable PPP contract type. Hence, the key factors of contract selection criteria and different types of PPP contracts (alternatives) were identified for the proposed model by conducting an intensive literature review and questionnaire surveys with experts. Finally, the conceptualized model was refined according to the feedback from the semi-structured interview and four pilot tests were conducted in order to validate the model.

To be concluded, this chapter discussed the vital stages involved in the development of analytical network process (ANP) model. Finally, the proposed was presented. Thus, the research objectives was successfully achieved in this chapter. The following chapter discussed assessment of the real PPP project by conducting this analytical network process (ANP) model on four case studies.

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CHAPTER 5
APPLICATION OF THE ANALYTICAL NETWORK PROCESS (ANP) MODEL IN INFRASTRUCTURE PROJECTS

This chapter addresses the last research step of the research which is to rank the appropriate optimal PPP contract type for a specific infrastructure project by applying the analytical network process (ANP) model to case studies. For this purpose, Water project, My Thuean expressway project, mass transit project, and road project were adopted as case studies. We used the proposed ANP model in two types of case studies which are ongoing project and finished project. Water project is ongoing project, and we made a depth-interview with a group of four PPP experts who are currently involved in this project. And the other three case studies were done on finished projects.

5.1 Respondent's profile for the "Water project" case study

The respondents were involved in project-based PPP projects. A group of four experts participated in this case study entailed one director, two economists, and one senior consultant from the very well-known PPP Consultants Co., Ltd. However, the project is ongoing and the confidentially of the project, we cannot mention the detail information of the project name, location, and the other related information. They prepared the feasibility study and the environmental impact assessment from 21 September 2016 to 14 March 2018. In 2022, they analyzed the environment, social and public participation, economic analysis, laws and incentives, appropriate Public-private partnership model, and financial return for Public-private partnership (PPP). For this research, we participated to choose the appropriate Public-Private Partnership contract type by applying the analytical network process (ANP) and their traditional method too. This case study's goal is to confirm and evaluate the proposed model in a real project and to find out the limitation of the proposed model. Moreover, we also would like to understand the contract selection criteria that will consider in the real project from both

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sides of the private sector and the public sector. Thus, the data from these four experts can be able to address all the objectives of this step.

Table 5.1 Profiles of interviewees for the case study

No	Designation	Organization	Experience	Sector
1	Director	Consultant	≥10 years	Public
2	Senior Consultant	Consultant	≥10 years	Public
3	Economist	Consultant	5-10 years	Private
4	Economist	Consultant	5-10 years	Private

5.2 Case study of choosing appropriate Public-Private Partnership contract type for "Water project"

Chao Phraya Basin is the key economic areas of the country with the use of a large amount of water for different activities. This project's objective is to mitigate water scarcity in the Chao Phraya Basin by diverting water in a wet season from the Yuam River and then storing it in the reservoir which has space for storing a large amount of water. For this case study, the proposed model that we got from Chapter 4 was applied in the beginning. However, after the in-interview result of the expert group, we decided to modify the contract selection criteria based on the unique characteristics of this project.

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(a) (b)

(c)

Fig 5.1 (a,b,c) In-depth interview with expert group

And then the finalized model was developed. This model includes six main criteria and twelve sub-criteria and four alternatives. They are:

- Managerial system
    1. Risk management process (Risk identify, risk assessment, risk management)
    2. Allocation of risks and benefits between the public and private sectors
    3. Allocation of duties and responsibilities of the public and private sectors
    4. Allocation ownership of project assets
- Legal framework
    1. Legal conditions
- Good government
    1. Participation of people in all stages of PPP program
    2. Sharing of PPP knowledge among public, private and
- Politics
    1. Policy and plan continuity (cover people interest, private antevert public interest, national interest, holistic policy)
- Project configurations
    1. Consistency with skills and expertise during the project operations

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2. Consistency with skills and expertise during the project development and

- Finance

1. PPP gross cost
2. PPP net cost
3. Appropriateness of public investment spending.

It can be seen that the above criteria are similar with the previous seven criteria that we got the in-depth interview result with seven PPP experts. In managerial system criterion, it includes four main sub-criteria about risk sharing and allocation between the public sector and private sector and it included in the prior survey result. In project configurations criterion, it mentioned about skills and expertise during the project development and operations, it is similar concept in efficiency in cost and time management criteria. And finance criterion also already included however, in the proposed model, the details of price comparison did not include. It should be noted that in future the study. The remaining three criteria legal framework, politics, and good government are new criteria that are considered in this case study and the detail explanation are below.

Legal and politics

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Successful PPP projects are mostly underlying on concrete and strong political commitment. The best PPP option should be designated by the private sector in accordance with the political stability of the country (Khudhaire and Naji 2021; Mohammed and Harputlugil 2017). For instance, to attract private financing, the government mostly uses the BOT contract type. However, the private sectors have the willingness to run partially or completely into debt by investigating the possibility of long-term income based on the country inflation rate, political risks, legal risks, and government experience with PPP projects (Likhitruangsilp et al. 2017a), the option will be DBFO in general (Asian Development Bank 2005).

Government objectives for the PPP process: Are governments' goals for PPP projects to lower service costs, enhance billing and collection, or prioritize coverage,

for example? The decision of choosing a PPP contract is mainly depends on this criterion.

Ownership of the facilities: Depending on the contract type, the asset ownership varies. For example, in the BOO contract types the asset ownerships will be under the private whereas other types of contracts, the physical ownership will always be in public hand (Yescombe and Farquharson, 2018).

Good government

Before starting the PPP infrastructure project, Government should consider the requirement of Low-Income group. The improvement of access to infrastructure projects as the advancement of economic growth is the main objective of PPP establishment in underdeveloped countries (Asian Development Bank 2005). Therefore, it's crucial to consider the variety of possibilities and any inherent benefits or drawbacks in the matter of providing services to the impoverished. Then, we can think about certain pro-poor actions that could be incorporated into the process. A PPP can be customized to meet specific reform goals as part of a reform package. Therefore, the PPP process and contract can be modified to fit the needs of low-income populations to the extent that is desirable and practical. Because each PPP option has different advantages and disadvantages (Asian Development Bank 2005).

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5.3 Application of proposed model in "My Thuen Express Way Project" from Vietnam

The respondent who participated in this survey was from Vietnam and he has over 10 years of working experience in the PPP consultant field. The expert judgment was used to make the paired comparisons. He was working on this "My Thuen Express Way Project". All the results were performed by using super decision software. Based on his paired-wise result, the calculations generated the Build-Operate-Transfer (BOT) is the most suitable contract type for this project and they were also doing this project with Build-Operate-Transfer (BOT) contract type. Risk allocation and sharing criterion is the most important criterion among others. The second suitable one is Build-

Transfer-Operate (BTO) contract type. Even though BOO and DBFO contract types were the third and fourth options, in Vietnam they do not use these contracts for PPP projects.

Figure 5.7 Pairwise comparison by super decision software

Main Network: expressway project.sdmod: ratings: Unweighted Super Matrix

Clusters	1.BOT	2.BTO	3.BOO	4.DBFO	1.Risk alloca...	2. Government...	3.The private ...	4. Finance co...	5. Technical i...	6.Efficienc...	7.Land o...	Choosing c
Alternatives	0.000000	0.000000	0.000000	0.000000	0.618789	0.584544	0.643687	0.687312	0.408396	0.400213	0.393879	0.000000
	0.000000	0.000000	0.000000	0.000000	0.214388	0.166995	0.155982	0.152886	0.408396	0.290800	0.393879	0.000000
	0.000000	0.000000	0.000000	0.000000	0.097045	0.130903	0.105226	0.104635	0.086507	0.195852	0.112224	0.000000
	0.000000	0.000000	0.000000	0.000000	0.069777	0.117558	0.095106	0.055168	0.096701	0.113135	0.100018	0.000000
Criteria	0.384209	0.318531	0.337351	0.337057	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.161419	0.165764	0.177798	0.208511	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.115320	0.121295	0.123325	0.108623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.186039	0.173571	0.150410	0.168742	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.043058	0.051342	0.047082	0.050323	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.064193	0.087373	0.077009	0.067231	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.045763	0.082124	0.087026	0.059514	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5.8 Unweighted supermatrix result by software named “Super Decision”

Main Network: expressway project.sdmod: ratings: Weighted Super Matrix

Clusters	1.BOT	2.BTO	3.BOO	4.DBFO	1.Risk allocati...	2. Government's...	3.The private s...	4. Finance con...	5. Technic...	6.Efficienc...	7.Land owne...	Choosing c
Alternatives	0.000000	0.000000	0.000000	0.000000	0.618789	0.584544	0.643687	0.687312	0.408396	0.400213	0.393879	0.000000
	0.000000	0.000000	0.000000	0.000000	0.214388	0.166995	0.155982	0.152886	0.408396	0.290800	0.393879	0.000000
	0.000000	0.000000	0.000000	0.000000	0.097045	0.130903	0.105226	0.104635	0.086507	0.195852	0.112224	0.000000
	0.000000	0.000000	0.000000	0.000000	0.069777	0.117558	0.095106	0.055168	0.096701	0.113135	0.100018	0.000000
Criteria	0.384209	0.318531	0.337351	0.337057	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.161419	0.165764	0.177798	0.208511	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.115320	0.121295	0.123325	0.108623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.186039	0.173571	0.150410	0.168742	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.043058	0.051342	0.047082	0.050323	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.064193	0.087373	0.077009	0.067231	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.045763	0.082124	0.087026	0.059514	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5.9 Weighted supermatrix result by software named “Super Decision”

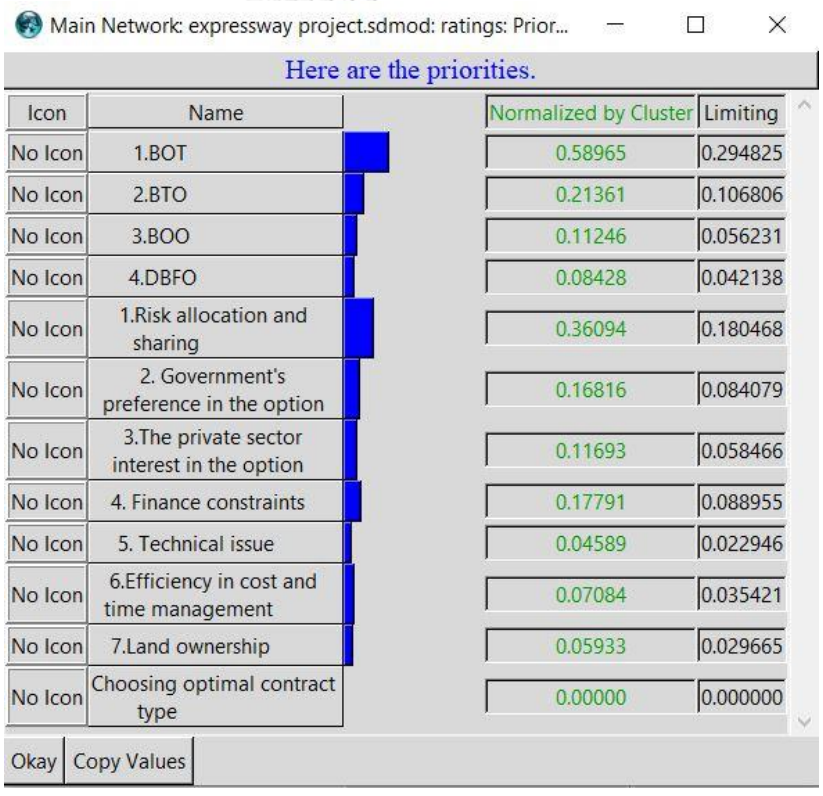

Figure 5.10 Priorities result from the criteria and alternatives

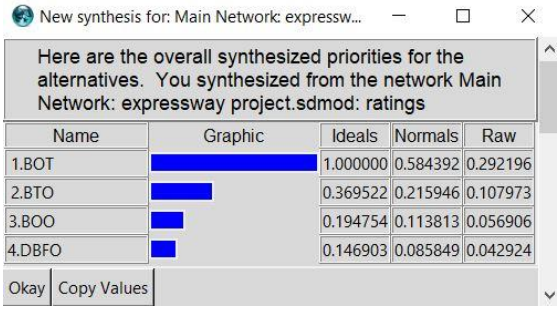

Figure 5.11 Synthesizing the relative weights of the alternatives

5.4 Application of proposed model in "Mass transit project"

The respondent who participated in this survey has five to ten years of working experience in a PPP consultant company and his role is in a management position. He participated in this interview for the mass transit project and the result showed that both BOT and BTO contract types have the same weight. As can be seen that the most influential criterion is risk allocation and sharing between the public sector and the private company.

Figure 5.12 Pairwise comparison by super decision software

Main Network: mass transit.sdmod: ratings: Unweighted Super Matrix

Clusters	1.BOT	2.BTO	3.BOO	4.DBFO	1.Risk allocatio...	2. Government'...	3.The private s...	4. Finance c...	5. Technical i...	6.Efficienc...	7.Land owne...	Choosing optim...
Alternatives	0.000000	0.000000	0.000000	0.000000	0.424411	0.424411	0.052076	0.052076	0.424411	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.424411	0.424411	0.052076	0.052076	0.424411	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.037366	0.037366	0.191835	0.191835	0.037366	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.113812	0.113812	0.704014	0.704014	0.113812	0.250000	0.250000	0.000000
Criteria	0.260595	0.260595	0.260595	0.260595	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.242780	0.242780	0.242780	0.242780	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.025015	0.025015	0.025015	0.025015	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.060144	0.060144	0.060144	0.060144	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.059277	0.059277	0.059277	0.059277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.139470	0.139470	0.139470	0.139470	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.212719	0.212719	0.212719	0.212719	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5.13 Unweighted supermatrix result by software named “Super Decision”

Main Network: mass transit.sdmod: ratings: Weighted Super Matrix

Clusters	1.BOT	2.BTO	3.BOO	4.DBFO	1.Risk allocation a...	2. Government's pr...	3.The private sector i...	4. Finance constrain...	5. Technical issues	6.Efficiency in ...	7.Land owners...	Choosing optim...
Alternatives	0.000000	0.000000	0.000000	0.000000	0.424411	0.424411	0.052076	0.052076	0.424411	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.424411	0.424411	0.052076	0.052076	0.424411	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.037366	0.037366	0.191835	0.191835	0.037366	0.250000	0.250000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.113812	0.113812	0.704014	0.704014	0.113812	0.250000	0.250000	0.000000
Criteria	0.260595	0.260595	0.260595	0.260595	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.242780	0.242780	0.242780	0.242780	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.025015	0.025015	0.025015	0.025015	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.060144	0.060144	0.060144	0.060144	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.059277	0.059277	0.059277	0.059277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.139470	0.139470	0.139470	0.139470	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.212719	0.212719	0.212719	0.212719	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5.14 Weighted supermatrix result by software named “Super Decision”

Main Network: mass transit.sdmod: ratings: Priorities

Here are the priorities.

Icon	Name	Normalized by Cluster	Limiting
No Icon	1.BOT	0.33128	0.165639
No Icon	2.BTO	0.33128	0.165639
No Icon	3.BOO	0.12541	0.062704
No Icon	4.DBFO	0.21204	0.106019
No Icon	1.Risk allocation and sharing	0.26060	0.130298
No Icon	2. Government's preference in the option	0.24278	0.121390
No Icon	3.The private sector interest in the option	0.02502	0.012508
No Icon	4. Finance constraints	0.06014	0.030072
No Icon	5. Technical issues	0.05928	0.029638
No Icon	6.Efficiency in cost and time management	0.13947	0.069735
No Icon	7.Land ownership	0.21272	0.106359
No Icon	Choosing optimal contract type	0.00000	0.000000

Okay | Copy Values

Figure 5.15 Priorities result from the criteria and alternatives by super decision software

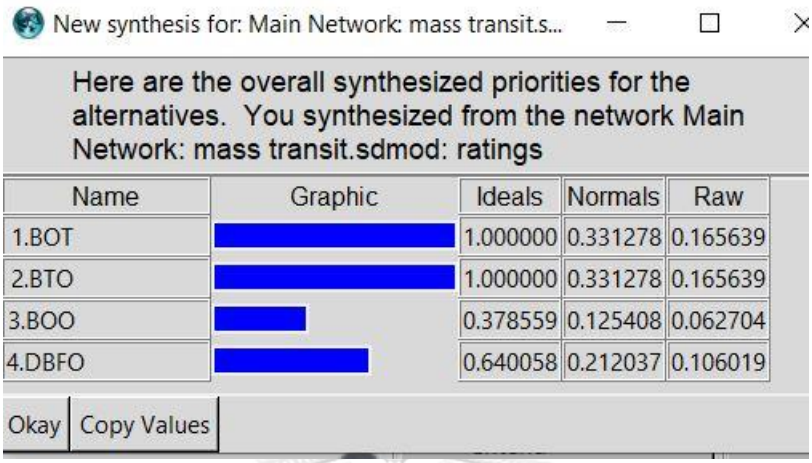

Figure 5.16 Synthesizing the relative weights of the alternatives

5.5 Application of proposed model in "Road project"

The interviewee who participated in this survey has over ten years of working experience and takes a director position in a very well-known PPP consultant firm. He suggested that to add one more criterion about public participation in this project. Therefore, in this survey, a total of eight criteria were involved according to his suggestion. Moreover, we added six main criteria that his company always considers selecting an appropriate PPP contract type. On that account, we have six main criteria including financing, good government, legal framework, managing system, political constraint, and project configuration.

Figure 5.17 Pairwise comparison by super decision software

Clusters	BOO	BOT	BTO	DBFO	Financing	Good government	legal framework	Managing system	Political constraints	Project confriguration
Alternative	0.000000	0.000000	0.000000	0.000000	0.038750	0.493020	0.036595	0.039749	0.039749	0.041681
	0.000000	0.000000	0.000000	0.000000	0.121812	0.184607	0.110685	0.106090	0.106090	0.135158
	0.000000	0.000000	0.000000	0.000000	0.242931	0.045154	0.354403	0.392644	0.392644	0.368697
	0.000000	0.000000	0.000000	0.000000	0.596507	0.277220	0.498316	0.461517	0.461517	0.454464
Criteria	0.159580	0.159580	0.159580	0.159580	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.042813	0.042813	0.042813	0.042813	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.100630	0.100630	0.100630	0.100630	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.064077	0.064077	0.064077	0.064077	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.382497	0.382497	0.382497	0.382497	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.250402	0.250402	0.250402	0.250402	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
financing -sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Good government - sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.125000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.875000	0.000000	0.000000	0.000000	0.000000
Legal framework -Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	0.000000
Managing system - Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.057243	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.596932	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.345825	0.000000	0.000000
Political constraints-Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	0.000000
Project -sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

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Figure 5.18 Unweighted supermatrix result by software named “Super Decision”

Clusters	BOO	BOT	BTO	DBFO	Financing	Good government	legal framework	Managing system	Political constraints	Project confriguration
Alternative	0.000000	0.000000	0.000000	0.000000	0.019375	0.246510	0.018298	0.019875	0.019875	0.041681
	0.000000	0.000000	0.000000	0.000000	0.060906	0.092304	0.055343	0.053045	0.053045	0.135158
	0.000000	0.000000	0.000000	0.000000	0.121465	0.022577	0.177202	0.196322	0.196322	0.368697
	0.000000	0.000000	0.000000	0.000000	0.298254	0.138610	0.249158	0.230758	0.230758	0.454464
Criteria	0.159580	0.159580	0.159580	0.159580	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.042813	0.042813	0.042813	0.042813	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.100630	0.100630	0.100630	0.100630	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.064077	0.064077	0.064077	0.064077	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.382497	0.382497	0.382497	0.382497	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.250402	0.250402	0.250402	0.250402	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
financing -sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.500000	0.000000	0.000000	0.000000	0.000000	0.000000
Goal	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Good government - sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.062500	0.000000	0.000000	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.437500	0.000000	0.000000	0.000000	0.000000
Legal framework -Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.500000	0.000000	0.000000	0.000000
Managing system - Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.028621	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.298466	0.000000	0.000000
	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.172913	0.000000	0.000000
Political constraints-Sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.500000	0.000000
Project -sub	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5.19 Weighted supermatrix result by software named “Super Decision”

Here are the priorities.

Icon	Name	Normalized by Cluster	Limiting
No Icon	BOO	0.05916	0.016907
No Icon	BOT	0.11970	0.034208
No Icon	BTO	0.34403	0.098317
No Icon	DBFO	0.47711	0.136347
No Icon	Financing	0.18242	0.091210
No Icon	Good government	0.04894	0.024470
No Icon	legal framework	0.11503	0.057516
No Icon	Managing system	0.05443	0.027213
No Icon	Political constraints	0.45606	0.228031
No Icon	Project confriguration	0.14312	0.071560
No Icon	commerical, financial, and financing requiremen~	0.00000	0.000000
No Icon	Private sector's interest in the option	1.00000	0.045605
No Icon	Choosing appropriate PPP optimal contract type	0.00000	0.000000
No Icon	Public participation	0.12497	0.001529
No Icon	Quality improvement	0.87503	0.010706
No Icon	Prerequisites to implementing a particula~	1.00000	0.028758
No Icon	Efficiency in cost and time management	0.05725	0.000779
No Icon	Risk allocation and sharing	0.59694	0.008122
No Icon	What functions the private sector is respon~	0.34580	0.004705
No Icon	PPP policy of the governemnt	1.00000	0.114016
No Icon	Type of project (technical constraints)	0.00000	0.000000

Figure 5.20 Priorities result from the criteria and alternatives by super decision software

New synthesis for: Main Network: Mr supachai.sdmod: ratings

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Main Network: Mr supachai.sdmod: ratings

Name	Graphic	Ideals	Normals	Raw
BOO		0.124002	0.059162	0.016907
BOT		0.250892	0.119702	0.034208
BTO		0.721080	0.344031	0.098317
DBFO		1.000000	0.477105	0.136347

Figure 5.21 Synthesizing the relative weights of the alternatives

5.6 Discussion

After assessing the responses from the four experts for a "Water Project" case study, it could be seen that some criteria such as participating of people in all stages of PPP programs, sharing of PPP knowledge among the public, private, and people sectors also consider the public participation in PPP projects that did not provide in the literature review. This consultant company has over thirty years of working experience in PPP projects and most of the experts are already involved in two PPP projects. Therefore, this criterion also should consider selecting appropriate PPP contracts although these are not involved in literature review and document analysis. Moreover, they also considered the price comparison such as PPP gross cost, and PPP net cost. However, the proposed model did not consider the value for money concept. The rest three case studies that performed in finished projects, the model can apply successfully, and we found that risk allocation and sharing criterion is the most important criterion to consider about suitable PPP contract type. As a result, this study brings the use of ANP in practical settings one step closer. This research can be expanded for future study by include benefit, risk, cost, and opportunity control hierarchies. In addition, by using the limiting priorities as an input in the mathematical programming approaches, it can be created.

5.7 Conclusion

The contract selection process, which is one of the most important processes for PPP infrastructure projects, must be methodically taken into account by the decision-makers. Due to this, contract selection has been successfully used in many different industries, and researchers have been studying it for many years within a broad framework that includes both experimental and analytical methodologies. In this study, selecting the best PPP contract type was looked at as a multi-criteria decision problem, and an ANP model is suggested. The evaluation standards were created based on the experts' collective experience, the special features of this project, and the application of the model to a real-world case study. The select PPP contract type Build-Transfer-Operate (BTO) by using an analytical network process is also acknowledged by the senior consultant. This study demonstrates that ANP is a tool for strategic decision-making, such as choosing the best PPP contract type to ensure long-term financial success for all stakeholders: public, private, and individuals. Generally, PPP consultants used the traditional method to choose the PPP contract, but The decision-making process involving the ANP will be managed more easily by employing software that is simple to use, such as the super decision created by Saaty. Furthermore, this research makes it evident how the selection criteria affect the chosen contract type and, concurrently, which of the contract selection criteria is more crucial for the particular contract type.

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CHAPTER 6
RESEARCH CONTRIBUTIONS AND CONCLUSION

6.1 Research summary

There are various challenges in every PPP infrastructure project around the world. Among them, the contract selection process is also included. The objective of this paper is to establish a conceptual framework for selecting the most appropriate PPP contract type based on the ANP method. In this paper, we discuss the details of the proposed ANP model. The twenty-eight main criteria were compiled from our comprehensive literature review and were verified by the in-depth interviews with seven PPP experts. The twenty-eight criteria were then reduced to seven criteria. These criteria became the input of the ANP model and were pairwise compared. The model incorporates the four PPP options: BTO, BOT, BOO, and DBFO. The model then ranked the most appropriate PPP option for a certain infrastructure project. Based on this ANP model, three finished PPP transportation projects were employed to demonstrate the proposed model. The weights of these criteria and PPP alternatives are based on the project characteristics. The model thus can recommend the optimal PPP contract type resulting from the priorities of the weight of the criteria. After that, the proposed model was applied to a real PPP ongoing project. In this case, the proposed seven criteria to add three more criteria according to the project's unique characteristics and the recommendation of four very experienced experts who take responsibility for consulting for this project.

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6.2 Research conclusion

There was a total of twenty-eight criteria affecting the PPP contract selection of the transportation projects, out of which seven were identified as criteria associated while considering the suitable PPP contract type and that can be addressed by the common criteria to choose a suitable PPP contract type for a specific infrastructure project. From the finding of this research, it is evident that there are several practical

criteria that need to be modified based on the nature of the project and the unique characteristics of the specific PPP infrastructure. Moreover, for practical usage, the proposed model needs to add the cost analysis (value for money) to obtain a more effective and efficient analytical network process (ANP) model.

6.3 Research contribution

This research can assist the stakeholders such as political decision-makers, private investors, and strategic consultants who are responsible to propose and select the various type of available PPP options that will suit their PPP projects in making relevant decisions. Furthermore, the proposed decision-analysis model (ANP) makes sure to understand the importance of the weight of the criteria that will meet their objectives to develop a successful PPP project before making the decision. Moreover, using this supported optimal decision model can minimize the time-consuming of adopting the best form of PPP contract type, and it leads to project success.

6.4 Limitation of research and future works

This research was focused only on the widely used PPP contract types in Thailand. Moreover, most of the respondents who participated in this research are from Thailand and only one respondent is from Vietnam. And most of the respondents have experience in transportation sectors only. The same research could be done for the other PPP sectors by investigating the influence of contract selection criteria. The overall contract selection criteria can be analyzed sector by sector and can be modified based on these criteria according to the unique characteristics of the specific project.

Moreover, this proposed analytical network process (ANP) application, also contains its limitation. More specifically, ANP should be more efficient if the number of criteria (or sub-criteria) is not over ten. This might limit the number of criteria that affect in the contract selection process. And the decision-makers need enough time framework to make a pairwise comparison of comparing criteria to criteria, alternatives to alternatives, and the criteria to alternatives. In order to overcome this limitation,

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contract selection criteria must be cautiously carried out. Moreover, for the real practice the quantitative comparison should involve. Therefore, for future study benefit, opportunities, cost, and risk (BOCR) model should perform which is capable of more specific concept although it will increase the complexity of the evaluation system. Although the proposed model an analytical network process (ANP) model is the new approach, in practice this model still cannot be applied. Due to the limitation of the Thai Government's legal system, the input criteria still need to be modified.

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APPENDIX A: IN-DEPTH INTERVIEW

AN ANALYTICAL NETWORK PROCESS (ANP) MODEL FOR CHOOSING OPTIMAL PUBLIC-PRIVATE PARTNERSHIP (PPP) CONTRACT TYPES FOR INFRASTRUCTURE PROJECTS

Dear Sir/Madam,

I am Miss Su Lae Yee Zaw, a master's student at Chulalongkorn University in Thailand. I am currently doing a thesis under the supervision of Assoc. Prof. Dr. Veerasak Likhitruangsilp about **"An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects"**. This survey is only for academic research. Your information will be very important for the accuracy of the research. Thank you so much for participating indeed. This interview includes two parts.

Researcher Information

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Thank you for participating in this survey. The objective of this survey is to finalize the contract selection criteria that will consider while choosing the appropriate PPP contract type for an infrastructure project. The influence factors are gathered from relevant works of literature and listed below.

In the following pages, we would like to obtain your opinion as an expert through a questionnaire survey, in which you are requested to specify the contract selection criteria that affect the choice of the suitable PPP contract types.

The information you provide will be of great value to this research. We sincerely hope you can assist.

Part 1 – Personal Information

1. How long have you worked on PPP infrastructure projects?
   - ☐ < 3 years
   - ☐ 3~5 years
   - ☐ 5~10 years
   - ☐ > 10 years

2. How many PPP infrastructure projects have you participated in?
   - ☐ Nothing
   - ☐ 1 project
   - ☐ 2 projects
   - ☐ > 2 projects

3. What kind of role can your company describe?
   - ☐ Government sectors
   - ☐ Private sectors
   - ☐ Consultant
   - ☐ Other:

4. What position are you working in your company?
   - ☐ Director
   - ☐ Project manager
   - ☐ Deputy Director
   - ☐ Engineer
   - ☐ Other:

5. Do you know about the decision-supporting methods?
   - ☐ Unknown
   - ☐ Known
   - ☐ Heard of it
   - ☐ Know very well

6. Do you know about the analytical network process?
   - ☐ Unknown
   - ☐ Known
   - ☐ Heard of it
   - ☐ Know very well

7. Does your organization/company use the decision-supporting method?
   - ☐ Unknown
   - ☐ Known
   - ☐ Heard of it
   - ☐ Know very well

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Part B: Summary of PPP contract selection criteria while choosing the PPP contract type for Infrastructure projects from the literature review

Please check the checklist box based on your own experience and opinion.

Agree ✓ , Disagree ✗

SI No.	Do you think these factors can influence on appropriate PPP contract selection process for infrastructure projects?	Agree	Disagree	Remark
1	Risk allocation and sharing			
2	Government's preference in the PPP option			
3	The private sector's interest in the option			
4	Types of project nature			
5	Strong private consortium			
6	Available financial market			
7	Payment mechanism (the source of revenue stream)			
8	The level of private finance involved			
9	Political support			
10	Technical constraints and goals of the sector			
11	Legal and regulatory constraints			
12	Institutional issues			
13	Finance constraints			

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14	Based on system or population features, the sector has certain requirements			
15	Type of asset			
16	What functions the private party is responsible for			
17	Transparent procurement			
18	Commitment made by partners			
19	Favorable legal framework			
20	Efficiency in cost and time management			
21	Land ownership			
22	The economic framework developed			
23	Financial return			
24	Integrated delivery of projects			
25	Efficiency of safety management at work			
26	Transfer sustainable technologies and methods			
27	Percent of completion			
28	Environmental conservation			

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Contact Information

Name:

Email:

Mobile:

Name of projects you are working on:

Thank you very much for your kind cooperation.

APPENDIX B: IN-DEPTH INTERVIEW

AN ANALYTICAL NETWORK PROCESS (ANP) MODEL FOR CHOOSING OPTIMAL PUBLIC-PRIVATE PARTNERSHIP (PPP) CONTRACT TYPES FOR INFRASTRUCTURE PROJECTS

Dear Sir/Madam,

I am Miss Su Lae Yee Zaw, a master's student at Chulalongkorn University in Thailand. I am currently doing a thesis under the supervision of Assoc. Prof. Dr. Veerasak Likhitruangsilp about **"An Analytical Network Process (ANP) Model for Choosing Optimal Public-Private Partnership (PPP) Contract Types for Infrastructure Projects"**. This survey is only for academic research. Your information will be very important for the accuracy of the research. Thank you so much for participating indeed. This interview includes two parts.

Researcher Information

Su Lae Yee Zaw	Master's student, Construction Engineering and Management, Chulalongkorn University, Thailand
Address	Ratchaprarop Tower Mansion, 99 Makkasan, Ratchathewi, Bangkok
Mobile	(+66)0809597626
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Dear Participant,

Thank you for participating in this survey. As part of this research, I am conducting one of the multi-criteria decision analyses based on an analytical network process (ANP) model to obtain decision makers' opinions on choosing suitable PPP contract types for their infrastructure projects.

Selecting an appropriate PPP contract type is a complex and time-consuming issue. It contains several criteria considering the type of project nature and the objectives of the government to obtain the optimal contract for both the public sector and the private company.

Therefore, the objective of this research is to identify and evaluate preferred alternatives based on the priority of the contract selection criteria.

In the following pages, we would like to obtain your opinion as an expert through a survey questionnaire, in which you are requested to prioritize four alternative options with respect to the criteria and goal.

The information you provide will be of great value for this research, and I am very much appreciative of your participation. We sincerely hope you can assist.

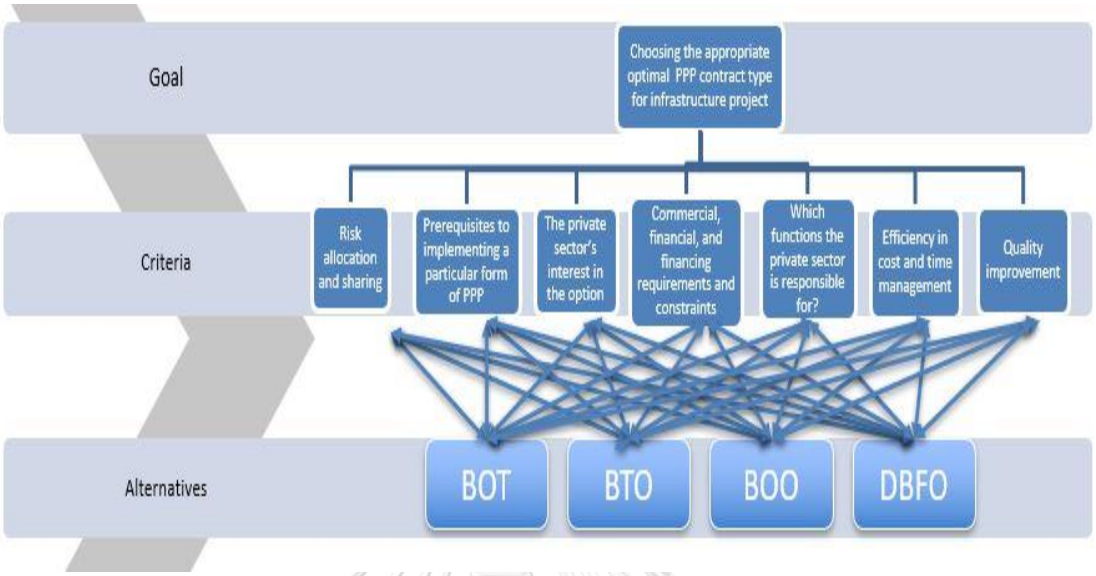

Fig. 1 ANP model to select optimal PPP contract type for the infrastructure project

Explanation

The main problem is divided into sub-problems by clearly identifying the goal, criteria/ sub-criteria, and alternatives as shown in Figure (1).

Goal : What we want to achieve,

Criteria : The set of parameters on which a decision depends, and

Alternatives : The elements upon which a decision must be made.

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For this research,

Goal is to choose appropriate PPP contract type for (please kindly mentioned the project that you have experienced e.g. Road project, mass transit project, etc.) project.

(7) Criteria include for the in-depth interview result of (7) PPP experts,

1. Risk allocation and sharing

2. Government's preference in the PPP option

3. The private sector's interest in the option

4. Finance constraints

5. Land ownership

6. Efficiency in cost and time management

7. Quality improvement

(4) Alternatives,

1. BOT

2. BTO

3. BOO

4. DBFO will include.

1. Build-Operate-Transfer (BOT)

In the BOT contract, the private partner provides the capital investment required to build a new facility. The private operator will own the assets for a time period set by the contract, which is sufficient to allow the developer to recuperate its investment costs through user charges (e.g., collect the revenue from users). Thus, the private sector's transfer period must be long enough to cover its investment. In some PPP projects, the public sector agrees to purchase a minimum level of output, which is sufficient for the operator to recover its costs during operation.

2. Build-Transfer-Operate (BTO)

In Build-Transfer-Operate (BTO) projects, the government pays the capital investment. Thus, the private company needs to transfer the ownership of assets to the public owner immediately after construction has been completed, rather than at the end of the contract.

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3. Build-Own-Operate (BOO)

In Build-Own-Operate (BOO) projects, the developer constructs and operates facilities without transferring the ownership to the public sector. This type of PPP arrangement is similar to privatization, but in BOO projects the government is still involved.

4. Design-Build-Finance-Operate

With the Design-Build-Finance-Operate (DBFO) approach, the responsibilities for designing, building, financing, and operations are bundled together. However, the asset ownership is always with the public entity. The DBFO arrangements vary greatly in terms of the degree of financial responsibilities, which are usually transferred to the

private partner [1]. Since the legal ownership of the facility remains with the contracting authority throughout the contract, the private sector's interest in the project is based solely on the contractual rights to operate the facility and to receive revenues from the off-taker, rather than on the ownership of the physical assets.

Table 1-Saaty comparison scale

Scale	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values
Use reciprocals for inverse comparisons	

Please rank the pairwise comparison by using a scale of 1 to 9. For example, table 1 means that " For financing issue, BOO is …. times more important than BOT. or You can use red color side for less important scale. For the financing issue, BOO is ….. times less important than BOT.

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No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		
2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BOT is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

1. Financing

2. Good Government

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		
2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BTO is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

3. Legal framework

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		
2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BTO is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

4. Managing system

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		
2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BOT is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

5. Political constraints

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		

2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BOT is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

6. Project configuration

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	BOO is … more important than BOT.																		
2	BOO is … more important than BTO.																		
3	BOO is … more important than DBFO.																		
4	BOT is … more important than BTO.																		
5	BOT is … more important than DBFO.																		
6	BTO is … more important than DBFO.																		

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7. Good government

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	Public participation is … more important than quality improvement.																		

8. Managing system

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	Efficiency in cost and time management																		
2	Efficiency in cost and time management is … more important than .																		
3	Risk allocation and sharing is … more important than .																		

9. Financing

No	Criteria	9	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8	9
1	Private sector's interest is … more important than Finance constraints.																		

Thank you very much for your kind participation.

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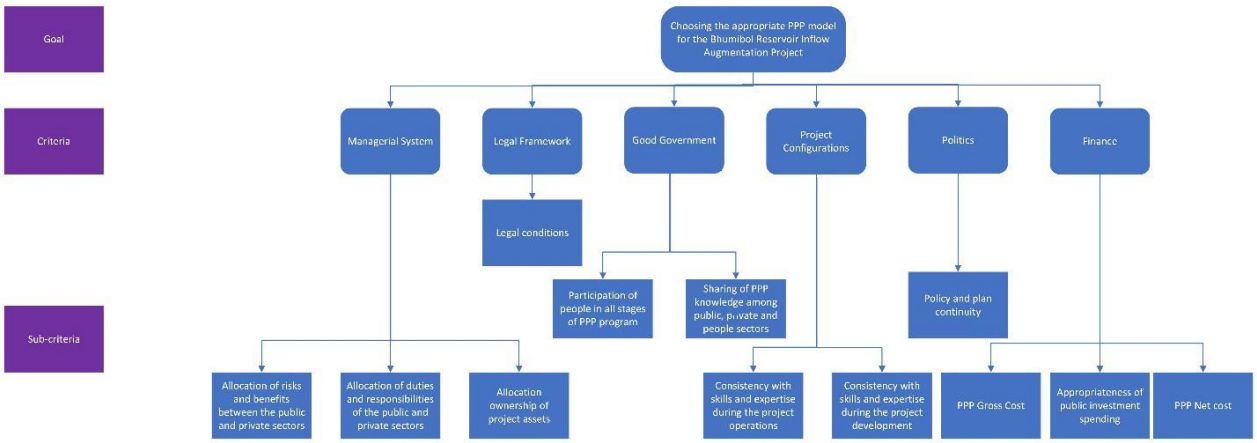
APPENDIX C Case study to select the appropriate PPP contract type for "Water Project"



Criteria, sub-criteria, and alternatives to choose the appropriate PPP contract type for the Bhumibol Reservoir Inflow Augmentation Project

For this case study, the main goal is to choose the appropriate PPP contract type for the Nam Yuam- Bhumibol Reservoir Inflow Augmentation Project.

There are six main criteria and twelve sub-criteria and four alternatives. They include:

1. Managerial system
    a. Allocation of risks and benefits between the public and private sectors
    b. Allocation of duties and responsibilities of the public and private sectors
    c. Allocation ownership of project assets
2. Legal framework
    a. Legal conditions
3. Good government
    a. Participation of people in all stages of PPP program
    b. Sharing of PPP knowledge among public, private and
4. Politics
    a. Policy and plan continuity
5. Project configurations
    a. Consistency with skills and expertise during the project operations
    b. Consistency with skills and expertise during the project development and
6. Finance

a. PPP gross cost
b. PPP net cost
c. Appropriateness of public investment spending

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