AN ENHANCED SUPPLIER SELECTION MODEL BASED ON OPTIMIZED ANALYTIC NETWORK PROCESS TOWARDS SUSTAINABLE INFORMATION TECHNOLOGY OUTSOURCING

PRASHAYA FUSIRIPONG

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Awang Had Salleh
Graduate School
of Arts And Sciences

Universiti Utara Malaysia

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Abstrak

Penyumberan Luar Teknologi Maklumat (ITO) telah menjadi sebahagian daripada strategi organisasi kerana ia menawarkan faedah seperti produk berkualiti tinggi, pengurangan kos dan peningkatan produktiviti. Pada asasnya, ITO ialah proses yang kompleks di mana pemilihan pembekal yang tepat melibatkan penilaian pelbagai kriteria. Untuk memastikan kemampanan projek ITO, kriteria penilaian harus mempertimbangkan faktor risiko dan kriteria kemampanan projek yang lain. Walau bagaimanapun, model pemilihan pembekal ITO sedia ada kurang memberi tumpuan kepada kriteria kemampanan dan faktor risiko. Selain itu, kaedah-kaedah sedia ada bergantung pada pertimbangan manusia dalam peruntukan pemberat. Oleh itu, kajian ini mencadangkan sebuah Model Pemilihan Pembekal Dipertingkat (ESS) untuk ITO mampan tumpuan kepada menghapuskan pertimbangan manusia dalam kaedah Proses Rangkaian Analitik (ANP). Model ESS telah dibina melalui kajian teori, penerokaan dan eksperimen. Kajian penerokaan dijalankan di Thailand menggunakan kaedah tinjauan yang melibatkan 45 responden. Dapatan daripada kajian telah digunakan untuk membina kriteria penilaian dan menjadi set data untuk ESS. Model ESS yang dicadangkan telah dinilai menggunakan semakan pakar dan kajian kes di Thailand. Model ESS mengandungi dua komponen utama: kriteria penilaian dan kaedah membuat keputusan. Komponen pertama mempunyai sembilan belas (19) kriteria kemampanan dan tujuh (7) faktor risiko. Manakala komponen terakhir ialah ANP yang dipertingkatkan dengan Algoritma Firefly (ANP-FA). Keputusan penilaian menunjukkan bahawa Nisbah Konsistensi (CR) bagi ANP-FA adalah lebih kecil daripada ANP, iaitu 0.003 berbanding 0.031. Hasil ini menunjukkan bahawa model ESS boleh dilaksanakan dalam menghapuskan pertimbangan manusia dalam pemilihan pembekal projek ITO. Sumbangan kajian boleh ditafsirkan dari dua perspektif. Model ESS yang dicadangkan adalah sumbangan teori dalam bidang Pembuatan Keputusan Pelbagai Kriteria dan Pemilihan Pembekal dalam projek ITO. Dari segi praktikal, model tersebut telah direalisasikan dalam organisasi di Thailand untuk memastikan kemampanan projek ITO.

Keywords: Penyumberan Luar Teknologi Maklumat (ITO), Model pemilihan pembekal, *Analytic network process*, Algoritma firefly, Pembangunan mampan

Abstract

Information Technology Outsourcing (ITO) has become part of the organization's strategy as it offers benefits such as high-quality products, cost reduction, and increased productivity. Essentially, ITO is a complex process in which selecting the right supplier involves evaluation of multi criteria. To ensure the sustainable of the ITO project, the evaluation criteria should consider risk factors and other sustainability criteria of the project. However, existing ITO supplier selection models lack of sustainability criteria and risk factors. Moreover, these methods rely on human judgment in weight allocation. Therefore, this study proposes an Enhanced Supplier Selection Model (ESS) for sustainable ITO mainly to eliminate human judgment in Analytical Network Process (ANP) method. The ESS Model was constructed through theoretical, exploratory and experimental studies. The exploratory study was carried in Thailand using survey which involved 45 respondents. Findings from the study was used to construct evaluation criteria and become datasets for ESS. The proposed ESS Model was evaluated using expert reviews and case studies in Thailand. The ESS model contains two main components: evaluation criteria and a decision-making method. The first has nineteen (19) sustainability criteria and seven (7) risk factors. While the latter is an enhanced ANP with Firefly Algorithm (ANP-FA). The evaluation results indicate that the Consistency Ratio (CR) for ANP-FA is smaller than ANP, which is 0.003 compared to 0.031. This outcome shows that the ESS model is feasible in removing human judgment in supplier selection of ITO projects. The study's contributions can be interpreted from two perspectives. The proposed ESS model is a theoretical contribution in Multi-Criteria Decision-Making and Supplier Selection in ITO project. In terms of practicality, the model has been realized in Thailand organizations to ensure the sustainability of ITO projects.

Keywords: IT outsourcing, Supplier selection model, Analytic network process, Firefly algorithm, Sustainable development

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List of Abbreviations

ACO	Ant Colony Optimization
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
ANP	Analytic Network Process
CI	Consistency Index
CR	Consistency Ratio
ELECTRE	Elimination and Choice Expressing Reality
ESS	Enhanced Supplier Selection
FA	Firefly Algorithm
FST	Fuzzy Set Theory
MCDM	Multi-Criteria Decision-Making
NRA	Normalization of Row Average
NRC	Normalization of the Reciprocal Sum of Columns
PCM	Pairwise Comparison Matrix
PROMETHEE	Preference Ranking Organization METHod for Enrichment of Evaluations
PSO	Particle Swarm Optimization
SE	Software Engineering
SB	Sum of Bias
SPSS	Statistical Package for Social Science
SSS Model	Sustainable Supplier Selection Model
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
WSM	Weighted Sum Method

CHAPTER ONE

INTRODUCTION

1.1 Background

Nowadays, most organizations are facing problems in Information Technology (IT) project implementation. These problems include inefficient IT staffs, difficulty in accessing and maintaining new technology, and also the increasing of project implementation cost (Faisal & Raza, 2016; Thakur & Anbanandam, 2015). Hence, IT outsourcing (ITO) plays an important role in reducing the cost, ensuring time to market and improving the quality of the products. ITO is defined as the process of handing over part or all of an organization's technology/systems-related functions to external service provider(s) (Gottschalk & Solli-Sæther, 2005; Loh & Venkatraman, 1992). Through ITO, the issue of staff inefficiency can be solved (Gonzalez, Gasco, & Llopis, 2005). Moreover, according to Kobelsky and Robinson (2010) in (Faisal & Raza, 2016), ITO is able to improve organizations' IT capabilities and reduce the expenditure on utilizing the latest IT tools. These have been the crucial motivation behind the adoption of outsourcing activities (Hanafizadeh, 2018).

The term "outsourcing" is mentioned as "turning over a part of the full task of a project to the selected supplier for providing products or services" (Estember & Jacob, 2019; Hanafizadeh & Zare Ravasan, 2017; Smuts, Kotzé, van der Merwe, & Loock, 2015). It involves identifying, gathering, and analyzing the appropriate information of the potential suppliers. Outsourcing also involves a contractual business between an organization and the selected supplier. The contract is used as the evidence in managing, maintaining, transferring or leasing both hardware and software (Jain & Khurana, 2016; Liu, Chan, & Ran, 2016); including Information Technology (IT) staffs

(Estember & Jacob, 2019; Smuts et al., 2015) as well as sharing the risk of new technology accessibility (Faisal & Raza, 2016; Sukru Cetinkaya, Ergul, & Uysal, 2014). Outsourcing in IT project includes software development (Lin, 2016; Thakur & Anbanandam, 2015), data center operation (Secundo, Magarielli, Esposito, & Passiante, 2017), help desk (Faisal & Raza, 2016), cloud services/web hosting (Liu et al., 2016; Morais, Costa, & de Almeida, 2014), Enterprise Resource Planning (ERP) (Khan & Faisal, 2015) and testing (Ismail & Razali, 2014).

According to Hodosi and Rusu (2019), ITO activities have increased along with the increase of IT spending between 2017 and 2020. Approximately 65% of the organizations in Sweden and Denmark have outsourced their IT projects (Hodosi & Rusu, 2019). The reasons for outsourcing of IT projects include enabling the organization to focus on its core business; overcome the lack of knowledge and skills within the organization; improve the quality and services; increase organization productivity and reduce cost (Estember & Jacob, 2019; Hamzah, Sulaiman, & Hussein, 2013; Jain & Khurana, 2016). Hence, selecting an appropriate supplier is a crucial activity in outsourcing. Through outsourcing, an organization is able to utilize the resource and capabilities of other companies (Sobinska & Willcocks, 2016). Due to the potential benefit of outsourcing, there is a steady grow and demand for IT projects.

However, there are many obstacles in outsourcing to influence the ITO success. Only 34% of the satisfaction was with the suppliers' innovation, whilst 66% had been the problem escalation to senior management (Hanafizadeh, 2018). This is supported by Hodosi and Rusu (2019) who reported that 25% of the ITO projects were reported failed. The findings indicate that the decision for selecting a qualified supplier in outsourcing is complex. Existing supplier selection models are not suitable for the ITO phenomenon due to these models did not offer transparent decision-making methods (Kilic, Zaim, & Delen, 2015; Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi, Miri-Nargesi, & Ansarinejad, 2017; Thakur & Anbanandam, 2015). Most criteria adopted in supplier selection model rely on domain expert (i.e. expert's suggestion) (Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017). Thus, the supplier selection should not only emphasize the maximum benefit but also need to consider other factors influencing on the project sustainability (Yadav & Sharma, 2016).

Apart from offering many benefits, ITO also presents some challenges and risks. Unexpected risks may have a negative impact on the organization (Yoon, Talluri, Yildiz, & Ho, 2018). Risk disruption eventually result in operational failure and leading to the loss of benefits to the organisation (Dupont, Bernard, Hamdi, & Masmoudi, 2018; Ho, Zheng, Yildiz, & Talluri, 2015). These risks include uncertain customer demand, uncontrolled expenditure, delay of product delivery, and hazard from nature and human (Chopra & Sodhi, 2014; PrasannaVenkatesan & Goh, 2016). There are several studies identifying the risk factors in the supplier selection model to evaluate the shortlisted suppliers (Alikhani, Torabi, & Altay, 2019; Li & Zeng, 2016; Rao, Xiao, Goh, Zheng, & Wen, 2017). According to Nduwimfura and Zheng (2015b), risk factors in ITO can be classified in five categories namely economic, organizational, legal, technical, and psychological. These factors should be a part of the evaluation criteria becoming the suppliers' performance indicator in the selection process (Karami and Guo (2012) and to avoid unexpected hazards or even enormous losses in ITO (Cong & Chen, 2015; Nduwimfura & Zheng, 2015b). According to Alikhani et al. (2019); Rao, Xiao, et al. (2017), if the risk of outsourcing arises at the supplier's site, the overall quality of a project entrusted to the supplier would suffer. As a result, unsustainable project ITO patterns emerges, including customer dissatisfaction and economic losses.

Moreover, sustainability has become an important characteristic in ITO project. Sustainable supplier selection balances occur in three sustainability perspectives; economic, social and environmental (Fallahpour, Udoncy Olugu, Nurmaya Musa, Yew Wong, & Noori, 2017; Luthra, Govindan, Kannan, Mangla, & Garg, 2017). Carter and Rogers (2008) define sustainable supply chain management as “the strategic, transparent integration and achievement of an organization’s social, environmental, and economic goal in the systemic coordinate of key inter-organizational business processes for improving the long-term economic performance of the individual and its supply chains”. These perspectives are adopted to assess the suppliers’ performance in the selection process based on various businesses such as textile (Fallahpour et al., 2017), medical (Ghadimi & Heavey, 2014) and food (Nourmohamadi Shalke, Paydar, & Hajiaghaei-Keshteli, 2018). On top of this, an efficient IT system is currently required in many organizations to support the global business competition as studies of Lin (2016); Nazari-Shirkouhi et al. (2017); Thakur and Anbanandam (2015). Hence, the technical capability of the supplier becomes a crucial part of the ITO and should be considered the supplier selection process (Zavadskas, Govindan, Antucheviciene, & Turskis, 2016).

The goal of pursuing a sustained outsourcing cannot be achieved by a single organization. When the organization outsources its projects to the supplier, it becomes more critical for the organizations to monitor and assess the sustainability of their business partners. Sustainable ITO is neglected in the supplier selection problem. Most organizations only consider their business efficiency and effectiveness while ignoring the integration of technology sustainability. This is because of a lack of knowledge in new innovation of IT system, rapid change in IT software, hardware, network (Faisal & Raza, 2016) and neglected software sustainability (Nazari-Shirkouhi et al., 2017;

Thakur & Anbanandam, 2015). Consequently, based on the review of the literature, the gathered criteria adopts the matching technique based on similar meaning (Fusiripong, Baharom, & Yusof, 2017) to determine it into sustainable criteria in four perspectives namely economic, social, environmental, and technology. However, environmental sustainability can be involved with the IT infrastructure (i.e. server, and network equipment) because using material consumes energy in IT systems incurring efficiency and effectiveness increasingly. Unfortunately, IT infrastructure adoption neglects green technology to reduce gas pollution and avoid the use of hazardous materials. These affect environmental sustainability significantly.

In addition to the absence of a sustainable evaluation criteria in supplier selection model, the Multi-Criteria Decision Making (MCDM) methods constributes as a cause in the non-transparent decision-making process. The MCDM methods are introduced in many studies; individual method (Ahmad, Saman, Mohamad, Mohamad, & Awang, 2014; Mukherjee & Mukherjee, 2015; Repschlaeger, Proehl, & Zarnekow, 2014; Yang & Peng, 2012) and integration method (Azimifard, Moosavirad, & Ariafar, 2018; Jain, Sangaiah, Sakhuja, Thoduka, & Aggarwal, 2016; Nazari-Shirkouhi et al., 2017; Secundo et al., 2017). One of the MCDM methods that has been widely used in supplier selection for both individual and integration methods is Analytic Hierarchy Process (AHP). AHP is able to measure both tangible and intangible criteria (Yadav & Sharma, 2016) and generated important weights (Vinodh, Patil, Sai Balagi, & Sundara Natarajan, 2014). The uncertainty and vagueness in AHP are due to dependency on human judgment quantitative assessment (Zhang, Deng, Chan, Adamatzky, & Mahadevan, 2016) opinion and knowledge (Çakır, 2017). Moreover, if AHP comprises of numerous alternatives, and it needs a huge amount of paired comparison (Azimifard et al., 2018). Human capability is a limitation in assessment; results will occur error.

There are a number of studies that integrates AHP with other approaches in solving the uncertainty matters (Manivel & Ranganathan, 2019); as with AHP combined with Fuzzy Set Theory (Nilashi, Ahmadi, Ahani, Ravangard, & Ibrahim, 2016; Özdemir & Tüysüz, 2017; Uygun, Kaçamak, & Kahraman, 2015).

Nevertheless, the consistency in the AHP method also relies on the humans' opinion and experience by using the "trial and error" approach (Hossain, Adnan, & Hasin, 2014). Some studies proposed metaheuristic approaches instead of the trial and error approach. Girsang, Tsai, and Yang (2015) claim that ant colony algorithm becomes an effective approach to resolve inconsistency in AHP. Likewise, particle swarm is also deployed (Yang, Wang, & Yang, 2012; Zhang & Dai, 2016). However, there are some limitation in the two swarm algorithms; undefined initial value and instable convergence process, which negatively affect the solution (Gai-Ge, Amir, Xin-She, & Amir, 2014; Shayeghi & Alilou, 2015; Zhong, Jian, & Zijun, 2009).

The existing supplier selection models for ITO are lack of evaluation criteria focusing on sustainability and risk factors. In addition, the methods for supplier selection face several issues such as ambiguity and vagueness by human's subjective (Fallahpour et al., 2017; Secundo et al., 2017; Yadav & Sharma, 2016; Zhang et al., 2016), which lead to bias and obscure decision-making process. Moreover, the supplier selection models focused on criteria relationships in a hierarchical manner. Supplier selection aiming for sustainability should rely on the interaction among criteria and risk factors because the interrelationship among criteria has appropriate in real-world decision making problems (Gölcük & Baykasoğlu, 2016). Thus, AHP could not be deployed in supplier selection for ITO as it has limited capability to analyze criteria dependency. Saaty (1999) proposed the Analytic Network Process (ANP) method to overcome the dependence between criteria. Nevertheless, ANP method also has the same issues as AHP (i.e. the method relies on the human's involvement (Saaty, 1999, 2004)). To overcome the mentioned issues (standardized criteria, inconsistency in human judgment and unstable convergence of swarm algorithm), this study aimed to improve the multi criteria supplier selection model in ITO by adapting software sustainability concepts and Firefly Algorithm (FA) in order to ensure sustainable supplier selection and eliminate humans' involvement in the decision making process.

1.2 Problem Statement

Existing supplier selection models have focused on adopting MCDM which requires two components: evaluation criteria and decision making method (Uygun et al., 2015; Yadav & Sharma, 2015). Most evaluation criteria and risk factors rely on the experts' knowledge, organizations' requirement and unexpected jeopardy (Karami & Guo, 2012; Nazari-Shirkouhi et al., 2017; Rao, Xiao, et al., 2017; Thakur & Anbanandam, 2015). Some supplier selection models have identified sustainable criteria along with risk factors on sustainability to assess the supplier capability (Alikhani et al., 2019; Gold & Awasthi, 2015), the one for supplier selection model of ITO is neglected. Sustainability in the supplier selection model is inadequate (Sofia, Luis, Ambrosio, José, & Ali, 2017) for ITO, due to, not taking software sustainability into account. This reflects the quality of the development and maintenance of the IT systems (Venters et al., 2018). In addition, the relationship between factors in the models of ITO is not taken into account. To date, many supplier selection models have provided integrated decision-making methods to determine the importance of selection criteria (weight allocation) (Fallahpour et al., 2017; Nazari-Shirkouhi et al., 2017; Özdemir & Tüysüz, 2017; Secundo et al., 2017; Uygun et al., 2015). Nevertheless, the methods also involve humans for weight allocation throughout the decision-making process, hence creating more dependency on humans (i.e. domain experts). The subsequent paragraphs explain the detial issues in supplier selection models for ITO, which need further improvement.

1. The absence of sustainability perspective and risk factor in evaluation criteria for ITO

It is vital for decision-makers to implement best practices of ITO for both organization and supplier in today's supplier selection environment. The organizations need to address their quality of products and services, IT experts' efficiency, cost reduction, and sharing risks of IT system. The selected supplier is not to repeal before the end of contract and a long-term implementation. Based on the observations made by Liu et al. (2016); Mukherjee and Mukherjee (2015); Nazari-Shirkouhi et al. (2017), decision-makers do not consider evaluation criteria required for sustainability. This practice is observed by many studies in the supplier selection model of ITO (Kahraman, Beskese, & Kaya, 2010; Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017; Tooranloo, Ayatollah, & Karami, 2018; Yang & Peng, 2012).

Risk factors are among the crucial indicator in ITO implementation. These factors are relevant to project monitoring and controlling for undesirable outcomes and their negative impact occurrence (Javani & Rwelamila, 2016; Samantra, Datta, & Mahapatra, 2014). Karami and Guo (2012) proposed a supplier selection model of ITO that includes risk factors related to the technical expertise, supplier's financial strength and service contract in the selection process. Based on the observations in the supplier selection model of ITO without the risk on sustainability integration; it is different from the work of Alikhani et al. (2019) and Gold and Awasthi (2015). On top of this, the risk factors adopted in the model for ITO do not consider software sustainability. Similarly, the studies in 2012 and 2017 by Cao, Cao, and Wang (2012); Ebrahimnejad, Naeini, Gitinavard, and Mousavi (2017); Nazari-Shirkouhi et al. (2017) neglected to take the risk on sustainability into account.

In order to sustainable ITO, the evaluation criteria and risk factors must include sustainability perspective. Supplier selection model consider three perspectives influencing the sustainability of supplier selection (Azimifard et al., 2018; Fallahpour et al., 2017; Luthra et al., 2017); economic, social and environment. However, if operation of the organization involves technology, then technology sustainability should also address Zavadskas et al. (2016). Technology is a crucial part of software sustainability (Venters et al., 2018). Existing supplier selection model of ITO does not only neglects the sustainability of supplier selection but also neglects software sustainability.

2. Limitation of the ANP method in supplier selection model

Current studies on AHP have been adopting weight allocation in supplier selection problem (Azimifard et al., 2018; Jain et al., 2016; Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017). The related among criteria adopting in AHP is a hierarchy structure. Nevertheless, hierarchy structure does not represent many real-world decision-making problems (Gölcük & Baykasoğlu, 2016). Each evaluation criteria are related to each other; especially, in terms of sustainable supplier selection (Luthra et al., 2017). Hence, there is a dependency relationship between the criteria. Accordingly, the risk factors become a crucial indicator to prevent the undesirable outcome from the ITO (Nduwimfura & Zheng, 2015b) by the supplier selection. AHP method is inadequate to deal with the interrelated criteria because AHP relies on hierarchy structure to define the decision problem (Zhu, Xu, Zhang, & Hong, 2015). The evaluation criteria weights obtained in AHP can be argued that they do not portray the relationship between the criteria (Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017). To achieve real-world decision-making, there is a need for an interrelationship structure, which can be constructed using statistical analysis. ANP is an appropriate method to the weight allocation, which represents the interrelationship each other. This is supported by Gölcük and Baykasoğlu (2016).

Even though ANP offers the capability of interrelation structure, it inherits AHP limitation of relying on human's involvement through knowledge and experience (Saaty, 1999). This causes the input data to be of uncertain and vague (Çakır, 2017; Zhang et al., 2016) affecting the unfair weight allocation throughout the decision-making problem. In facts, there are many integration methods to overcome the uncertainty of human judgment (Çakır, 2017; Kilic et al., 2015; Nazari-Shirkouhi et al., 2017; Secundo et al., 2017; Uygun et al., 2015).

As the AHP weight allocation for evaluation criteria is uncertain and differs between domain experts (Hossain et al., 2014), studies have been looking into employing Swarm Intelligence (SI) (i.e. ant colony and particle swarm) to resolve the issues (Girsang et al., 2015; Yimin, Keqing, & Zeshu, 2016; Zhang & Dai, 2016). This is because SI is an algorithm on self-organized and decentralized system to overcome NP-hard problems that a number of solutions may exist to be infinite (Chakraborty & Kar, 2017). There are diverse problems (i.e. financial, engineering and inventory management) that adopt SI to find out the optimal solution (Liu, Wang, Tu, Ding, & Hu, 2019; Srivastav & Agrawal, 2017; Uthayakumar, Metawa, Shankar, & Lakshmanaprabu, 2020). FA adopts in the optimization problem (i.e. optimal lot size for stock management process) of supply change (Elkhechafi, Benmamoun, Hachimi, Amine, & Elkettani, 2018). This algorithm is one of SI algorithms that is heuristic concentrates (refer to trial and error) to generate new solution in search space to select the optimal solution, (Fister, Fister Jr, Yang, & Brest, 2013). Another one is the tuning parameters to learn a good value to build the balancing between explorations against exploitation. FA is proposed because the algorithm is able to adjust parameter value in ANP to discover the optima solution. This study adopts FA to be integrated into ANP in determining the weight for the evaluation criteria such an approach omits the humans' involvement (i.e. domain expert).

1.3 Research Questions

i. What are the evaluation criteria and risk factors relevant to the supplier selection model towards sustainable ITO?

ii. How are the improvement of the Analytics Network Process (ANP) in order to eliminate human involvement in determining the important weights for evaluation criteria?

iii. How are the evaluation of the enhanced supplier selection model?

1.4 Research Objectives

The aim of the study is to enhance the supplier selection model based on optimizes Analytic Network Process (ANP) towards sustainable ITO. The objectives of the study are:

i. To construct evaluation criteria and risk factors for supplier selection model towards sustainable ITO.

ii. To design an enhance Analytic Network Process (ANP) with Firefly Algorithm (FA) in order to eliminate human involvement in determining the important weights for evaluation criteria.

iii. To evaluate the enhanced supplier selection model for sustainable ITO.

1.5 Scope of the study

The scope of this study includes the ITO and supplier selection criteria and method. The followings are further descriptions on the ITO phenomenon, supplier selection criteria and method and ITO in Thailand:

- IT outsourcing phenomenon scope

Organizations need high supplier's capability performance, especially IT system development and maintenance, due to, the change in business competition. The organizations lack of the capability for the development and maintenance in the IT system (Faisal & Raza, 2016). This is a reason for the need outsourced some part/full IT system to a suitable supplier. The selected supplier must have the expertise and specific ability in each project of ITO. It is difficult to obtain the appropriate supplier under the diverse evaluation criteria and systematic decision method from humans' involvement (Khan & Faisal, 2015; Liu et al., 2016; Nazari-Shirkouhi et al., 2017). The advantages of the ITO are to enhance the business competition in the global business, reduce the expenditure for IT investment, and improve the staffs' IT skills (if the selected supplier has a high performance). This reveals that ITO is a part of increasing organizations' capability. On the contrary, ITO failure is a consequence of the wrong supplier selection.

- Supplier selection criteria and method scope

Currently, most organizations have adopted the IT system to improve business achievement. However, organizations lack experts to develop and maintain the IT system to support their business such as a digital bank (Thakur & Anbanandam, 2015), operating and maintaining IT tools and infrastructure (Faisal & Raza, 2016; Nazari-Shirkouhi et al., 2017) and software development (Alpar & Lucian-Viorel, 2010). The potential supplier has become important for IT system development and maintenance which obtain from the selection process. The supplier selection model has constructed evaluation criteria and risk factors relevant to sustainability. This is also relevant to construct the transparent decision-making method. Based on the review of the literature, there are suitable evaluation criteria on three sustainability dimensions (i.e. economic, social and technology) (see Table 2.6). On top of this, the risk factors identification has reflected the sustainability and successful ITO refer to Table 2.10.

Furthermore, decision-making methods are an important part of the supplier selection model. Existing methods rely on human involvement; the outcomes of methods suffer from the human prejudices to the weight allocation, especially ANP method. FA is integrated into ANP to eliminate human involvement. The novel method integration is called ANP-FA method. ANP-FA does not only eliminate humans, but also allocate the weight values in terms of relationships with each other. As a result, ANP-FA can adopt in real organizations when they need the supplier selection for IT projects outsourcing.

- IT outsourcing in Thailand scope

Generally, the supplier selection of ITO in Thai organizations has various methodologies adoption such as committee consensus, familiarity with a supplier and low price bidding (refer to Chapter Four). These methods are an obstacle to obtain the right supplier from the selection process. In addition, the lack of empirical data, especially evaluation criteria, incurres bewilderment adopting in the supplier selection of ITO in Thai organizations (Tangadulrat, 2010). The proposed model has constructed the evaluation criteria and risk factors on sustainability along with a novel integrated decision-making method. Therefore, organizations have a group of evaluation criteria and risk factors for sustainable ITO being used in the supplier selection model for Thai organizations. There is also the transparent method to allocate the weight values that support the real-world decision problem.

1.6 Significance of the Study

The model offers benefit in both theoretical and practical aspects; body of knowledge and organization.

- Body of knowledge

The aim of this study is to develop a supplier selection model focusing on the decision-making problem in ITO. The study contributes to the field of MCDM, especially ANP method. The integrating swarm intelligence (SI) has been highlighted in this study to eliminate humans' involvement in ANP method as well as increase transparency in the decision-making problems. The study has also corporated the construction of evaluation criteria and risk factors sustainable ITO. These are believed as crucial for the supplier selection model of ITO.

- Purchasing committee

The proposed supplier selection model can support the purchasing committee. The model has proposed suitable evaluation criteria and risk factors for sustainable ITO being used in supplier selection problems. These criteria and risk factors are relevant to three sustainability dimensions: economic, social and technology. In addition, the model also proposes the integrated decision method of ANP-FA to the weight allocation without humans' involvement. This is obvious that the committee has the evaluation criteria and risk factors along with a transparent decision method for supplier selection problems to lead sustainable ITO.

- Organization

The proposed supplier selection model is a tool for the organization to acquire a supplier for the IT project outsourcing. This model provides many indicators in the supplier selection for sustainable ITO, and eliminates humans from the selection process because humans are a crucial problem incur the unfairness affecting the wrong decision. The wrong decision has many disadvantages such as losing the business competition, budget overrun in IT investment and losing the opportunity to access modern technology. The proposed model can increase the efficiency and effectiveness of the supplier selection process; resulting in the organization obtaining the right supplier. This will reflect in the quality of products and services, competitive opportunity, and customer satisfaction increasing along with expenditure reduced.

1.7 Outlines of the Thesis

The thesis is presented in eight chapters as follows:

- Chapter Two: Literature Review

This chapter provides a review on the existing supplier selection model for ITO literature. In particular, it provides a review of the literature in the areas of evaluation criteria and risk factors contributing to the supplier selection. The chapter outlines the sustainable development of ITO. Attention focused on the improved ANP method by integrating the FA. The findings from the literature review are to determine the evaluation criteria regarding the sustainability and risk factors for supplier selection problem of ITO. The instrument was constructed to the exploratory study which supported for producing the proposed model.

- Chapter Three: Research Methodology

This chapter discusses the research methodology employed to achieve the research objectives. The chapter discusses the five phases to construct the Enhanced Supplier Selection (ESS) model. The model emphasizes on constructing the practical evaluation criteria and risk factors regarding sustainable supplier selection of ITO. In addition, it aims to eliminate human involvement in the ANP method to achieve the transparent decision-making process.

- Chapter Four: Exploratory Study

Chapter Four outlines the outcomes obtained from the exploratory study conducted among decision-makers in Thailand. The chapter reveals the opinion and knowledge on selecting the evaluation criteria and risk factors associated and influenced on three sustainability dimensions. In addition, the relationship among evaluation criteria and risk factors have been identified; including its priority. The findings from this chapter support the construction of the proposed model.

- Chapter Five: ESS Model Development

Chapter Five discusses in detail about the proposed model. The discussion proposed two parts: 1) preliminary study and 2) the design of the weight determination method. The preliminary study designed the deployment of FA into ANP to overcome human involvement. The design of the weight determination method was based on the ANP method and the preliminary study. The method was called ANP-FA determining the weight values on the relationship between criteria without human involvement.

- Chapter Six: ESS Model Evaluation

Chapter Six reports on the evaluation of the proposed model through three stages: experiment, verification and validation. The experimental approach proved the deployment of FA that can eliminate human from ANP method. The verification was performed through expert review, while case study, the proposed model was validated on its practicality.

- Chapter Seven: Conclusions

This last chapter concludes the study by recapitulating the study. The contributions of this study are again highlighted. The limitations of the study are addressed. Finally, the future directions in the related field are presented.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Chapter Two explains the overall IT Outsourcing (ITO) in terms of its advantages and disadvantages which effect the organizations in improving their competencies and global competitions. A supplier selection model is a tool reveal in sustainable supplier selection problems finding out a suitable supplier, including ITO. The model relies on Multi-Criteria Decision-Making (MCDM) approach. The MCDM comprises the evaluation criteria and decision-making methods. It is able to increases the efficiency and effectiveness of the decision-making process. The evaluation criteria involves three sustainability dimensions covering economic, social, and technology, including risk factors for sustainable ITO. The Analytic Network Process (ANP) method adopts to allocate the weight values in terms of interrelationship. There are some weaknesses of ANP method as inherited from the Analytic Hierarchy Process (AHP) method. Thus, the concept of hybrid method has adopted to eliminate the shortcomings of ANP method.

2.2 Information Technology Outsourcing

ITO has become a critical strategy in many organizations for nowadays transferring full/some part of IT functions to the supplier (Lin, 2016; Montenegro, Nuñez, & Larco, 2017). Because IT is as one overhead and significant cost factor (Leimeister, 2010). Moreover, ITO is very hard to select the right supplier as it depends on many criteria consideration such as studies of Khan and Faisal (2015); Mukherjee and Mukherjee (2015); Thakur and Anbanandam (2015). Nonetheless, the need for the supplier has been realized caused by lack of organizational capability in developing, maintaining and operating the IT system. These reflect the improving quality and services, increasing organization productivity and cost reduction (Estember & Jacob, 2019; Hamzah et al., 2013; Jain & Khurana, 2016). This is consistent with a study of Faisal and Raza (2016) reporting the organization evolved around ITO, with annual growth rates around 10% and account for approximate 320 billion dollars in 2015. Therefore, ITO becomes an important activity for organizations (Hanafizadeh & Zare Ravasan, 2017; Nduwimfura & Zheng, 2015a; Tjader, May, Shang, Vargas, & Gao, 2014).

Accordingly, most organizations desire to outsource their IT projects to the supplier (Alexandrova, 2012). The aims focus on their core business improvement such as education (Faisal & Raza, 2016), banking (Thakur & Anbanandam, 2015), and travel (Lin, 2016) along with lack of capability to handle their IT systems efficiently (Nazari-Shirkouhi et al., 2017). Therefore, many existing IT projects are outsourced as application development (Lin, 2016), infrastructure planning operation and maintenance (Gorla & Somers, 2014; Thakur & Anbanandam, 2015), IT support (Faisal & Raza, 2016) and Enterprise Resource Planning (ERP) (Khan & Faisal, 2015). These outsourcings involve the IT resources (i.e. software and hardware) transfer/leasing to the supplier (Jain & Khurana, 2016); including IT staffs (Smuts et al., 2015). Obviously, IT projects do not belong to the core business but has to develop and maintain to support the core business of the organization.

Faisal and Raza (2016); Thakur and Anbanandam (2015) mention that the strengths of suppliers are superior technical, complementary skills and scarce expertise. Silva, Gusmão, Silva, Poleto, and Costa (2015) also address that the supplier is better equipped than internal staff to keep learning new technology, and skills. This is also highlighted in the study of Sukru Cetinkaya et al. (2014). On contrary, the wrong supplier selection will cause negative impacts to the IT system; resulting in the organization's loss of core competencies and exposure to unexpected risks (Karami & Guo, 2012). Nevertheless, nowadays organizations also relies on the supplier's capability to improve their IT system (Khan & Faisal, 2015; Thakur & Anbanandam, 2015).

The result is to find out a professional supplier to administrative IT systems for the development and maintenance supporting the business. There are two forms of supplier applied in the organization as on-shoring (Thakur & Anbanandam, 2015) and off-shoring (Mukherjee & Mukherjee, 2015) that have different characteristics, especially working collaboration. The on-shoring has no barrier about understanding the culture and language in the communication among parties. This is opposite against off-shoring supplier faced the that issues in the working collaboration (Mukherjee & Mukherjee, 2015). However, off-shoring affects the cost reduction rather than the on-shoring supplier. If organizations outsourced their IT projects to developing countries such as India, China and Egypt. They can hire IT professionals is the lower price (Nduwimfura & Zheng, 2015a). The studies by Ebrahimnejad et al. (2017); Faisal and Raza (2016); Lin (2016); Morais et al. (2014); Mukherjee and Mukherjee (2015); Qiang and Li (2015); Thakur and Anbanandam (2015) have highlighted that ITO is a good mechanism for improving IT system along with cost reduction. Furthermore, the organizations can share the risk to the supplier, if the organization obtains the right supplier from the efficient selection process.

2.3 Supplier Selection Model

Supplier selection is a critical decision strategy in the supply chain management (SCM) (Fallahpour et al., 2017). The right supplier can lead to the advantange of business competition such as high-quality of products and services and increase customer satisfaction (Rezaeisaray, Ebrahimnejad, & Khalili-Damghani, 2016; Secundo et al., 2017). There are four steps in looking for the right supplier according to De Boer, Labro, and Morlacchi (2001). They introduced the construction framework of the supplier selection model as shown in Figure 2.1

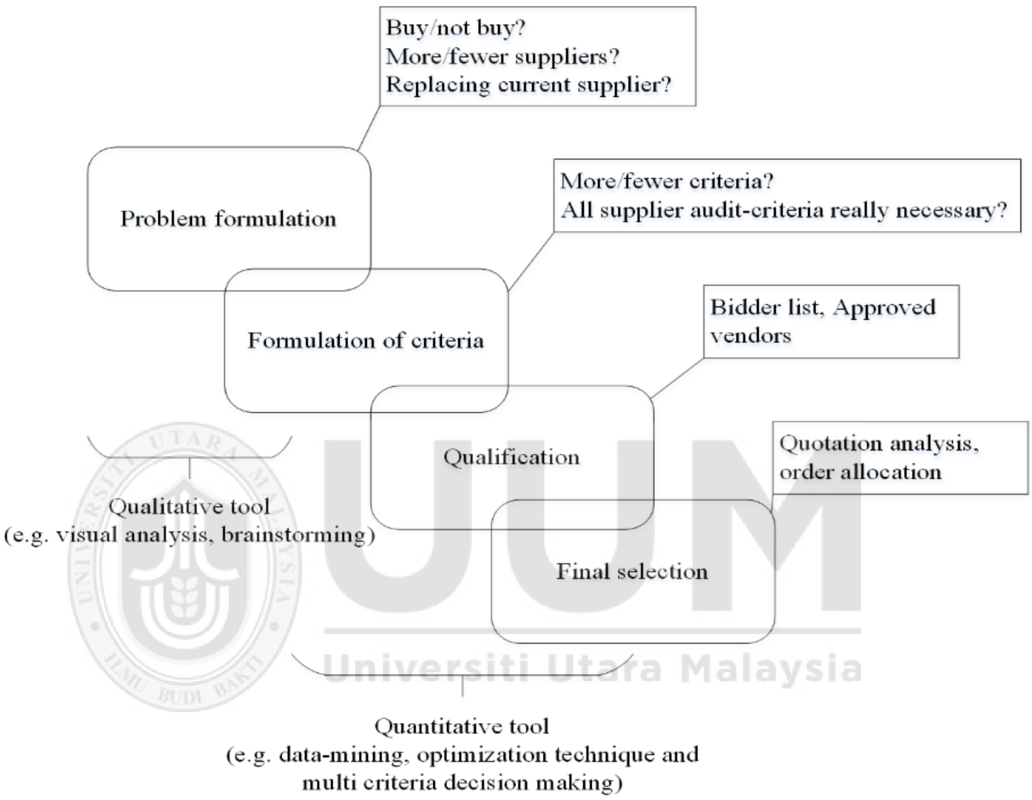

Figure 2.1

The framework of supplier selection model construction (De Boer et al., 2001)

The framework to the construction of the supplier selection model consists of two components; they are the formulation of criteria and decision-making methods according to the works of Jain et al. (2016); Yadav and Sharma (2016). Firstly, the formulation of criteria is converted from the organization’s requirement and collected from referenced literature along with experts’ opinion to measure the suppliers’ performance (Ahmadizadeh-Tourzani, Keramati, & Apornak, 2018; Lima-Junior &

Carpinetti, 2016). This reflects the diverse criteria depending on the type of product being considered along with many qualitative criteria as well as quantitative criteria. Dickson (1996) identifies and analyzes 23 criteria for supplier selection based on the survey of the purchasing manager. The results shows that these criteria are suitable for the supplier selection problem. Jain et al. (2016) argues that there are only eight criteria (produce quality, price/cost, quality of the relationship, manufacturing capability, warranty, on-time delivery, environmental performance and brand name) as suitable for finding out the headlamp supplier. Whilst Yadav and Sharma (2016) classifies criteria into six main criteria (quality, cost, delivery, service, long-term relationship and flexibility) and 22 corresponding sub-criteria to the supplier selection of the automobile industry of Indian context. These studies points out the criteria difference adopting in each situation of the supplier selection problem as followed to the studies of Ahmadizadeh-Tourzani et al. (2018); Jain et al. (2016); Yadav and Sharma (2016).

Sustainability has significantly become the supplier selection with the aim of measuring the suppliers' sustainability performance in the supplier selection process according to sustainable criteria (Öztürk & Özçelik, 2014). This is why organizations can improve their long-term businesses under environmental awareness and social responsibility in addition to economic achievement (Fallahpour et al., 2017). Therefore, many existing supplier selection models have adopted the sustainability concept to determine the evaluation criteria based on three sustainability dimensions (i.e. economic, environmental and social) based on the studies of Azimifard et al. (2018); Fallahpour et al. (2017); Rabbani, Foroozesh, Mousavi, and Farrokhi-Asl (2017). In addition, some supplier selection models do not only concern the sustainable criteria, but also mentions to the risk factors, as a one factor to the suppliers' capability measurement (Alikhani et al., 2019; Gold & Awasthi, 2015; PrasannaVenkatesan & Goh, 2016).

The second component of supplier selection model is decision-making method to synthesize the evaluation criteria. Most evaluation criteria consisted of intangible (qualitative) criteria cannot be measured with the numeric exactly. Thus, the assessment of criteria relies on the human knowledge and their opinion (Fusiripong et al., 2017). MCDM has become a robust analytic method for the supplier selection model (Ahmadizadeh-Tourzani et al., 2018). However, the capability in each MCDM method has a different aim to use in the supplier selection model. For example, AHP/ANP method has the capability in synthesizing the weight values of both quantitative and qualitative criteria simultaneously (Saaty, 2004; Saaty, 2013). The synthesis process relies on humans' preference with uncertainty information (Jain et al., 2016; Manivel & Ranganathan, 2019; Secundo et al., 2017). Another MCDM method is the ranking method as TOPSIS method to the supplier score calculation (Azimifard et al., 2018; Vinodh et al., 2014). Table 2.1 further discusses the supplier selection model in details.

Table 2.1

Supplier selection model adopted by organizations

Proposed model	Descriptions	strengths	weaknesses	example of existing studies using the supplier selection model
Multi-Criteria supplier selection model using the Analytic Hierarchey Process approach	The model aimed to construct the criteria for the supplier selection of automobile industry under the different supply environment. In addition, the model had allocated the weight values in each criteria along with providing the supplier score by using AHP method.	The model constructed suitable criteria, which contained of six main criteria and their corresponding criteria, for the supplier selection problem of automotive industry in the Indian context. The model had also reduced the complexity of supplier ranking process in the AHP method by using the Weight Cum Rating method.	The formulation of criteria in the model relies on a single country context, which could not extend to the other automotive companies in different countries. Then another one was increasingly the computation complexity when have more number of supplier.	Yadav and Sharma (2015)
An integrated DEMATEL and Fuzzy ANP techniques for evaluation and selection of outsourcing provider for a	The model aimed to construct the formulation of criteria along with the interrelationship each other. In addition, the model proposed the hybrid decision-making method as Fuzzy ANP method to the	The model could overcome the criteria independent structure, which could not support real-world problems (Gölcük & Baykasoğlu, 2016). In which the model had constructed the interrelationship among criteria in terms of cause and	The weight allocation of the model involved the human preference. The occuring covered both the criteria synthesis and computation of supplier score.	Uygun et al. (2015)

Proposed model	Descriptions	strengths	weaknesses	example of existing studies using the supplier selection model
telocommunication Company	weight allocation and supplier score computation.	effect. In addition, the model had overcome the inconsistency and information uncertainty of human involvement to the weight allocation by integrating the Fuzzy Theory into ANP method.		
A decision support model for sustainable supplier selection in sustanable supply chain management	The model aimed to construct the sustainable criteria into three sustainability dimensions (economic, environmental and social). In addition, the model proposed the hybrid decision-making method by using the Fuzzy Preference Programming with the Fuzzy TOPSIS method. The hybrid method had allocated the weight values and supplier score computation to the sustainable supplier selection.	The sustainable criteria and sub-criteria owned robustness in terms of importance and applicability that adopted in the model. The model had also modified the fuzzy AHP method to increase accuracy of the dealing with inconsistency and uncertainty to the weight allocation. In addition, the model has reduced some shortcomings AHP in terms of supplier ranking with TOPSIS under uncertainty of human perference	The model relied on the human to allocate the weight value and lack of the dependence relationship of criteria.	Fallahpour et al. (2017)

Proposed model	Descriptions	strengths	weaknesses	example of existing studies using the supplier selection model
Model of global sustainable supplier selection including (1+n)th tier suppliers	The model aimed to propose a comprehensive framework of criteria and including social and environmental sustainability risk along with the propose Fuzzy AHP as the decision-making method to the weight allocation and rank the suppliers.	The model could synthesize the off-shore supplier in addition to on-shore supplier and had specifically factor in the risk of sustainability-related non-compliance of the suppliers' supply chains for global sustainable supplier selection problems.	The criteria of the comprehensive framework in the model lacked of interrelationship between criteria and risk factors on sustainability. In addition, the model, that adopted the AHP method, had a more complexity computation when number of the criteria/supplier increased.	Gold and Awasthi (2015)

The results in Table 2.1 shows that the proposed supplier selection model pay attention to the business requirement to construct the evaluation criteria along with the sustainability dimensions such as economic, environmental and social (Fallahpour et al., 2017). Some models have also determined the risk factors for the sustainable supplier selection to prevent the undesirable outcome from suppliers following studies of Gold and Awasthi (2015). The undesirable outcomes might occur from two hazard states as disruption (i.e. natural disaster, strikes and so on) and operation (i.e. cost fluctuation, equipment failure, demand uncertainty and so on) (Dupont et al., 2018; PrasannaVenkatesan & Goh, 2016). Unfortunately, the relationship of criteria adopted in the model is also based on the independence structure (Gold & Awasthi, 2015), which is not suitable for realistic supplier selection problems (Gölcük & Baykasoğlu, 2016). Furthermore, the supplier selection models have eliminated the information uncertainty of humans by using the hybrid method concept, especially with AHP and ANP methods (Gold & Awasthi, 2015; Uygun et al., 2015). The hybrid method also increases the accuracy of dealing with inconsistency to the weight allocation (Fallahpour et al., 2017). However, these supplier selection models must rely on human involvement in the weight allocation.

2.4 Supplier Selection Model of IT Outsourcing

Although there are various supplier selection models have identified the evaluation criteria on sustainability dimensions. These criteria focus on sustainable supplier selection (Fallahpour et al., 2017; Rabbani et al., 2017) and some models include the risk factors on sustainability (Gold & Awasthi, 2015). On contrary, the supplier selection model of ITO has only identified the criteria for measuring the suppliers' capability based on the studies of Khan and Faisal (2015); Mukherjee and Mukherjee (2015); Thakur and Anbanandam (2015). The model needs further improvement since it does not concern the sustainability as studied by Mukherjee and Mukherjee (2015); Secundo et al. (2017); Thakur and Anbanandam (2015). In addition, the decision-making method in the model adopts the concept of the hybrid method to eliminate some shortcomings of AHP and ANP method to the weight allocation (Cao et al., 2012; Efe, 2016; Kilic et al., 2015). The examples are information uncertainty and reducing the complexity of supplier score computation when having a huge amount of suppliers. Thus, this study has determined the evaluation criteria involved sustainability; including risk factors for supplier selection model of ITO. The hybrid method adopted in the model has been also proposed to eliminate human involvement to the weight allocation. Consequently, the details in model construction are elaborated further subsequently.

2.4.1 Determining the Sustainability for Supplier Selection of IT Outsourcing

Sustainability is a key for the organizations perform their business in long-terms achievement based on environmental awareness and social responsibility besides economic growth (Luthra et al., 2017). Therefore, most organizations have adopted the sustainability concept into the supplier selection process such as in the Fallahpour et al. (2017); Rabbani et al. (2017); Rao, Goh, and Zheng (2017). Since the supplier is a key of organizations' strategy to perform their business, especially with non-core business (i.e. IT system) (Secundo et al., 2017; Thakur & Anbanandam, 2015). In addition to sustainable supplier selection, IT system should apply the sustainability concept to drive the implementation longevity. This involves software sustainability consisting of two distinct viewpoints as sustainable software and software engineering for sustainability (SE4S) (Venters et al., 2018). Hence, these sustainabilities have been further described in the details for sustainable ITO in the supplier selection process.

2.4.1.1 Sustainability adopted in supplier selection

Sustainable development plays a vital role the long-terms success sustaining the performance and competitiveness on the organizations (Rao, Goh, et al., 2017; Zavadskas et al., 2016). As the common meaning that states sustainability is a "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Sustainability has been covered into three dimensions namely economic, environmental and social as shown in Figure 2.2.

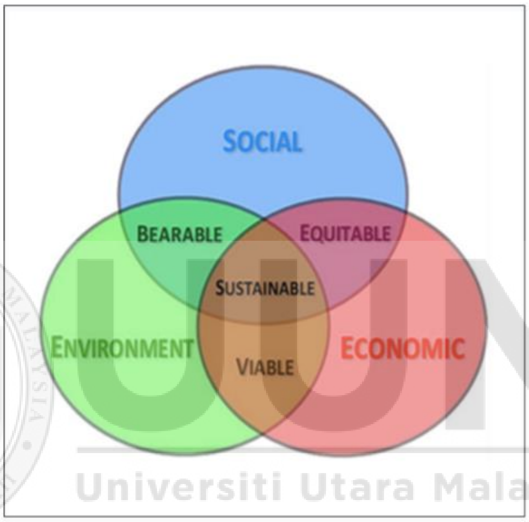

Figure 2.2
Three sustainability dimensions (Marnewick, 2017)

Sustainability has considered the balance of three dimensions (i.e. economic, environmental and social) to utilize the supplier selection along with help organizations to maintain their competitive position (Rao, Goh, et al., 2017). This has led to determine the evaluation criteria relevance to assess the suppliers' capability (Azimifard et al., 2018; Luthra et al., 2017; Rabbani et al., 2017). Moreover, the balancing of three dimensions implies the relationship of criteria in sustainability dimensions (Jayakrishna & Vinodh, 2015). Some previous researches adopted the sustainability concept to construct the relationship of criteria. According to Luthra et al. (2017), the relationship of criteria is based on independence structure. The structure is insufficient for the real-world supplier selection problems as addressed in the study of Gölcük and Baykasoğlu (2016). This is different from the work of Girubha, Vinodh, and Kek (2016) who adopted interpretative structural modeling (ISM) to identify the interrelationship among criteria on three sustainability dimensions as referred to the dependence structure.

There are many existing studies adopting three sustainability dimensions to determine the evaluation criteria for supplier selection based on referenced literature and experts' suggestions. For example, textile business (Fallahpour et al., 2017), automotive business (Luthra et al., 2017), medical device business (Ghadimi & Heavey, 2014), food business (Nourmohamadi Shalke et al., 2018), and steel business (Azimifard et al., 2018). Therefore, three sustainability dimensions are appropriate to the formulation of the evaluation criteria for the sustainable development of supplier selection. Table 2.2 has describes the meaning of each sustainability dimension to determine the evaluation criteria by summarized from the review of the literature.

Table 2.2

Sustainability for supplier selection

Sustainability	descriptions	references
Economic	• Ability to supply and deliver the products and services at reasonable price based on the good quality level. • Delivering the needed products and services to the organization following the schedule and contract. • Flexibility of price and supply products and services for organization when they have the market variation.	Fallahpour et al. (2017); Luthra et al. (2017); Rabbani et al. (2017)
Environment	• The supplier utilizes the green concept to produce the products for reducing pollution that negatively impact the natural as well as reduction of using the harmful materials.	Azimifard et al. (2018); Fallahpour et al. (2017)
Social	• The interests and rights of stakeholders' relevant (i.e. shareholder, consumers and communities). • Human right, which involves with worker of both safe and healthy, understanding the difference of the religious and cultural at the international work, and labor right.	Azimifard et al. (2018); Fallahpour et al. (2017); Rabbani et al. (2017)

The result in Table 2.2 illustrates a suitable three sustainability dimensions to determine the evaluation criteria in terms of economic, environmental and social. The economic dimension involves the reasonable price for employing the supplier. Also, the dimension points out the direct outcome form a supplier such as the quality of the products and services, delivery products and services on time and so on. These have led to identify the corresponding criteria to assess the supplier capability that reflects the organization's economic growth (Fallahpour et al., 2017; Luthra et al., 2017; Rabbani et al., 2017). In addition to economic growth, organizations have concerned the environment issues because the stakeholders of organization (i.e governments, customer and communities.) enforces organizations to protect the environment (Azimifard et al., 2018). This reflects to the environmental dimension to determine the criteria relevant to the green concept (i.e. green warehousing, green transportation and green technology) as mentioned in the study of Fallahpour et al. (2017). The last sustainability is social dimension involving the human. There are many existing studies identifying the relevant criteria to the social sustainability ensure that supplier has supported their employees in terms of human right, well-being as well as motivational activities at work (Fallahpour et al., 2017; Rabbani et al., 2017).

2.4.1.2 Sustainability adopted in software system

Sustainability in the meaning of Brundtland (1987) points to the word 'need' that can identify in a variety of dimensions as time, present and future as well as the acknowledging changing requirements of stakeholders and evolution (Venters et al., 2018). In relation to software, they also highlight the two distinct viewpoints as software and sustainability-related to sustainable software and software engineering for sustainability (SE4S). Sustainable software involves the principles, practices and processes that contributed to the software endurance (i.e. technical stainability) while

SE4S supports the software system in various dimensions of sustainability when business requirements change (Penzenstadler, 2013). Both of them are essential for developing and maintaining a sustainable software system (Penzenstadler, Bauer, Calero, & Franch, 2012). This is because a software system has been linked to the uncertainty of business processes requiring continuous development, deployment and maintenance (Betz & Caporale, 2014).

Therefore, sustainability in Software Development Life Cycle (SDLC) becomes a crucial development process, which consists of five steps starting from the requirement, design, coding, testing and implementation, as following the study of Raisian, Yahaya, and Deraman (2017). They also mentions to the employee welfare and hardware resources investment to support the future software system from requirement changed as well as system maintenance. This is different from the work of Penzenstadler et al. (2012) that distinguishes four aspects of sustainability in software engineering that does not only highlight developing and maintaining but also includes IT resources to respond positively impacting the environment. Thus, the resulting sustainable software system involves several perspectives such as human capability and welfare, enabling communication and interaction, reasonable cost in the software development as well as long-time usage of the software system both functional and technical (Amri & Saoud, 2014).

Furthermore, the software system requires IT infrastructure efficiency that comprises various pillars (i.e. server, network and so on) as addressed in the work of Cevere and Gailums (2017). Unfortunately, the efficient IT infrastructure relies on high energy consumption, greenhouse gas emissions and using harmful material. Therefore, in order to sustain energy efficiency but also taking into account the environment, Marnewick

(2017) adopted the concept of green technology into the IT infrastructure. Consequently, the study has summarized sustainability dimensions for software systems along with their description from the referenced literature as shown in Table 2.3.

Table 2.3

Sustainability for software system

Sustainability	descriptions	references
Economic	• Software system incurs the both indirect and direct added value (i.e. wealth creation to the shareholder, profitability, captial investment and income) based on reasonable cost throughout the development and implementation phases. • Obtaining the long term profits based on the high quality of both products and services of software system	Amri and Saoud (2014); Raisian et al. (2017); Venters et al. (2018)
Individual	• IT staffs welfare that comprises of the mental and physical well-being, freedom and working hours. In addition, the knowledge/skills constructive for IT staffs, especially developers, is supported. • The supported IT staffs, especially developers, involves their knowledge/skill constructive.	Amri and Saoud (2014); Raisian et al. (2017)
Environment	• Energy consumption in IT infrastructure of the software system should sustain the environment, which the resources consumption, especially hardware components, has applied the concept of green technology (i.e. lowering greenhouse gas emission, using less harmful material, and encouraging reuse and recycling).	Amri and Saoud (2014); Salam and Khan (2016)
Social	• The social community in the software development process has explained the participation, communication and interaction for the requirement collection to increase the software useful life and improve the software product. This also addresses the software accessibility to support the users' adoption.	Amri and Saoud (2014); Raisian et al. (2017)

Sustainability	descriptions	references
Technology	• This sustainability has addressed the functional and technical aspects that reflect the software survivability. The business process changed is significant addressing the functional software evolution. This also influences the incessant technology evolution such as maintainability, and sustain perdurability of software systems (including IT infrastructure).	Amri and Saoud (2014); Betz and Caporale (2014); Raisian et al. (2017)

Table 2.3 identifies a suitable sustainability dimensions for software system. There are five dimensions namely economic, individual, environmental, social, and technology. These dimensions covers the sustainable development of the software system starting from requirement collection to the implementation. The economic sustainability indicates to the investment of the software system development on reasonable cost. The investment is to added value for software system producing the high quality of services and products as well as response the shareholder wealth and profitability. This is why shareholders have reinvested to sustain software system long-live (Marnewick, 2017).

The survivability and perdurability of the software system also relies on the IT staffs in various aspects (i.e. technical, business understanding and welfare). Therefore, the ability of IT staffs has indicated the technical capability and business understanding to survive the software system based on the maintainability and software improvement (Amri & Saoud, 2014). These do not only mention technology sustainability but also involve the social and individual sustainability because the development process requires to the working collaboration both non-technical and technical along with good welfare (i.e. appropriate working hours, mental and well-being) for IT staffs (Raisian et al., 2017).

Furthermore, software system relies on not only the performance of IT infrastructure but also a sustainable environment (Salam & Khan, 2016). This makes the software system to adopt the concept of the green technology for IT infrastructure construction (Marnewick, 2017). Consequently, the sustainability in the software system has addressed the responsibility of working society to the long-life usage of the software system on environmental awareness along with economic growth.

2.4.1.3 Sustainability adopted in IT outsourcing

The study has gathered the sustainability dimensions into two aspects namely sustainable supplier selection and sustainable software system. All sustainability dimensions also provide the meaning explaination as shown in Table 2.2 and Table 2.3 respectively. Therefore, this study has summarized the sustainability dimensions of both sustainable supplier selection and sustainable software systems to become the sustainable ITO. This is because ITO involves the software system development and maintenance by the supplier. The outcomes have shown in Table 2.4.

Table 2.4

Sustainability for IT outsourcing

Sustainability	descriptions	references
Economic	• Quality of development and maintenance to the IT system incurring both indirect and dirct added value (wealth creation to the shareholder, profitability and income) based on reasonable cost/price • Obtaining the long term profits from products and services of IT system throughout the contrast	Amri and Saoud (2014); Fallahpour et al. (2017); Venters et al. (2018)
Environment	• IT infrastructure utilizes the green concept to reduce the greenhouse gas emission occuring from energy consumption as well as using less harmful material in hardware component all IT system.	Azimifard et al. (2018); Fallahpour et al. (2017); Salam and Khan (2016)
Social	• IT system communities involves the participation, communication and interaction for stakeholder and users under trustiness. • IT staffs' welfare based on the safe and healthy understand the difference of the religious and culture, mental and working hours.	Amri and Saoud (2014); Azimifard et al. (2018); Fallahpour et al. (2017)
Technology	• Technical knowledge is able to sustain the survivability of IT system when the changing business process influences the incessant IT system evolution in terms of maintainability and perdurability of IT system	Amri and Saoud (2014); Betz and Caporale (2014); Raisian et al. (2017)

It is obvious that sustainable ITO consists of four dimensions namely economic, social, environmental and technology (see Table 2.4). This is because Zavadskas et al. (2016) state that if the project outsourcing involves technology; the organization should take the supplier's ability of technology into account. However, the individual dimension in the sustainable software systems do not appear in the sustainable ITO. Because the dimension has been merged in the social dimension of sustainable ITO mentioning the staff welfare. On top of this, the technology dimension of sustainable ITO mentions the ability of IT supplier’s technical skills to manage and improve the software system in the longevity. This also reflects the IT infrastructure performance to support the business changed.

2.4.2 Determining the Evaluation Criteria on Sustainable IT Outsourcing

The identification of evaluation criteria in the decision process considers both quantitative (measurable) and qualitative (immeasurable) criteria (Digalwar, Borade, & Metri, 2014). The performance evaluation criteria of a supplier are proposed by Dickson (1996) who identifies 23 criteria such as quality, delivery and performance history, and so on. However, the difference in business requirements in each organization affects the identification of evaluation criteria being used in the ITO decision process (Yang & Huang, 2000) as well as type of IT projects outsourced to the supplier. The examples are software development (Thakur & Anbanandam, 2015), software testing (Ismail & Razali, 2014), IT service operation and maintenance (i.e. hardware and network) (Faisal & Raza, 2016; Morais et al., 2014; Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017), and Enterprise Resource Planning (ERP) (Efe, 2016; Kilic et al., 2015; Oztaysi, 2015). In addition, the identification of evaluation criteria must affect the organization’s benefit. This makes Yang and Huang (2000) to provide the five criteria such as management, strategy, technology, economic and quality in the decision process. These criteria are also chosen by experts/decision makers (Akomode, Lees, & Irgens, 1998). There are many existing studies adopting experts/decision makers suggestion to identify the evaluation criteria (Chen & Wang, 2009; Chen, Wang, & Wu, 2011; Wang, Lin, & Huang, 2008). This approach makes sure that these criteria have achieved the organization's requirement and benefit and consistent with the characteristics of IT project outsourcing. According to Wang, Lin, and Huang (2008), the experts identify five criteria (strategy, economics, risk, environment and quality) requiring to Information System (IS) outsourcing decision problem. Likewise, Chen and Wang (2009) use the interview approach from five decision makers in Taiwan-based computer information manufacturers to identify ten criteria namely technical capability, financial, performance history, quality, price, flexibility, reputation, delivery time, experience and market share. Meanwhile, Morais et al. (2014) identify three criteria based on decision makers' consensus being used the supplier selection problems of IT service outsourcing.

Besides, the evaluation criteria are also identified by the referenced literature. According to Kahraman, Engin, Kabak, and Kaya (2009), the evaluation criteria in ITO selection focus on supplier's professionalism, technical competence, financial stability and responsiveness to customer needs, along with, Nazari-Shirkouhi et al. (2017) proposes risk, management, economic, technology, resource, quality and strategy criteria in ITO selection based on referenced literature. There are some works attempted to divide criteria into categories based on number of using in academic papers (Chang, Yen, Ng, & Chang, 2012; Watjatrakul, 2014). The criteria are retrieved from the referenced literature by matching the meaning similarity among criteria being used in ITO (Chang et al., 2012). Similarly, Watjatrakul (2014) identifies five categories of criteria for IT supplier selection based on similar meaning on referenced literature.

Likewise, Khan and Faisal (2015) identifies five (5) criteria namely price, technical, capability/quality, service and market leadership/reputation being used in ERP supplier selection. This is opposed with the study of Kahraman et al. (2010) who propose seven (7) main criteria and 22 sub-criteria in the ERP supplier selection. In addition, the banking industries aim to outsource their IT project to the supplier as well. Thus, the banking industries are required to identify the evaluation criteria in the supplier selection problem. According to Thakur and Anbanandam (2015), the evaluation criteria in the supplier selection of ITO for banking industry consist of quality, cost/price, flexibility, assets, reliability and relationship. Whilst Cao et al. (2012) argues that three (3) main criteria and 11 sub-criteria become the proper evaluation criteria in ITO selection for the banking industry. Furthermore, the health industries requires the evaluation criteria to assess the supplier's capability in the selection process. According to Liu and Quan (2013), the ITO applies ten (10) evaluation criteria for the supplier selection process; the evaluation criteria comprises the technical capability, financial performance, performance history, quality, price, flexibility, reputation, delivery time, experience, and market share. The improvement of IT systems with IT service outsourcing is an intention of the academic institutions. Thus, they propose four criteria namely the ability of technology accessibility, supplier reputation, knowledge of the industry, and quality of service in the selection process (Faisal & Raza, 2016). Therefore, multi-criteria contributing in the ITO selection process can be shown in Table 2.5.

Table 2.5

The evaluation criteria for supplier selection in IT outsourcing

	Authors index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Evaluation Criteria	Quality	x	x	x	x	x	x	x	x	x		x		x	x	x	x			x	x	16
	Cost / Price					x	x	x	x		x	x	x	x		x		x	x	x		12
	Flexibility					x		x	x	x	x	x		x				x		x		9
	Technical capability and expert	x				x		x	x					x		x		x	x			8
	Financial					x				x	x	x	x	x					x			7
	Technology		x							x	x		x		x		x				x	7
	Delivery	x				x	x							x				x	x	x		7
	Satisfaction/responsiveness						x	x		x	x	x								x		6
	Performance/Performance history	x				x		x			x			x					x			6
	Experience					x			x		x		x	x								5
	Management		x	x					x										x		x	5
	Relationship and communication process						x			x	x								x	x		5
	Economic		x	x	x																x	4
	Risk			x	x							x									x	4
	Strategy		x	x	x																x	4

Authors index	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Services									x	x					x				x		4
Resources			x						x	x										x	4
Culture							x		x	x		x									4
Information and system security							x		x			x									3
Information and system integrated compatibility							x		x	x											3
Maintenance, innovative of business							x		x					x							3
Market sharing					x						x		x								3
Market leadership							x								x	x					3
Configuration							x			x											2
Disaster recovery										x								x			2
Knowledge of industry									x							x					2
Reliability and usability							x												x		2
Contract management																x					1
Research and development									x												1
Asset																			x		1

Noted: - authors index

1: - Akomode et al. (1998)

2: - Yang and Huang (2000)

3: - Wang and Yang (2007)

4: - Wang, Lin, and Huang (2008)

5: - Chen and Wang (2009)

6: - Kahraman et al. (2009)

7: - Kahraman et al. (2010)

8: - Chen et al. (2011)

9: - Chang et al. (2012)

10: - Watjatrakul (2014)

11: - Cao et al. (2012)

12: - Karami and Guo (2012)

13: - Liu and Quan (2013)

14: - Morais et al. (2014)

15: - Khan and Faisal (2015)

16: - Faisal and Raza (2016)

17: - Qiang and Li (2015)

18: - Mukherjee and Mukherjee (2015)

19: - Thakur and Anbanandam (2015)

20: - Nazari-Shirkouhi et al. (2017)

The evaluation criteria in Table 2.5 are relevant to the ITO, which has been gathered from the review of the literature. These criteria have been adopted in various businesses required the supplier for ITO. There are 30 criteria being used in the selection process. In addition, each criterion has shown contribution through the "Count" approach as followed in the study of Chang et al. (2012). There are four criteria obtaining the high contribution number as first priority to be used in ITO selection problems. They are quality (16 times), cost/price (12 times), flexibility (9 times), and technical capability and experts (8 times) criteria respectively.

The contributed number of each criterion indicates the different aspects of experts, decision-makers and organization's need to use ITO. For example, existing studies adopt quality criterion being used in ITO selection, which comprises with IT service quality (Morais et al., 2014), quality of conformance product (Kahraman et al., 2009), management quality (Karami & Guo, 2012), quality and reliability of product (Chang et al., 2012) as well as information quality (Kahraman et al., 2010). In addition, the cost/price criterion is significant to the final organization's decision in the selection process, but it comes to the second priority of ITO selection process. Since the cost/price criterion indicate to the hiring of ITO in many perspectives. This makes the criterion represents the various expenditure aspects such as service cost (Cao et al., 2012), operation and set-up cost (Kahraman et al., 2010) and general cost/price (Qiang & Li, 2015; Thakur & Anbanandam, 2015). Likewise, the flexibility criterion represents the elastic in terms of operation between organization and supplier namely fees adjustment, services and requirements adjustment, deadline adjustment for delivery solution and the ability of increase/decrease service (Watjatrakul, 2014). The last criterion in the top four being used in ITO selection is the technical capability and expert criterion. The contributed number of the criteria is obtained by considering the quality of technical skill and ability in the solving technical problem (Mukherjee & Mukherjee, 2015).

Furthermore, it is already known that if the supplier selection has good evaluation criteria, the selected supplier has high performance to develop and maintain the IT system in the long-life and survivability in business changing. These evaluation criteria should indicate the sustainable ITO if these evaluation criteria involves four sustainability dimensions namely economic, social, environment and technology (see Table 2.4). Thus, the study describes the meaning of each criterion based on referenced literature. Similarly, many existing studies in sustainable supplier selection such as Fallahpour et al. (2017); Luthra et al. (2017); Rabbani et al. (2017) explain the meaning of each criterion matching in each sustainability dimension. Hence, the study adopts the matching technique to categorize the evaluation criteria in each sustainability dimension of ITO following the study of Chang et al. (2012). Consequently, the outcomes can be shown in Table 2.6.

Table 2.6

The evaluation criteria and its description for sustainable IT outsourcing

Sustainability	evaluation criteria	descriptions	references
Economic	Economic	The organizations have obtained the benefits return from the development and maintenance of the IT system on the business improvement; including reduce cost, sustain and increase the cash liquidity of an organization as well as increase the profits.	Wang, Lin, and Zhang (2008)
	Quality	The modern technologies are provided to support both internal and external organization operation in the current toward the future; including customer well perception.	Faisal and Raza (2016); Nazari-Shirkouhi et al. (2017); Thakur and Anbanandam (2015)
	Service	The ability of the service supports for the business plan and/or organization requirement regarding information technology as well as information and technical consultation required.	Khan and Faisal (2015); Lin (2016)
	Performance/performance history	The IT project histories of the supplier have performed.	Liu and Quan (2013); Mukherjee and Mukherjee (2015); Watjatrakul (2014)

Sustainability	evaluation criteria	descriptions	references
	Management	The increasing effective IT department responses to the business and customer requirement changing.	Nazari-Shirkouhi et al. (2017)
	Strategy	The planning compensation of a shortage of resources and planning modern technologies to support the business.	Nazari-Shirkouhi et al. (2017)
	Cost/price	The expenditure of development and maintenance in the IT system as well as the reasonable prices employment.	Mukherjee and Mukherjee (2015); Nazari-Shirkouhi et al. (2017); Thakur and Anbanandam (2015)
	Finance	Financial stability as earning, cash flow, and annual growth increases the organization’s confidence in terms of investment.	Mukherjee and Mukherjee (2015)
	Delivery	The delivered IT solution (refer to software, hardware, network) to effectively support the competencies on time.	Kahraman et al. (2009); Mukherjee and Mukherjee (2015); Qiang and Li (2015)
	Satisfaction/responsiveness	The response level to the organization solves problems and services throughout the implementation including the employees’ and their customers’ preference	Thakur and Anbanandam (2015)

Sustainability	evaluation criteria	descriptions	references
	Flexibility	There is an elasticity for adjustment of business and technology requirement changing.	Kronawitter, Wentzel, and Papadaki (2013)
	Contact management	The appropriately implemented period is consistent to the development and/or maintenance of the IT project occurred the steadiness.	Faisal and Raza (2016)
	Market leadership	The product/service is a favor in the market such as SAP.	Khan and Faisal (2015)
	Market sharing	The percentage of the total sale in products and services incurs in the market successfully.	Lin (2016)
Social	Social	Supplier's staffs welfare is based on the safe and healthy, understand the difference of the religious and culture, mental and working hours.	Fallahpour et al. (2017)
	Culture and language	The ability to work collaboration is under different culture, language, and working time.	Khan, Niazi, and Ahmad (2010); Mukherjee and Mukherjee (2015); Smuts, Merwe, Kotz, and Loock (2010)
	Relationship and communication	The effective communication is a good interaction among organizations (i.e. IT director, IT staffs and	Kronawitter et al. (2013); Smuts et al. (2010)

Sustainability	evaluation criteria	descriptions	references
		users) and an IT supplier for implementing ITO in terms of both technique and management skill.	
	Reliability and usability	The strong relationship between an organization and a supplier under the team approach to support the good working collaboration.	Alexandrova (2012); Smuts et al. (2010)
	Resource	The stakeholders and IT workers involve with the development and maintenance of IT system.	Chang et al. (2012)
Technology	Technology	The modern IT system effectiveness have provided the faster process and supported the current business to the future such as software, hardware as well as network infrastructure.	Nazari-Shirkouhi et al. (2017)
	Technical capability and expertise	The design capability of IT system and technical skills support the business process towards the long-term development and implementation.	Khan and Faisal (2015)
	Configuration	The planning ability configure a new system to integrate the existing system by not affecting the currently performed.	Watjatrakul (2014)
	Disaster recovery	The immediately planning recovery IT system when incuring from the unnatural events such as flood, fire and so on.	Mukherjee and Mukherjee (2015)

Sustainability	evaluation criteria	descriptions	references
	Information and system security	The rapid restoration of the information and IT system down incurs from e-robbery; including the planning of security policy.	Chang et al. (2012); Hanafizadeh and Zare Ravasan (2017); Lin (2016)
	Information and system integrated compatibility	The capability of management and operation is to integrate the existing system with the new system.	Chang et al. (2012); Lin (2016)
	Maintenance and innovation of business	The creation of the new functions/services builds to support the business changed on the existing IT system.	Lin (2016)
	Asset	The IT infrastructure and tools supports the business and changing requirements.	Faisal and Raza (2016); Thakur and Anbanandam (2015)
	Experience	There is years' experience in ITO relevance (supplier's staff)	Chen et al. (2011); Watjatrakul (2014)
	Knowledge of the industry	The knowledge in the business is clearly understood by the requirement.	Lin (2016)
	Research and development	The ability of the R&D investment and performance.	Chang et al. (2012)

The outcome in Table 2.6 shows the evaluation criteria influencing three sustainability dimensions based on the meaning similarity. These evaluation criteria can indicate the sustainable ITO to assess the supplier in the selection problems which consists of economic, technology and social but without environmental dimension. This is different from studies of Fallahpour et al. (2017); Rabbani et al. (2017); Rao, Goh, et al. (2017) who identify the evaluation criteria relevant in the economic, social and environment for sustainable supplier selection problems. Nevertheless, sustainable ITO also indicates environmental sustainability by considering the asset criterion (refer to IT infrastructure) in technology sustainability. According to Marnewick (2017), green technology is adopted in the IT infrastructure to reduce the greenhouse effect on gas emission and using harmful materials on it. Consequently, the evaluation criteria in three sustainability dimensions are suitable for adoption in the supplier selection model for ITO.

Unfortunately, the risk criterion does not include in the sustainable ITO. Due to the risk factors in supplier selection of ITO might occur from both supplier and ITO (Alikhani et al., 2019; González, Gascó, & Llopis, 2016). Even though the contributed number in ITO selection is chosen 4 times from referenced literature. This reflects the study of Gold and Awasthi (2015) who have considered risks in the sustainable supplier selection. This is why the risk factors are crucial in the sustainable supplier selection problems. On contrary, it might affect the undesirable outcome in sustainable ITO if risk factors are absent in the supplier selection process. The study of Karami and Guo (2012) proposes the risk factors that are different cultures, lack of supplier expertise and lack of project management experience in supplier selection of ITO. Therefore, the risk factors should be considered in the supplier selection to prevent undesirable outcomes in sustainable ITO. The risk factors have been identified and further discussed in section 2.4.3.

2.4.3 Determining the Risk Factors for Supplier Selection of IT Outsourcing

In order to perform assessment on the supplier for ITO, the factors that influence the undesirable outcome are identified following the study of Karami and Guo (2012). Evidently, the undesirable outcome is the most imperative factor towards successful ITO implementation, since the natural of ITO emphasizes the supplier capability (i.e. technical capability, team collaboration and cost management). Commonly the issues regarding the hazards might occur from supplier. The incompetent supplier is a hazard to the ITO success (González et al., 2016) and also impact the whole ITO implementation. Study by Fan, Suo, and Feng (2012) has identified risk factors for ITO. On top of this, the hazard of unexpected situation (i.e. natural disaster and human make) might occur in the supplier-side. Therefore, existing studies in supplier selection have determined the risk factors to the supplier assessment followed the works of Alikhani et al. (2019); Dupont et al. (2018); Li and Zeng (2016); Yoon et al. (2018). Consequently, the collection of risk factors from the review of the literature will involve risk in the supplier-side and ITO. Both two aspects have been further explained in subsequently.

2.4.3.1 Risk factors adopted in supplier selection

The risk factors in supplier-side aspects have been studied on the operation and disruption hazards. One of the often-cited risk factors that influence the supplier capability is risk management (Dupont et al., 2018; Yoon et al., 2018). A work of Alikhani et al. (2019) has gathered the risk factors along with description based on the review of the literature and experts' review. These risk factors indicate the potential for losses due to supplier failure in the future. It might impact the organization vulnerable against unexpected risks (Yoon et al., 2018). For example, Ericsson company lost $400 million since Phillips semiconductor plant fire was in 2000; it could not deliver the electronic part to the Ericsson company (Chopra & Sodhi, 2014). This incured huge damage to the organization when supplier had no risk management. A study by Rao, Xiao, et al. (2017) determines the group of risk factors being used in the supplier selection problem. These risk factors are likely to be made available for hazards on the supplier-side in the risk management that affects the organization.

Therefore, the determining risk factors has been highlighted as a significant factors for the supplier selection problems (Alikhani et al., 2019; Rao, Xiao, et al., 2017; Song, Ming, & Liu, 2017). The existing studies have identified risk factors to assess the supplier's capability dealing with undesirable outcomes (Dupont et al., 2018; Yoon et al., 2018). Alikhani et al. (2019) identify ten risk factors including quality, cost, long-tem cooperation, bankruptcy, on-time delivery, supply constraint, supplier's profile, continuity, second-tier supplier and contractual and opportunism. This is different from the study of Rao, Xiao, et al. (2017) who determining 11 risk factors for supplier selection problem.

Furthermore, the risks impact the sustainability of the supply chain, due to, economic uncertainty, increasing outsourcing activities and information technology advance (Song et al., 2017). These also reflect the supplier selection process if these risks occur on the organization from the incompetent supplier. Thus, Gold and Awasthi (2015) consider the sustainability risk in the supplier selection problems highlighting in three sustainability dimensions (economic, environmental and social). Moreover, Song et al. (2017) have identified the risk factors by organizing into four group as operation, economic, environment and social category. This is also emphasized in the Deloitte survey that risk factors are a crucial factor in the supplier selection problem (PrasannaVenkatesan & Goh, 2016). Consequently, this study has gathered the risk factors and its meaning to assess the supplier's capability in the supplier selection process as followed in Table 2.7.

Table 2.7

Risk factors for supplier selection

Risk factors	descriptions	references
Technology	Rapidly changing technology, the supplier's capability can quickly learn new technology and innovation development.	Rao, Xiao, et al. (2017); Song et al. (2017)
Information	The distortion of information transmission between the organization and supplier reflects on the low-security level of Management Information System (MIS).	Rao, Xiao, et al. (2017)
Management	Unqualified and inefficient teams of the management level are a hazard to business.	Rao, Xiao, et al. (2017)
Economic	Changing the business environment of the supplier such as the financial crisis that affects the supplier investment and cash flow.	Rao, Xiao, et al. (2017); Song et al. (2017)
Environment	Natural disasters such as flooding and earthquakes have a huge impact on the supplier.	Alikhani et al. (2019); Song et al. (2017)
Societal	Non-stability in performing business on location such as politic destabilization, unfair laws and policies; including unhealthy human well-being.	Song et al. (2017)
Quality	The high rate of product rejection indicates the low level of product quality, which affects the product qualification in the organization desired.	Alikhani et al. (2019)

From the determination made in Table 2.7, risk factors have been mentioned to the operation and disruption hazard that might occur from the supplier-side. The organization adopts these risk factors to assess the supplier's capability handling the undesirable outcomes such as in the study of Alikhani et al. (2019). There are three risk factors (economic, environmental and societal) focussing on the sustainability aspect in the supplier assessment through sustainable global supplier selection in a study of Gold and Awasthi (2015) who propose the sustainability-risk in the supplier selection problems. The identification of risk factors in supplier selection is highlighted. The next section discusses the risk in ITO.

2.4.3.2 Risk factors adopted in IT outsourcing

Most organizations outsource the IT system to the supplier due to organizations highlight to the core business (Faisal & Raza, 2016; Nazari-Shirkouhi et al., 2017; Thakur & Anbanandam, 2015). Thus, the organizations require experts and reduce costs to the development and maintenance of IT systems. Nonetheless, ITO might also face failure and unexpected hazards, which impacts the organization's tremendous loss. Unless, the organizations have under effective management. The studies by Nduwimfura and Zheng (2015b) and Aris, Arshad, and Mohamed (2008) mention the risk management to identifying, analyzing, controlling and monitoring the risk that might occur from ITO. It indicates risks as integrated into the ITO, especially occurring from the incompetent supplier (Nduwimfura & Zheng, 2015b)

This is evidence that the identification of risk factors is a crucial part of ITO. The existing studies in risks identification of ITO also rely on the review of the literature and experts' opinion such as the works of Fan et al. (2012); González et al. (2016); Samantra et al. (2014); Silva et al. (2015) without considering success ITO. These risk factors are determined under two issues of ITO; those are the serious impact on the organization and undesirable outcome. According to Samantra et al. (2014), there are different 11 risk factors in ITO undesirable outcomes and their corresponding influencing factors. This is opposite Silva et al. (2015) identifying risk factors followed by the experts who know the organization's vulnerabilities in ITO service. A study by Fan et al. (2012) adopts 23 experts in IT industry to verify the risk factors that have gathered from the review of the literature. The risk factors involve the risks ITO operation. González et al. (2016) also explain in details of the ITO risk that cover in the many previous studies such as supplier's staff qualification, security problems, supplier's inability, hidden costs and so on. Consequently, this study has gathered the risk factors to indicate the future potential loss and undesirable outcome in the current action. The results have shown in Table 2.8.

Table 2.8

Risk factors for IT outsourcing

Risk factors	descriptions	references
Unexpectation financial and cost	The budget planning might occur mistakes in the IT system investment along with costs not appearing in the ITO contract.	González et al. (2016); Samantra et al. (2014)
Uncertainty and weakness in management level	The weakness of management skills at the top executive level can lead to conflict, dissatisfaction in the worker team as well as wrong strategy planning effecting the increasing expenditure.	Fan et al. (2012); Samantra et al. (2014)
Culuter and lanagauge barrier	The different cultures might have a negative impact on the outsourcing understanding and relationship between organization and supplier.	Samantra et al. (2014)
Requirement instability	Rapidly changing in global business, it affects the requirement in the operation process of ITO.	Fan et al. (2012)
Working colloboration	The operation of ITO relies on the coordination between organization and supplier to build efficient IT system.	Samantra et al. (2014); Silva et al. (2015)
Unreliability of selected supplier (s)	The ineffectiveness of both delivery and quality of ITO operation affecting tasks expectation from organizations.	Fan et al. (2012); González et al. (2016)
Technology complexity	The task accomplishment in ITO operation might relate to the information security and complexity of technological adoption.	Fan et al. (2012); González et al. (2016)

Based on the identification of risk factors that affect the ITO, they point to the 7 risk factors (see Table 2.9). This has indicated the undesirable outcome from ITO because of unstable requirements and different working environments. It might negatively affect the ITO operation and might incur the conflict between the organization and supplier in practical. Additionally, the risk factors highlight the likelihood that negatively impacts the organization's budget overrun occurring the strategy and management mistakes including the investment of IT infrastructure. Nevertheless, these risks are also neglected in considering supplier's capability under sustainability risk along with affecting ITO success. The identification of risk factors is discussed in the next sub-section.

2.4.3.3 Risk factors adopted in Supplier Selection of IT Outsourcing

Karami and Guo (2012) identified ten risk factors to measure the supplier's capability for managing the possible and impact ITO failures. All risk factors proposed in that study involve technical expertise, stronger supplier's financial as well as service contract. These risks are a part of Table 2.8 but also might neglect the risk occurring in work collaboration, security of data accessibility and flexibility of requirement changing both business and technology. It might negatively impact ITO success if the organization ignores these factors monitoring and controlling in ITO. These risks should assess the suppliers' capability to properly manage risk. A study by Samantra et al. (2014) has also determined these risk factors in the risk management in ITO. It reflects the controlling and monitoring risk occurrence to lead ITO success. The studies by Ismail and Razali (2014); Khan et al. (2010); Kronawitter et al. (2013) identified the success factors for ITO. Therefore, the study has gathered the success factors from the review of the literature as shown in Table 2.9.

Table 2.9

Success factors for IT outsourcing

Successful factors	descriptions	references
Relationship and communication management	The collaborative activities to build relationships among staff between organization and supplier based on confidence and trustworthiness; including the efficient communication.	Alexandrova (2012); Kronawitter et al. (2013); Smuts et al. (2010)
Executive management level support	The efficient and effective strategy for ITO management from the executive level; including the negotiation and commitment in the business process within IT project development and maintenance based on contract	Alexandrova (2012); Kronawitter et al. (2013)
Professional human resource / staff management	The staffs' quality and management in practices and provide superior technical expertise.	Alexandrova (2012); Kronawitter et al. (2013)
Quality and service performance	The good qualities and services in IT products such as after-sale service and service guarantee in the time commitment along with improvement continuously.	Smuts et al. (2010)
Cost / financial management	The reasonable cost/price on a suitable of quality of IT products and services.	Kronawitter et al. (2013); Smuts et al. (2010)
Knowledge	Understading business process to develop and maintain IT system along with the ability of transferring knowledge	Alexandrova (2012)
Flexibility	The elasticity in the solution delivery and extensible project contract when business requirement and technology change	Kronawitter et al. (2013)

Technology / physical infrastructure	IT systems can support modern business in the digital era. It involves the develop application software, maintain hardware as well as provides the physical infrastructure fundamental (i.e. high-speed internet access and stability in power/electric supply)	Smuts et al. (2010)
Multi culture and language	Supporting the different cultures and languages to working collaboration	Ismail and Razali (2014)
Reputation	Supplier's portfolio recognized from organizations and the leadership in the market in the IT system such as SAP system	Ismail and Razali (2014)
Risk management and assessment	Handling the ITO failure on various perspective such as over budget	Kronawitter et al. (2013)

Obviously, the success factors involving in the operational process in ITO has reflected the supplier's capability. This is related to the operational risk being used in the supplier selection problem (see Table 2.7). However, the risk in supplier selection does not only relate operational but also to the disruption risk (i.e. flooding, earthquakes and fire). The disruption risks as addressed in the studies of Dupont et al. (2018) and Yoon et al. (2018) will be an obstacle in the product delivery of the supplier to the organization. In the other words, the supplier might arise disruption in developing and maintaining IT system of the organization when emerging disaster. This is why the supplier should have the ability for managing those threats. The risks have occurred on supplier-side and might affect the success ITO. Consequently, this study has determined the risk factors for supplier selection of ITO by using the meaning matching technique. The outcomes of the matching technique can be seen in Table 2.10

Table 2.10

Risk factors for supplier selection of IT outsourcing

Risk factors	success factors	descriptions	references
ITO policy	Executive management level support	The policy uncertainty of IT outsourcing project.	Nduwimfura and Zheng (2015b); Samantra et al. (2014)
ITO management	Executive management level support	Lack of understanding in the management and operation of IT outsourcing projects.	Rao, Xiao, et al. (2017); Varajão, Cruz-Cunha, and da Glória Fraga (2017)
Cost management and unexpected cost	Cost / financial management	Budget management occurs erroneousness in terms of IT system management and operation; including IT infrastructure investment. It also includes the communication cost and post-outsourcing cost occurrence which might be a hidden cost in ITO process.	Alikhani et al. (2019); González et al. (2016); Rao, Xiao, et al. (2017); Varajão et al. (2017)
Quality of IT products and services	Quality and service performance	Quality does not follow the agreement.	Alikhani et al. (2019); Varajão et al. (2017)
Security of data accessibility	Technology / physical infrastructure	Lack of security policy to access the privacy data of organization.	Alikhani et al. (2019); González et al. (2016); Varajão et al. (2017)

Risk factors	success factors	descriptions	references
Knowledge of business process and new technology	Knowledge	Misunderstanding the business process in organization needs.	González et al. (2016); Varajão et al. (2017)
Technology complexity	Technology / physical infrastructure	Complicate to the technology integration between existing system and new system and including building the redundancy system	Nduwimfura and Zheng (2015b); Rao, Xiao, et al. (2017); Song et al. (2017)
IT staff and turnover manner	Professional human resource / staff management	Lack of experience and IT skill in develop and maintain IT system; including the high turnover in the IT staffs.	González et al. (2016)
Organization’s culture and language	Multi culture and language	Different culture and language in working collaboration	Nduwimfura and Zheng (2015b); Samantra et al. (2014); Varajão et al. (2017)
Changing business and technical requirement	Flexibility	Unclear information requirement; including the business and technology changing.	Nduwimfura and Zheng (2015b)
Working collaboration	Relationship and communication management	Un-trustworthiness of experience and capability in IT skill of supplier.	Alikhani et al. (2019); Rao, Xiao, et al. (2017)
Supplier’s image	Reputation	A negative image of the organization.	Alikhani et al. (2019); Varajão et al. (2017)

The possibility of unexpected occurrences on the supplier-side has been indicated in Table 2.10. Therefore, these risk factors can assess the supplier's capability to manage the undesirable outcomes occurring in ITO. In addition, these risk factors affect the ITO success. Consequently, these risk factors are highlighted in the supplier selection model.

As discussed in section 2.4, the second issue that needs to be addressed in the supplier selection method based on the hybrid method is the synthesis technique, whereby eliminating human involvement to the weight allocation. Accordingly, ANP method is a suitable for real-world decision-making problems. It is discussed in the next sub-section.

2.4.4 Supplier Selection Method

There are many decision-making methods adopting in the supplier selection model both individual and integration approaches (Yadav & Sharma, 2016). These methods involve weight allocation and rank the potential suppliers. One of the methods for solving the supplier selection problem is MCDM methods. The MCDM methods are referred to as "making preference decision over the available alternatives that are characterized by multiple, usually conflicting criteria" (Triantaphyllou, 2000). It is in accordance with many studies in Fallahpour et al. (2017); Jain et al. (2016); Kilic et al. (2015); Rabbani et al. (2017); Secundo et al. (2017); Senvar, Tuzkaya, and Kahraman (2014); Yadav and Sharma (2016) adopting the AHP/ANP method to allocate the weight values of the evaluation criteria in the supplier selection model. Other decision making methods in MCDM (i.e. Decision-Making Trial and Evaluation Laboratory (DEMATEL), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) and Technique for Order of Preference by Similarity to Ideal Solution

(TOPSIS)) have been adopted to define the relationship among criteria (Uygun et al., 2015) and supplier ranking (Fallahpour et al., 2017; Kilic et al., 2015).

ANP method has been adopted to synthesize the evaluation criteria for weight allocation. The weight outcome can support in the real world supplier selection problems because the criteria weights has represented the relationship each other (Gölcük & Baykasoğlu, 2016). Therefore, ANP method should be adopted greater than the AHP method referring the review of the literature reported in the study of Zavadskas et al. (2016). In addtion, the AHP method relies on the hierarchical structure (Saaty, 2013), which is insufficient to the weight allocation for real supplier selection problems (Gölcük & Baykasoğlu, 2016). ANP method also has some shortcomings by inheriting AHP method, which is a crucial part of the ANP method (Saaty, 1999). Details of both ANP and AHP methods will be further discussed below.

2.4.4.1 Analytic Network Process (ANP)

ANP method (Saaty, 2004) enables decision-makers to synthesize the criteria on the dependency and feedback (refer to network structure), whereby there is no specific level similar the hierarchical as shown in Figure 2.3 (a) and (b) respectively. The network structure comprises clusters (dimensions) and the evaluation criteria inside. The evaluation criteria in each dimension have the relationship of both/either outer-dependence and/or inner-dependence (Saaty, 2004).

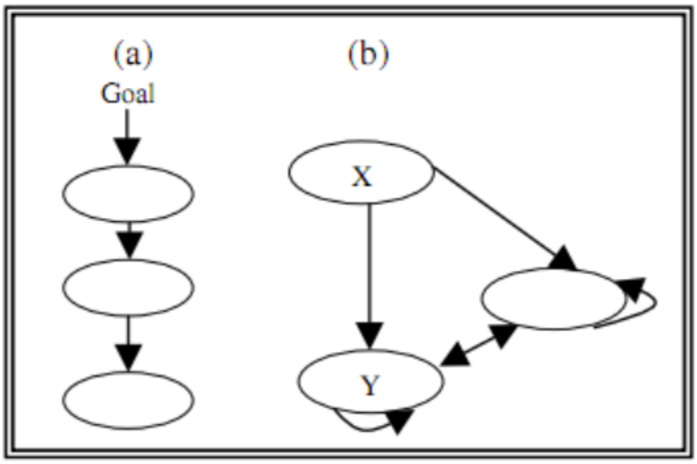

Figure 2.3
(a) hierarchy structure (b) network structure

Practically, ANP method is suitable in real-world decision-making. However, ANP method lacks a mechanism to generate the relationship among criteria and clusters as well as identifying the corresponding interdependencies (Gölcük & Baykasoğlu, 2016). The study also mentions the difficultly in calculating weight in the inner dependency relationship. These issues in ANP can overcome with integrating DEMETAL method as referred in many studies of Gölcük and Baykasoğlu (2016); Hsu, Liou, and Chuang (2013); Kuo, Hsu, and Li (2015); Uygun et al. (2015). In addition, the issue of time-consuming and complex computation with a huge number of criteria and clusters in ANP method incurs the difficulty to keep consistency in Pairwise Comparison Matrix (PCM) being used in inner dependency relationship. However, the consistency in PCM is also improved by "trial and error" approach by human (Hossain et al., 2014).

These shortcomings are clearly an obstacle to the ANP method. However, ANP is also a suitable decision method for the weight allocation on the network structure. The structure consists of elements that are considered as the nodes of a number of cluster. In addition, the level of each may both dominant and be dominated in a pairwise comparison. Each cluster $\{C_1, C_2, \ldots, C_n\}$ includes the corresponding elements in it

$(e_{n1}, e_{n2}, e_{n3}, \ldots e_{nm_n})$. These elements are performed to build into the supermatrix as shown in Figure 2.4. Then, Saaty's nine-point scale is adopted in the PCMs for weight allocation in inner-dependency in all clusters relevance (Saaty, 2004).

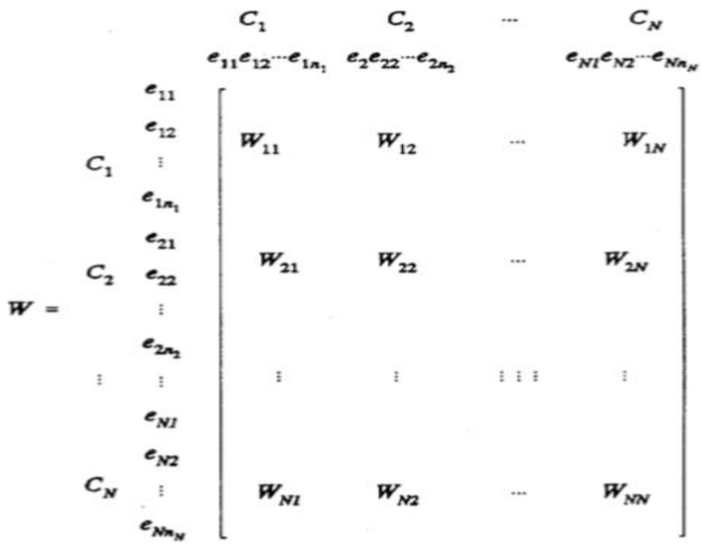

Figure 2.4

Supermatrix structure

The weight values in each cluster are calculated from PCMs as denoted W_{ij}. It has shown that the criteria in each cluster influence both the inner and outer clusters. The step details in the ANP method to synthesize the influencing weights is explained below:

1. Determine the cluster; including its corresponding criteria that relevant the target achievement
2. Build the relationship among cluster and its corresponding criteria both inner and outer cluster
3. Distinguish the problem into sub-problem into the PCM and the assigned judgment values by humans' knowledge and their experience
4. Synthesize the PCM to obtain the accepted consistency; that has Consistency Ratio (CR) < 0.1 (Saaty, 2013) otherwise, the synthesis process is repeated

5. Construct the Un-Weight supermatrix, it contains the weight values that related to the top of evaluation criteria in the supermatrix
6. Construct the Weight supermatrix, sum of weights in each column must be equal one (1)
7. Construct the Limited supermatrix, Weight supermatrix is to powers until the value in each column in the same row is the stabilized value.

According to Jayakrishna and Vinodh (2015), these seven steps can be applied to the weight allocation in terms of direct and indirect dependency among criteria. Unfortunately, ANP method has faced the obstacle of human uncertainty and vagueness of information (Uygun et al., 2015), and inconsistency (Ergu, Kou, Peng, & Shi, 2011). These issues occur from the human involvement in ANP, which is inherited from the AHP method. This is because ANP is built on the AHP fundamental (Saaty, 2004). On contrary, ANP can overcome the hierarchical structure being used in AHP (Gölcük & Baykasoğlu, 2016). Therefore, AHP issues will be discussed in the next section.

2.4.4.2 Analytic Hierarchy Process (AHP)

Most researches have widely adopted the AHP method to the weight allocation (Azimifard et al., 2018; Çakır, 2017; Mukherjee & Mukherjee, 2015; Repschlaeger et al., 2014). Since AHP can decompose the problem into sub-problems by using the PCM (Saaty, 2013). Figure 2.5 illustrates the PCM structure, which is a positive square matrix.

$$
A = \begin{array}{c} \\ C1 \\ C2 \\ \ldots \\ Cn \end{array}
\begin{array}{c} \begin{array}{cccc} C1 & C2 & \ldots & Cn \end{array} \\
\begin{pmatrix} a_{1,1} & a_{1,2} & \ldots & a_{1,n} \\ a_{2,1} & a_{2,2} & \ldots & \ldots \\ \ldots & \ldots & \ldots & \ldots \\ a_{n,1} & \ldots & \ldots & a_{n,n} \end{pmatrix} \end{array}
$$

Figure 2.5

Pairwise Comparison Matrix (PCM)

The author also proposes the Saaty's scale as shown in Table 2.11. It demonstrates the judgment value (a) of the human's preference. Each judgment value (a_{ij}) represents to the paired comparison judgments for pair-elements homogeneous.

Table 2.11

Saaty's scale

Intensity of importance	definitions
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate value

PCM is comprised of the judgment values and is computed to obtain the important weight in each criterion. The important weights have computes by the additive normalization method (Saaty, 1977; Saaty, 1980). Whilst the eigenvalue (EV) method has considered the PCM consistency based on maximum eigenvalue (Saaty, 1977).

Based on the work of Saaty (2013), a_{ij} represents the criteria i over criteria j. In other words, the ratio of weight (ω) in criteria i over criteria j can estimate as to the a_{ij} followed in the Equation 2.1.

$$a_{ij} = \frac{\omega_i}{\omega_j} \tag{2.1}$$

Nevertheless, in the real world, the judgment value is hardly equal to the weight ratio the same in Equation 2.1. This is because the judgment value consists of the biased value (δ_{ij}) (Saaty, 2013) which is represented by Equation 2.2.

$$a_{ij} = \frac{\omega_i}{\omega_j}(1 + \delta_{ij}) \tag{2.2}$$

Therefore, if needed a_{ij} to become the ideal judgment value, then δ_{ij} is close/equal to zero; however, it is hard to the occurrence (Saaty, 2013). This is the main reason that PCM has easily faced with the inconsistency.

Additionally, PCM requires the consistency before the important weight is adopted. Therefore, the study of Saaty (1980) proposed a calculation method to identify consistency by using the CR value based on maximum eigenvalue (λ_{max}). Therefore, Consistency Index (CI) is defined as equation 2.3. This is to investigate the judgment consistency across all pairwise comparisons as addressed in study of Alonso and Lamata (2006).

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{2.3}$$

Where λ_{max} is the maximum eigenvalue, and n is the PCM dimension (number of criteria). Moreover, PCM needs to measure the consistency level ensuring that the important weight can adopt. Thus, Saaty defined the CR as

$$CR = \frac{CI}{RI} \tag{2.4}$$

Where RI is the average value of CI for random matrices using the Saaty scale as shown in Table 2.12.

Table 2.12

Random Consistency Index

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

The PCM consistency can occur only when CR does not exceed 10% (0.10) (Saaty, 2013). On the contrary, PCM needs to revise by decision makers. The revising process takes some time to reach the PCM acceptance. Therefore, existing research attempted to solve the inconsistency problem of PCM by integrating swarm intelligence (SI) such as particle swarm optimization (PSO) and ant colony optimization (ACO) (Gao & Shan, 2012; Girsang et al., 2015; Yang et al., 2012). Table 2.13 further demonstrates for the SI methods to solve the inconsistency problem in AHP method.

Table 2.13

Existing studies on pairwise matrix inconsistency

SI methods	descriptions	strengths	weeknesses	references
Particle swarm optimization (PSO)	This study proposes the PSO and Taguchi method to repair the inconsistent matrix to a substitute matrix by modifying the judgment values in the feasibility space.	PSO is able to find out the consistency and sustain the primitive assessment through the substitute matrix from inconsistent matrix. In addition, PSO has eliminated the human error in the assessment process.	The number of criteria/alternatives increases; it incurs much number of PCMs. This may be a negative impact to the slower convergence rate of PSO.	Yang et al. (2012)
Ant colony optimization (ACO)	This study proposes the ACO integrate into AHP to overcome the inconsistency by using ant tour in each element of PCM. The ant tour impacts the modifying judgment value to generate the consistent PCM.	ACO can find out the more than one consistent matrix and sustain experts' opinions in modified version of matrix.	The weight of each criterion generated by ACO is not changed, which might be unable to use in the decision problem, so it needs to the human re-assessment.	Girsang et al. (2015)

Existing studies attempted to solve the inconsistent AHP by integrated SI such as PSO and ACO (see Table 2.13). This is obvious that SI algorithm has an efficiency instead of "trial and error" approach. The approach relies on the human involvement to modify the judgment value until appearing consistent (Hossain et al., 2014). Unfortunately, these SIs have some limitations such as undefined initial value and slightly slow convergence (Gai-Ge et al., 2014; Wang, 2018). In order to overcome these limitations, Yang (2008) proposed the firefly algorithm. This algorithm has powerful for quick convergence of finding out the optimized solution and can initialize the value in feasibility space (Shayeghi & Alilou, 2015). A detailed explanation of firefly algorithm is discussed in section 2.5.

2.4.4.3 Hybrid Multi-Criteria Decision-Making (HMCDM) method

Many studies have adopted the HMCDM methods in the supplier selection models as referred in Fallahpour et al. (2017); Jain et al. (2016); Secundo et al. (2017); Yuce and Mastrocinque (2015). The HMCDM methods handle the shortcoming in AHP and ANP as well as supplement the effective ranking methods (i.e. TOPSIS and PROMETHEE) (Zavadskas et al., 2016). The uncertainty and vagueness of human preference; it is solved with the combined Fuzzy Set Theory (FST) method (Efe, 2016; Jain et al., 2016; Nazari-Shirkouhi et al., 2017). On top of this, the methods supplement the ranking methods (TOPSIS and PROMETHEE) to reduce the number of PCMs when the alternatives increasing as in works of Barrios et al. (2016); Kilic et al. (2015); Vinodh et al. (2014). ANP solves by identifying the relationship among criteria with the DEMETEL method, which describes the relationship on the cause and effect approach (Uygun et al., 2015). Therefore, these limitations have been solved with the concept of HMCDM. The detailed explanation of each HMCDM is briefed in Table 2.14.

Table 2.14

Existing the hybrid AHP/ANP that adopted in supplier selection model

HMCDMs	issues	strengths	weaknesses	references adopting in supplier selection model
AHP/ANP + TOPSIS/PROMETHEE	AHP and ANP methods have faced the compensation (i.e. trade-offs) between good scores and bad scores in the alternative evaluation. The methods also suffer the large number of PCMs when alternatives increase (Macharis, Springael, De Brucker, & Verbeke, 2004).	The hybrid methods need much less PCM in the alternatives (supplier) evaluation. In addition, the method avoids the trade-offs process occurring in the AHP and ANP methods during the alternatives evaluation. This has also allocated the important weight for both ranking methods.	The hybrid method also cannot overcome the rank reveral problem when a new alternative is introduces.	Azimifard et al. (2018); Barrios et al. (2016); Kilic et al. (2015); Vinodh et al. (2014)
ANP + DEMATEL	ANP method lacks of constructed the relationship structure (ANP structure) among criteria before	The hybrid method is to overcome the identify the relationship among criteria for the ANP method	The weight allocation in the inner dependencies is difficult to obtain	Hsu et al. (2013); Uygun et al. (2015)

HMCDMs	issues	strengths	weaknesses	references adopting in supplier selection model
	synthesizing the criteria (Saaty, 1999)	(Gölcük & Baykasoğlu, 2016). The hybrid method has also improved the unweighted and weighted supermatrix rather practical than traditional ANP.	from human knowledge but, it can be obtained by calculating in the DEMETAL method based on cause and effect relationship (Gölcük & Baykasoğlu, 2016).	
AHP/ANP + FST	The Saaty scale being used in the AHP/ANP method is insufficient for the human's preference.	The hybrid method has eliminated the uncertainty of human preference and increased capability for dealing with inconsistent and uncertain judgments (Uygun et al., 2015).	The assignment of weight is difficult to zero when the criteria obtains the least importance. (Lima Junior, Osiro, & Carpinetti, 2014)	Digalwar et al. (2014); Jain et al. (2016); Manivel and Ranganathan (2019); Secundo et al. (2017)

The HMCDM in Table 2.14 solves the limitations of the AHP method since the human uncertainty and vagueness has been eliminated by using FST method. This is why the synthesis process in AHP increases the capability to deal with inconsistency and uncertain judgments (Uygun et al., 2015; Yadav & Sharma, 2015). The HMCDM has also increased the effectiveness of ranking method (TOPSIS and PROMETHEE) by providing the scientific weight allocation (Macharis et al., 2004). In addition, the method reduces the number of PCMs consideration when alternatives (supplier) increase. These hybrid methods of AHP solving also impact in positive the ANP method as following in the study of Uygun et al. (2015) and Kilic et al. (2015). Furthermore, the hybrid methods identify the relationship among criteria, which is a weak-point of the ANP method (Gölcük & Baykasoğlu, 2016; Uygun et al., 2015). This is evidence that the concept of the hybrid method can overcome many shortcomings of both AHP and ANP method. Nevertheless, existing hybrid methods also involve the human involvement to the weight allocation. The results might incur the mistake decision in supplier selection problems.

2.5 Firefly Algorithm

Yang (2010) proposed the new metaheuristic algorithm namely Firefly Algorithm (FA). FA is constructed from the firefly behaviors as following the flashing light. Thus, the flashing light is a crucial part of a firefly's movement based on brightness intensity to find out the best solution. The firefly movement has also arisen within the feasibility space. There are three idealized rules being used as guidelines for FA algorithm performance. The guidelines are described below:

- All fireflies are unisex; the firefly's attractiveness disregard their sex
- Fireflies' brightness is proportional to attractiveness, and both attraction and brightness decrease when the distance between any two fireflies' increases. This

implies that the less brightness of firefly moves towards the strong brightness. On the contrary, a firefly moves randomly.

- Fireflies' brightness is proportional to determine the objective function to lead an optimized outcome.

Therefore, three steps are summarized in the pseudocode as shown in Figure 2.6.

Firefly Algorithm

Objective function $f(\boldsymbol{x}), \quad \boldsymbol{x} = (x_1, ..., x_d)^T$
Generate initial population of fireflies $\boldsymbol{x}_i$ $(i = 1, 2, ..., n)$
Light intensity I_i *at* $\boldsymbol{x}_i$ *is determined by* $f(\boldsymbol{x}_i)$
Define light absorption coefficient γ
while $(t <MaxGeneration)$
for $i = 1 : n$ *all* n *fireflies*
    for $j = 1 : n$ *all* n *fireflies (inner loop)*
    if $(I_i < I_j)$, *Move firefly* i *towards* j; **end if**
        Vary attractiveness with distance r *via* $\exp[-\gamma r]$
        Evaluate new solutions and update light intensity
    end for j
end for i
Rank the fireflies and find the current global best $\boldsymbol{g}_*$
end while
Postprocess results and visualization

Figure 2.6

Pseudocode of Firefly Algorithm

According to FA pseudocode, there are two variables considering in the algorithm; they are the intensity and attractiveness (Yang, 2010). The light intensity is an attraction of other fireflies to move toward a brighter firefly. This is obvious that the firefly's attractiveness depends on light intensity but both values are inversely proportional to the distance. This implies that if the distance decreases then attractiveness and light intensity increase. Equation 2.5 has shown the proportion between attractiveness and light intensity of brightness which can be defined as follows:

$$\beta(r) = \beta_0 e^{-\gamma r^2} \tag{2.5}$$

Where β_0 depictes the attractiveness when distance (r) is equal to zero, and gramma (γ) depicts the light absorption coefficient. β represents the attractiveness when r is not equal to zero.

In the Equaltion 2.5, there are two parameters being used in the attractiveness formulation; they are the light absorption coefficient and distance. The values should be defined. According to Yang (2010), the light absorption coefficient indicates the ability of convergence speed for searching the optimized solution identifying the value in range between 0.1 and 10. They also compute distance with Cartesian distance (see Equation 2.6).

$$r_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2} \tag{2.6}$$

However, in the practices, most researches have modified two values depending on the different optimization problems in the works of Elkhechafi et al. (2018); Karthikeyan, Asokan, Nickolas, and Page (2015); Persis and Robert (2016); Shomalnasab, Sadeghzadeh, and Esmaeilpour (2014). For example, Persis and Robert (2016) defined the light absorption coefficient as equal to 1, while they used the average value of link reliability instead of distance. This is different from the study of Karthikeyan et al. (2015) who used the humming distance to calculate the firefly brightness. They also identified values between 0.01 and 0.15 as light absorption coefficient.

Naturally, the firefly's movement incurs changing the fireflies' position depending on the light intensity. Therefore, the movement consists of two scenarios namely attraction and randomness. Both scenarios need to consider the light intensity as followed in Equation 2.7.

$$x_i = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i) + \alpha(Rand - 0.5) \quad (2.7)$$

Alpha (α) depicts the randomization coefficient, Rand parameter represents the uniformly distributed number in the range $[0, 1]$. This is clear that Equation 2.7 can be divided into three parts by the plus sign notation. The first part is a current position of a firefly before movement while the second part focuses on a firefly movement toward the brighter. The rest part is a randomness. In equation 2.7, if a firefly moves toward the stronger brightness, so the firefly's position is changed as equation below:

$$x_i = x_i + \beta_0 e^{-\gamma r^2}(x_j - x_i)$$

On contrary, the firefly moves randomly; the new position is computed as equation below.

$$x_i = x_i + \alpha(Rand - 0.5)$$

In random movement, there are additional considerations of two parameters as alpha (α) and $Rand$. Existing studies also define both parameters depending on the optimization problems. Therefore, Table 2.15 has summarized the values being used for all parameters of the firefly algorithm in different domains for the optimization problems.

Table 2.15

Firefly's parameters definition

Problem descriptions	domains	γ	α	r	$rand$	referenced existing studies of firefly algorithm adoption
This study adopted the firefly algorithm to solve Lot size optimization in the stock management process by considering minimize cost and maximum service level.	Inventory management	1.0	0.2	Cartesian Distance	[0, 1]	Elkhechafi et al. (2018)
This study found out the shortest path of routing in Mobile Ad-Hoc Network to assign the optimal weight in pair network node.	Network routing	1.0	1.0	Average of Reliability Estimation	Specific associated value in each characteristic of the network node, but also remain in range [0, 1]	Persis and Robert (2016)

Problem descriptions	domains	γ	α	r	$rand$	referenced existing studies of firefly algorithm adoption
This study combined the discrete firefly algorithm and local search to find out the optimal solution for job scheduling based on the machine assignment and operation scheduling simultaneously.	Job scheduling	[0.01, 0.15]	[0, 1]	Hamming Distance	[0, 1]	Karthikeyan et al. (2015)
This study applied the firefly algorithm to determine the optimal similarity measure to enhance the collaborative filtering algorithm as well as increase the accuracy of the recommender system	Recommendation system	1.0	0.5	Cartesian Distance	[0, 1]	Shomalnasab et al. (2014)

The assignment of firefly's parameters has diverse in different domains to obtain the optimized solution (see Table 2.15). This is evidenced that firefly's parameters depend on the optimization problems. Therefore, the firefly's parameters are determined to relevant to finding optimized weight value from ANP method. One of the problems in ANP is inconsistency because judgment value in PCM is without a transitivity relationship (Ergu et al., 2011), which arises from bias values. On contrary, the bias value is close/equal to zero; ANP is without inconsistency. It indicates that the bias value significantly impacts the inconsistency of ANP method. In addition, the distance value has become a crucial part of defining the firefly's brightness. In this case, the Cosine Similarity (CS) method can be adopted to calculate the distance between two fireflies. This is because CS method is proposed to modify the judgment value until accepted the consistency ($CR < 0.1$) (Khatwani & Kar, 2017).

2.6 Weighted Sum Method

Weighted Sum Method (WSM), which is also known as "Simple Additive Weighting" method, is one of the simplest methods in MCDM. It is adopted for calculating the final score in each potential supplier (Mukherjee & Mukherjee, 2015; Yadav & Sharma, 2016). Consequently, the final supplier score is computed by multiplying between weight value and supplier score as the criteria consideration and then is these products over all the criteria as shown in Equation 2.8.

$$s_i = \sum \omega_j * x_{ij} \tag{2.8}$$

Where:

s_i = Final score for i^{th} supplier

ω_i = Weight value for j^{th} criterion

x_{ij} = Score for i^{th} supplier that expected in j^{th} criterion

Huang, Chen, and Chang (2015) pointed out the main advantage of the WSM due to the ease of use. Unfortunately, WSM has no the mechanism for weight allocation explicitly (Abdullah & Adawiyah, 2014). The WSM needs to adopt other methods (i.e. AHP/ANP) to the weight allocation, instead of assigning weight arbitrarily. Therefore, the method has been used to compute the supplier score from weight criteria as followed in the studies of Mukherjee and Mukherjee (2015); Yadav and Sharma (2016). Similarly, this study has adopted the method to the supplier score computation.

2.7 Supplier Selection Model Evaluation

The supplier selection model involves measuring the effectiveness and efficiency of the supplier. To measure successfully, the case study approach is needed. This study selected one of organizations to the model evaluation as it is being used widely in various the proposed supplier selection models (Azimifard et al., 2018; Fallahpour et al., 2017; Liu et al., 2016; Luthra et al., 2017; Yadav & Sharma, 2016). On top of that, it is an appropriate tool for making a consistent supplier selection model with a real practices (Yadav & Sharma, 2016). Therefore, in this study, the case study assists in organizing the evaluation criteria and the constructing decision making method in a structed manner.

The case study is a quality tool that helps to the evaluation criteria being investigated by domain experts. It involves organizing the evaluation criteria into three sustainability dimensions (economic, social and technology) of sustainable ITO used in the supplier selection model. Therefore, the appropriate evaluation criteria for each sustainability can be organized systematically as follow in the studies of Fallahpour et al. (2017); Luthra et al. (2017). Additionally, each of the evaluation criteria determines the priority indicating the important level in the supplier assessment similar to the study of Ahmad et al. (2014). These priorities are also a guideline in decision-making method to the weight allocation in this study.

On top of that, the case study is also used to evaluate the proposed decision-making method such as in the work of Fallahpour et al. (2017). One of the important in the method evaluation is to investigate the importance of the weight in each criterion (Yadav & Sharma, 2016). As mentioned earlier, the comparative approach adopts to compare other methods (Fallahpour et al., 2017). The approach is the best techniques to investigate the result deriving from the proposed method against the traditional method (Ertuğrul & Karakaşoğlu, 2008). The approach have been used in studies of the proposed method, among them are Girsang et al. (2015), Lima Junior et al. (2014) and Manivel and Ranganathan (2019). Similar to the abovementionsed studies, the comparative approach is adapted in this study.

2.8 Summary

This chapter has successfully discussed the existing work found in the literature related to the ITO and the supplier selection model; including sustainable development as well as related issues. The discussion is started with an overview of ITO. The weaknesses of supplier selection model are discussed. Subsequently, the discussion is hereafter continued with the current issues in supplier selection model based on sustainable development. It indicates the gaps identified in the literature addressed by this study. The first issue is to identify the evaluation criteria on the three sustainability dimensions namely economic, social, and technology along with risk factors for sustainable ITO. The second issue is the need for integrating the firefly algorithm into ANP method to eliminate human involvement to the weight allocation. The weight values have highlighted the interrelationship among evaluation criteria to support real-world decision-making. Both firefly algorithm and ANP methods are elaborated in detail. In the end, a case study is explained to the supplier selection model evaluation. The next chapter explains how the study has been conducted.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to develop the supplier selection model, which lead to the sustainable development of IT Outsourcing (ITO). The model consists of two main elements: evaluation criteria and risk factors for supplier selection that lead to sustainable ITO and an Analytic Network Process (ANP) method enhancement. Two elements helped to answer the research questions and achieved the objectives as stated in Chapter 1. The chapter starts by presenting the research design in Section 3.2. Having done this, the chapter continues with the phases of the study from Sections 3.3 until 3.7. The chapter then concludes with a summary in Section 3.8.

3.2 Research Design

The mixed approach, which is as quantitative and experimental approaches were performed to achieve the aim of this study (Fallahpour et al., 2017). The quantitative approach was used to construct instruments for the survey (Faisal & Raza, 2016; Fallahpour et al., 2017), while experimental approach was employed to develop and improve the decision-making method (Nazari-Shirkouhi et al., 2017; Yadav & Sharma, 2015). The theory and concept of the supplier selection model were derived from theoretical studies while the exploratory study and model development were used to propose the Enhanced Supplier Selection (ESS) model. The proposed ESS model was later verified by the experts (i.e. expert review) and a case study was adopted for model validation. Figure 3.1 depicts the research design, which illustrates steps and outcome for each phase. It also maps the objective against the phases. There are four phases in conducting this study: 1) Theoretical study, 2) Exploratory study, 3) ESS model development, and 4) ESS model evaluation. Each of these phases is explained in detail in the following sections.

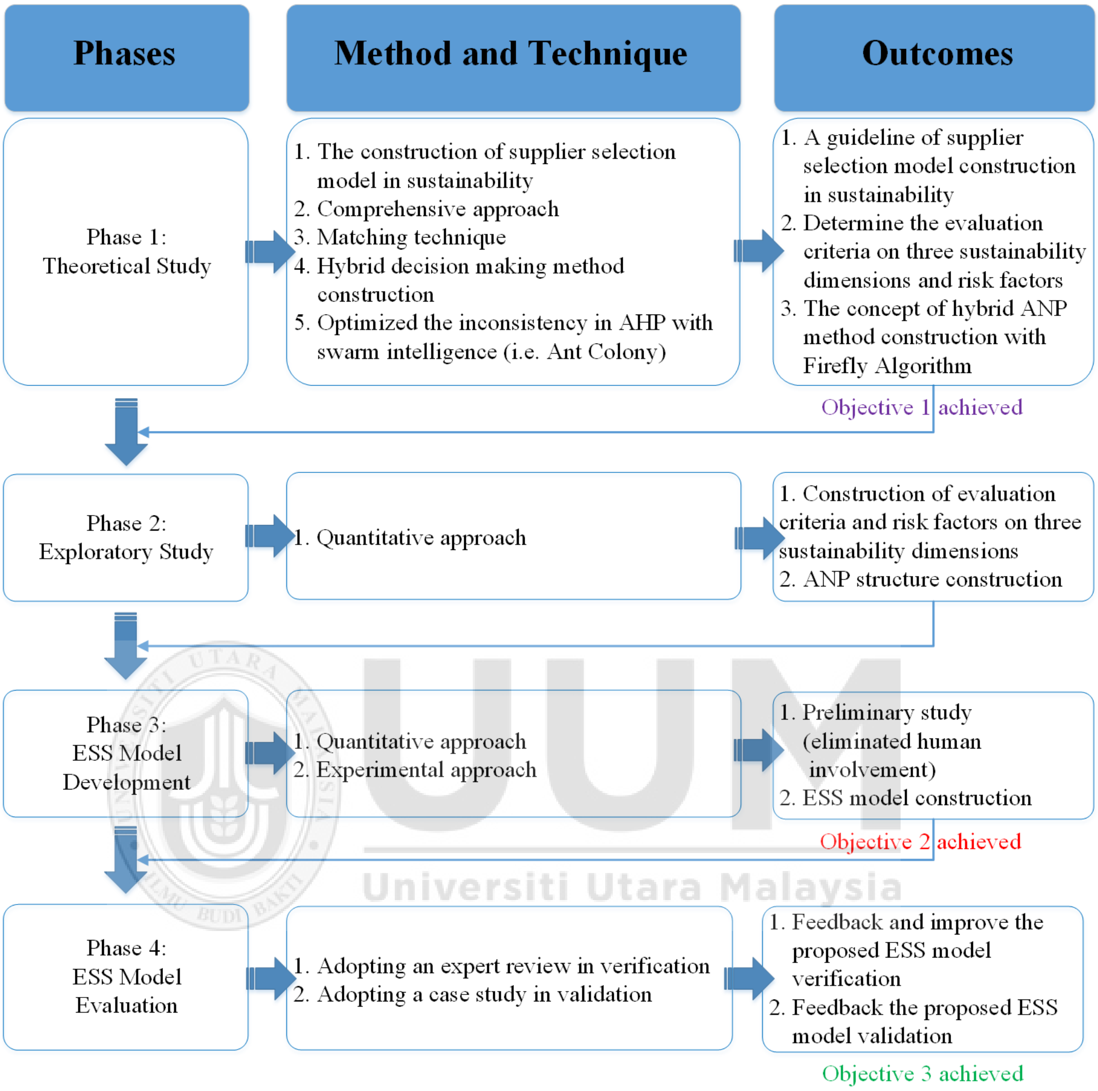

Figure 3.1

Research design

3.3 Phase One: Theoretical Study

The theoretical study had performed by the review of the literature to identify the issues, challengers, and gaps regarding the domain of the study. The main idea generated through the review of the literature by analyzing related work from journals, proceeding paper, books, and unpublished and published thesis. The problems and scopes of the constructed supplier selection model for ITO were defined in the theoretical framework (see in Figure 3.2).

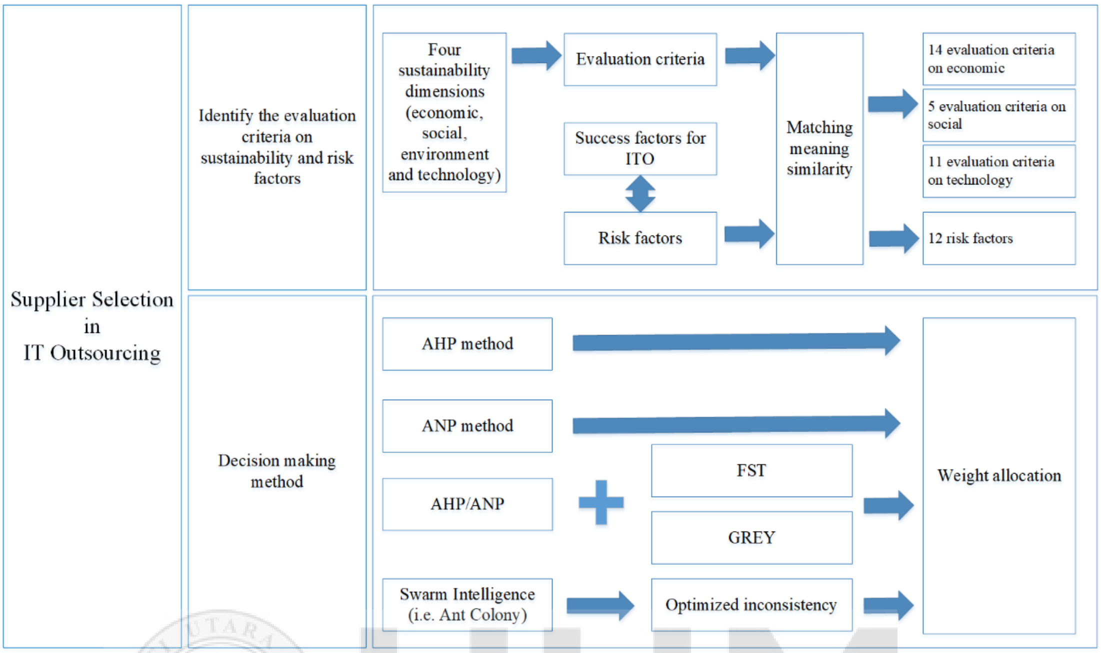

Figure 3.2
The theoretical framework

Figure 3.2 depicts two issues relevant to the construct supplier selection model of ITO namely identifying the evaluation criteria on sustainability dimensions and risk factors along with the decision making method construction, especially ANP method improvement. There were four sustainability dimensions identified based on sustainable supplier selection and software sustainability. Meanwhile, the evaluation criteria were collected from the review of the literature from 2000-2017. This study continues by determining the success criteria for ITO. Findings obtained from this activities were then analyzed to determine a set of criteria and risk factors for successful ITO and sustainability. The analysis was done through matching technique by determining on the similarity (i.e. meaning) of each criterion. The outcomes were the 30 evaluation criteria on three sustainability dimensions (economic, social and technology) along with 12 risk factors for supplier selection of ITO. Besides that, issues arise in ANP was inherited from AHP on human involvement to the weight allocation. The results of weight allocation had suffered the human prejudices. The ANP method was then improved by it with swarm algorithm, Firefly Algorithm (FA).

3.4 Phase Two: Exploratory Study

The second phase of the study was an exploratory study on the current practice of supplier selection problems for ITO in organizations of Thailand since most organizations were lack of empirical data in the supplier selection of ITO (Tangadulrat, 2010) that related to sustainability. The objectives of this study are to:

i. Study the current practices in the supplier selection of ITO among Thailand practitioners
ii. Investigate the practitioners' opinion on the evaluation criteria and risk factors used in supplier selection of ITO that lead to sustainable development.
iii. Analyze the interrelationship and prioritization of evaluation criteria and risk factors for supplier selection of ITO.

The exploratory study had adopted the quantitative approach, a survey (Sekaran & Bougie, 2016). To meet with the objectives, a self-administered instrument was used because of several advantages such as cost-effective, the ease to analyze data, wider area coverage and high degree of secrecy. Furthermore, the instrument allows ample time for the respondents to think that is perceived as more anonymous and reduces biases as well as not to be influenced by any party (Sekaran & Bougie, 2016). Five activities were performed in conducting the exploratory study, as laid out in the next subsection.

3.4.1 Instrument Design

The instrument was designed by using the guideline in studies of Ageron, Gunasekaran, and Spalanzani (2012); Chang et al. (2012). The contents of the instrument had established from referring to various theoretical finding and adapting several existing instruments emphasizing sustainable supplier selection problems. Among the existing instruments were Ageron et al. (2012); Faisal and Raza (2016); Fallahpour et al. (2017); Freeman and Chen (2015) (see in Appendix A). There are four main sections in the instrument to be answered by the respondents, who had prior knowledge and experience in the supplier selection of ITO. The instrument was organized in detail as below:

Section I: Demographic Information

This section assessed the respondents' background for supplier selection of ITO such as their position in the organization, year of experience and the sector of the organization, and their attachment in the organization. This section was answered by all of the respondents.

Section II: Supplier Selection Practices in IT Outsourcing

This section focused on the supplier selection process. The questions involved with the experience in the supplier selection of ITO. The procedures in the supplier selection were among the items in this section.

Section III: Priority of the Evaluation Criteria and Risk Factors on Sustainability for Supplier Selection of IT Outsourcing

This section had investigated the sustainability dimensions, evaluation criteria and risk factors that were important to the supplier selection of ITO. In addition, the evaluation criteria and risk factors were investigated to indicate the associated and influenced on the sustainability dimensions. This had adopted in the supplier selection problem for sustainable ITO.

Section IV: Importance Level of Evaluation Criterion and Risk Factor for Supplier Selection of IT Outsourcing

The final section had a target to identify the priority of both evaluation criteria and risk factors as a guideline to the weight allocation. Additionally, ANP structure had constructed consisting of both evaluation criteria and risk factors on sustainability dimensions. This structure synthesized the important weight values among criteria and risk factors for the supplier selection problem of ITO.

Finally, the instrument was verified by experts. They are the academicians (knowledge experts) as followed in studies of Khan and Faisal (2015); Ramanathan and Krishnan (2015). The experts' characteristics were suggested by Chang et al. (2012); Fallahpour et al. (2017) which included 1) currently interested in the objectives of the study, 2) a high academic degree (i.e. PhD.), and 3) faculty members at accredited universities. The study collected the experts' comments and feedback to improve the instrument. After the revision, the instrument was sent back to the same experts for their final approvals. The final instrument is shown in Appendix B.

3.4.2 Sampling of the Survey

The sampling frame of the study comprised of various organizations in Thailand that employed suppliers to perform their IT projects. The organizations performed their business in Thailand. The selected respondents were the organizations' members and a part of the procurement committee. They owned the prior knowledge and experience in the supplier selection of ITO. Thus, the respondents were unique sample, who involved the objectives of the study. The study had adopted non-probability sampling (purposive sampling). The purposive sampling intends for the specific respondents' characteristics (Sekaran & Bougie, 2016). Besides that, the purposive sampling uses the sample size at least 30 samples, which is minimum for statistical analysis effectiveness, but not more than 500 samples as it was addressed in Khairi and Baridwan (2015); Sekaran and Bougie (2016). The resulting of the sample size used in this study was 35 samples from 35 organizations in Thailand.

3.4.3 Pilot Study

The instrument had been validated through a pilot study answered by 13 respondents from 13 organizations relevant to the study. The number of respondents on the appropriate pilot study was suggested by Faisal and Raza (2016). The objective was to ensure the instrument's validity, completeness of the evaluation criteria and risk factors to use in the supplier selection problem. Consequently, the pilot study had investigated the reliability of instrument that involved with the prioritization of the evaluation criteria and risk factors for the supplier selection problem of ITO. Additionally, the time taken to answer the instrument was determined as well. More details on the pilot study can be obtained in Section 4.2.

3.4.4 Data Collection

Respondents were contacted through telephones and personal connections to ask for their willingness to participate in the study. Distribution of the instruments was made using three modes; mail postages, a visit to organization for a face-to-face discussion and an online survey. In the online survey mode, the link to the survey was mailed to the potential respondents, who earlier had agreed to participate in this study. It showed that the response rate was low on the online survey. This was because most respondents held a high position in the organization, and they had time issue in answering the questionnaire. This contradicts the outcome of the study by Faisal and Raza (2016) claiming that the online survey is efficient. In this study, a large amount of time had been used to wait for an appointment of a face-to-face meeting.

3.4.5 Data Analysis

Data from the exploratory study were analyzed by using Software Package for Social Science (SPSS) Version 24. The analysis performed with descriptive statistical including frequencies, means, and cross-tabulations. In addition, Pearson Correlation Coefficient (PCC) had analyzed the relationship between evaluation criteria and risk factors on three sustainability dimensions. The findings of the analysis are included in Section 4.4.

3.5 Phase Three: Enhanced Supplier Selection Model Development

The next phase was to develop the ESS model. The proposed model had been constructed based on two steps: preliminary study (experimental study) and model construction. More details explanation is further discussed in subsequently.

3.5.1 Preliminary Study

This preliminary study was to design the experimental step for the integration method between FA and ANP method. FA was integrated into the ANP method, in particular, modifying judgment values in the Pairwise Comparison Matrix (PCM). In existing literature review, PCM was performed by humans (domain experts) to assign and adjust the judgment values. Such human involvement had created prejudice to the weight allocation. Thus, this phase had proved that FA could replace the human in the adjustment of the judgment value automatically. This is why the weight determination from FA was without human prejudices. Figure 3.3 illustrates the experimental framework to overcome the human involvement in ANP method. This framework consisted of three main steps are: PCM construction, searching and matric comparison. These steps will be further explained in the next sections.

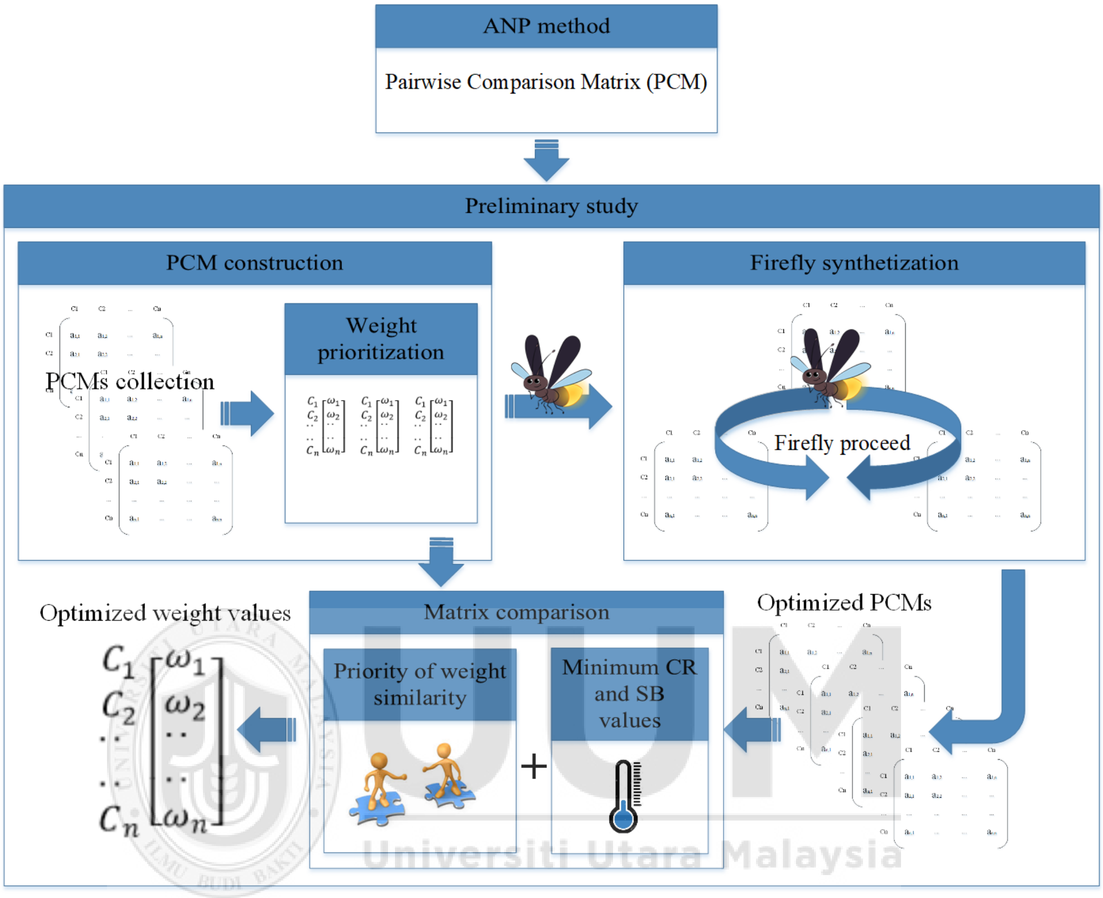

Figure 3.3

The experimental framework

3.5.1.1 Pairwise comparison matrix construction

PCM is a crucial part of ANP method to the weight allocation. The PCM represents to the sub-problems along with judgment values. The judgment value might be the same or different based on the human opinion and experience (domain experts). In this study, PCMs were built from the review of the literature relevant the supplier selection of ITO with the same evaluation criteria. In order to prove that FA could replace human, PCMs had become the feasibility space (PCMs dataset) of FA. In addition, the criteria prioritization had been identified as a guideline to allocate the weights from FA. This study had adopted the mechanism from Ahmad et al. (2014). The details of PCM construction is provided in Section 5.3.1.

3.5.1.2 Firefly synthetization

This step was to search the optimizing weight values. Four steps in the searching process covered firefly representation, firefly brightness formulation, firefly movement and PCM synthetization. This experiment had imitated the firefly's behaviors to search the optimized weight values in feasibility space. A firefly instead of a human modified the judgment value in PCM with the movement around the feasibility space. At the end of firefly movement, the consistency had been synthesized in each PCM followed in the study of Saaty (2013). Section 5.3.2 will be further explained in detail.

3.5.1.3 Matrix comparison

The comparative approach was to verify the human's knowledge to the weight allocation based on the priority of criteria because the priority of criteria can assign the judgment values for synthesis the weight values (Ahmad et al., 2014). The consistency ratio (CR) and sum of bias (SB) values also were a crucial part of indicating the perfectly PCM consistency; if both values were close/equal zero. Therefore, the outcome needed to verify both priority similarity as well as CR and SB values. Section 5.3.6 will further explain the details for the matrix comparison.

3.5.2 Weight Determination

The next phase was to develop the ESS model. The proposed model aimed to determine the weight values on the relationship between criteria and risk factors on three sustainability dimensions. The relationship between criteria was identified from the theoretical and exploratory study; it is called ANP structure. These criteria have been also identified priority to be a guideline to the weight allocation. In addition, ANP method has been improved by integrating FA. This integration method could determine the optimizing weight on the relationship between criteria and risk factors without human involvement.

The existing sustainable supplier selection model was the baseline model. They provided insight into the sustainable development of the supplier selection problem as addressed in studies of Fallahpour et al. (2017); Rabbani et al. (2017); Rao, Goh, et al. (2017). However, existing supplier selection models for ITO did not consider the sustainability such as in the studies of Cao et al. (2012); Liu et al. (2016); Nazari-Shirkouhi et al. (2017); Thakur and Anbanandam (2015). These models needed to integrate the concept of sustainability of both sustainable supplier selection and software sustainability to determine both evaluation criteria and risk factors. Figure 3.4 depicts the construction of the supplier selection model for sustainable ITO. The model emphasized to design a novel weight determination method without human involvement. This design consisted of ANP and ANP-FA construction. They will be further discussed subsequently.

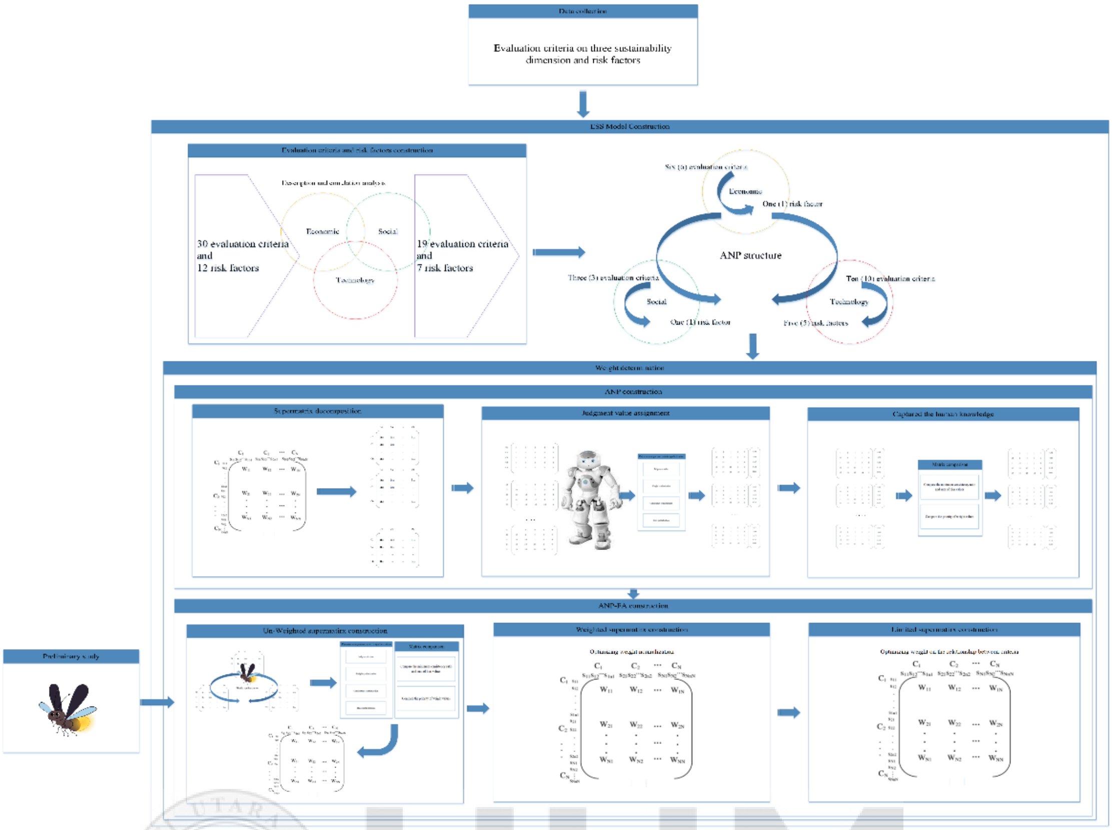

Figure 3.4

The proposed supplier selection model

3.5.2.1 Analytic network process construction

This step was to build PCMs dataset to find out the optimizing weight values. Three steps in the building process consisted of supermatrix decomposition, judgment value assignment and captured human knowledge. The supermatrix was transformed from the relationship between criteria on three sustainability dimensions and also decomposed into PCMs. Each PCM had been automatically assigned the judgment values without human involvement. At the end of PCM generation, the consistency had been synthesized in each PCM (Saaty, 2013) along with investigated the similar priority of weight values. Section 5.4.1 will further explain in details for the ANP construction.

3.5.2.2 Firefly algorithm into analytic network process construction

FA was integrated into ANP (ANP-FA) method to determine the optimizing weight values on the relationship between criteria and risk factors in three sustainability dimensions. FA had been used looking for optimal weight from PCM dataset (feasibility space). These optimal weight values had filled in the un-weighted supermatrix. Then, ANP-FA had computed those weight values in two steps namely weighted and limited supermatrix. The obtained outcomes became the optimizing weight values on the relationship between criteria and risk factors in three sustainability dimensions. A detailed explanation on ANP-FA construction will be discussed in section 5.4.2.

3.6 Phase Four: Enhanced Supplier Selection Model Evaluation

With the intention of ensuring the results of the study, the proposed ESS model was the transparency process for the supplier selection problem of ITO and ensuring that it performed according to the users' expectations. The evaluation process had been performed such as the study of Fallahpour et al. (2017). The evaluation process had been conducted into three stages namely experimental approach, verification and validation. They are discussed further in the next section.

3.6.1 Experimental Stage

The experimental stage had proved that FA could work instead of the human involvement in the ANP method, especially the modifying judgment values. The comparative approach was also adopted to investigate human knowledge because the weight determination occurred without human involvement. Human prejudices in the weight values had been also investigated by using the comparative approach. Section 6.2 will further explain the details for the experimental stage.

3.6.2 Verification Stage

The verification stage had performed to verify whether the proposed model to ensure that all required components presented the correctness. In this study, the verification stage had intended to verify: 1) the evaluation criteria and risk factors lead to sustainable ITO for supplier selection mdoel and 2) the ANP-FA development adopted in the proposed model to the optimized weight allocation on ANP structure. To accomplish this, the expert review had been conducted because it can be easily conducted, less cost and faster. Moreover, it has been accepted as a significant way to detect and remove defects (Azman, Zaibon, & Shiratuddin, 2018). There were three activities involving in verifying the proposed model:

i. Identifying the knowledge experts

The experts should be chosen among the academician (knowledge experts) by following the characteristics of experts as suggested by Chang et al. (2012); Mohd Zukhi, Hussain, and Husni (2020). The characteristics include 1) currently attached to the field of the study under examination, 2) a higher academic degree (PhD.), 3) faculty members at an accredited university, 4) authorship and 5) have at least 5 years of experience. Additionally, the case study had intended to verify the proposed model by domain experts, which became an insights from the real environment of Thai organization point-of-view. Hence, the case study had discussed in the validation stage section.

ii. Determining the verification criteria

The proposed model verified to ensure the acceptance in development steps of ANP-FA method and outcomes as shown in Figure 5.14. Furthermore, the evaluation criteria and risk factors on three sustainability dimensions should be verified with four criteria namely comprehensive, understandability, accurateness and organization. Therefore, the checklist had adopted to obtain the comment from the experts as shown in Appendix G, Appendix H and Appendix I.

iii. Collecting and analyzing the feedback

The knowledge experts' feedbacks were collected and analyzed for further improvement. Detailed explanation can be found in Section 6.3.

3.6.3 Validation Stage

Validation was the process of determining whether the proposed model met users' expectation that precisely represented in the real world following studies of Banaeian, Mobli, Fahimnia, Nielsen, and Omid (2018); Mukherjee and Mukherjee (2015); Nazari-Shirkouhi et al. (2017). Therefore, with the aim of revealing the practicality of the proposed model, a case study became the validation of the proposed model which had been compared with an organization's outcome. The key steps performed in the case study was similar to the study conducted by addressed in Al-tarawneh (2014); Jain et al. (2016); Nazari-Shirkouhi et al. (2017). There were three main activities in the validation stage as described subsequently.

i. Identifying the organization

An organization of the case study was chosen whether the organization has the supplier selection for ITO. Additionally, the organization should have the evaluation form for supplier assessment. The evaluation form had to define the evaluation criteria along with supplier score in each expected evaluation criterion to compute the supplier score before the organization decision.

ii. Determining the validation criteria

The validation criteria for the proposed model were determined by adopting them from the studies of Al-tarawneh (2014) to reveal the success of the proposed model as listed in Table 3.1. The feedbacks on the validation of the proposed model are discussed in Section 6.4. Similar to the verification stage, checklists were used to obtained feedback from the organization (domain experts) (see Appendix L).

Table 3.1

Validation criteria for ESS model

Validation criteria	variables
Gain satifaction	Perceived usefulness
	Decision support satisfaction
	Comparison with current method
	Cost-effectiveness
	Clarity
	Task Appropriateness
Interface satisfaction	Perceived ease of use
	Internally consistent
	Organization (Well organized)
	Appropriate for ogranization
	Presentation (readable and useful format)
Task support satisfaction	Ability to produce expected results
	Ability to produce relevant results
	Ability to produce usable results
	Completeness
	Ease of implementation
	Understandability (easy to understand)

iii. Collecting and analyzing the feedback

The selected organization (referring to domain experts) feedbacks were collected, analyzed and reported. Detailed explanation can be found in Section 6.4.

3.7 Summary

This chapter summarizes the research methodology in the study. The design of the research methodology comprised of the quantitative and experimental approaches. The research methodology constituted of four phases: the theoretical study, exploratory study, ESS model development; including preliminary study, and ESS model evaluation. Each phase was to achieve the objectives in Chapter One. By executing those phases, the ESS model developed to the supplier selection for sustainable ITO. The model enabled to the wider point-of-view for supplier selection problem in the current business requirements. Additionally, the evaluation criteria and risk factors on three sustainability dimensions focused on sustainable ITO. The ANP method had also been also improved by FA integration to eliminate human involvement. The proposed model became the tranparency process for supplier selection of sustainable ITO. Finally, the proposed model evaluated three stages namely experiment verification and validation.

CHAPTER FOUR

EXPLORATORY STUDY

4.1 Introduction

This chapter discusses in detail the findings from the exploratory study to construct the evaluation criteria and risk factors on sustainability for supplier selection of IT outsourcing (ITO) in Thai organizations environment. The exploratory study applied the survey and quantitative approach to collect and analyze the data. The study aimed to achieve the three objectives: 1) investigate the current practices for supplier selection of ITO, 2) investigate the priority of the evaluation criteria and risk factors associated and influenced on sustainability for supplier selection of ITO and 3) investigate the importance level of the evaluation criteria and risk factors used in current practices for supplier selection of ITO. The findings from this exploratory study facilitated the construction of the evaluation criteria and risk factors on sustainability dimensions; including identifying the priority of criteria to the weight allocation for supplier selection model.

This chapter starts with the discussion of the pilot study in Section 4.2, and continues with the data collection in Section 4.3. The findings are presented in Section 4.4 followed by the discussion in Section 4.5. This chapter ends with a summary in Section 4.6.

4.2 Pilot Study

The instrument went through reviewing and reversion after it was constructed to ensure that the content was comprehensive and appropriate. Additionally, the layout of the instrument needed to be friendly with clear instructions and understandable language.

These characteristics were used to validate the instrument by experts in Thailand before distributing it for collecting the pilot study and actual data from the selected samples.

The respondents in the pilot study indicated that the questions made sense and covered the searchable criteria and risk factors on sustainability for supplier selection of ITO. The content reliability was also investigated by using Cronbach's alpha analysis; the significance value should more than 0.6. The value was suggested by Sharma, Chandna, and Bhardwaj (2017). Table 4.1 shows the reliabitlity outcomes of evaluation criteria and risk factors in each sustainability dimension.

Table 4.1

Cronbach's alpha

Supplier selection criteria	sustainability dimensions	cronbach's alpha
Evaluation criteria	Economic	0.689
	Social	0.653
	Technology	0.622
Risk factors	Economic	0.760
	Social	0.801
	Technology	0.709

The results in Table 4.1 show that the questions in section 12 and 13 in Appendix B had a reliability looking for evaluation criteria and risk factors on three sustainability dimensions. This is because the cronbach's alpha was more than 0.6. The study also examined the reliability of question in section 14 and 15 indicating the priority of evaluation criteria and risk factors. The outcomes were significant, which the cronbach's alpha value was 0.844 and 0.766 respectively. Consequently, the instrument had a reliability and appropriately adopted in the collecting actual data for supplier selection of ITO.

4.3 Data Collection

The researcher contacted the potential respondents through telephones and personal connections to ask for their willingness to participate between September and December 2018 (45 of them). This study adopted three approaches namely face-to-face meetings, mail postages and online surveys to the data collection. However, there were 10 respondents refusing to participate because of the privacy policy and time issue. Therefore, the details of number of participants are presented in Table 4.2.

Table 4.2

Overview of respondents

Details	instrument returned	percentage
Number of respondents willing to participate	35	77.78
Face-to-Face respondents	31	68.89
Online respondents	2	4.44
Mail postage respondents	2	4.44
Rejected / incompleted survey	10	22.22
Total usable	45	100

This result shows that the face-to-face meeting clearly made the respondents to understand each question and answered them accordingly. If they had doubts about any question, they could immediately request clarification. Therefore, the number of instruments returned face-to-face was high. However, the online survey was currently appropriate for the respondents because the answering time was flexible rather than the face-to-face meeting and it did not disturb the working time. Unfortunately, there were only two respondents returning the instrument through the mail postage approach. This showed that the face-to-face meeting was an appropriate data collection approach in Thailand environment.

4.4 Findings

The section aims to report the finding of the exploratory study. The findings can be classified into nine (9) sub-sections, which are: 1) demographic information, 2) current practices of the supplier selection process, 3) current practices of the sustainability dimensions, evaluation criteria, and risk factors frequently adopted, 4) evaluation criteria associated with the sustainability dimensions, 5) evaluation criteria that influenced the sustainability dimensions, 6) risk factors that associated with the sustainability dimensions, 7) risk factors that influenced the sustainability dimensions, 8) priority of evaluation criteria used, and 9) priority of risk factors used.

4.4.1 Demographic Information

This section aims to assess the background of the respondents and the organization. A detailed explanation is described subsequently.

4.4.1.1 Respondents' background

To understand the respondents' background, they were asked to indicate their position in the organization and years of experience in supplier selection problems. Table 4.3 portrays the frequency and percentages of respondents according to their position.

Table 4.3

Respondents' position in organizations

Positions	frequency	percentage
Strategy manager	1	2.9
Purchasing manager	3	8.6
IT Director	6	17.1
IT project manager	13	37.1
IT team leader	6	17.1
Others	6	17.1
Total	35	100.0

The majority of the respondents were the IT project managers (37.1%), followed by IT directors, IT team leaders, other positions (i.e. company owner or the director) in the organizations which were equal 17.1%, while purchasing manager was 8.6%. The rest of them were the strategy manager (2.9%).

The analysis of cross-tabulation was used to classify the respondents based on their experience and position, as depicted in Table 4.4.

Table 4.4

Respondents' experience

Positions	< 2 years	2-5 years	6-8 years	9-12 years	13-20 years	> 20 years	total
Strategy Manager	0	0	0	0	0	1	1
Purchasing manager	1	1	0	0	1	0	3
IT director	0	1	2	1	0	2	6
IT project manager	0	1	1	5	5	1	13
IT Team leader	0	2	1	2	0	1	6
Other	0	0	1	2	3	0	6
Total	1	5	5	10	9	5	35

Out of the 35 respondents, only five had experience more than 20 years. Meanwhile, most of the respondents (19 of them) had experience between 9 and 20 years and among them, 10 were IT project managers. The rest of respondents (11 of them) had 1 to 8 years experience and among them, 2 were purchasing managers.

4.4.1.2 Organizational background

Table 4.5 lists the organization's business of the respondents. A healthy business was found in the highest ranking (17.1%). The ranking continued with four businesses namely technology/energy, travelling/hotel & restaurant, manufacturing and education accounted into 14.3%. Other businesses were from construction, logistics and advertise & creative media as equal 8.6%.

Table 4.5

Organization's businesses

Business types	frequency	percentage
Healthy (Hospital)	6	17.1
Technology / Energy	5	14.3
Travelling / Hotel & Restaurant	5	14.3
Manufacturing	5	14.3
Education	5	14.3
Construction	3	8.6
Logistics	3	8.6
Advertise & Creative Media	3	8.6
Total	35	100.0

4.4.2 Current Practices of Supplier Selection Process

This section addresses the decision-makers' opinions relevant to the procurement process of the organization. Normally, the organization organized a procurement committee that consisted of the various departments in making the decision. It also involved the decision methods used in the process. All of these components will be described in this section.

4.4.2.1 Departments' involvement in procurement committee

The respondents were asked what the departments participated in the procurement committee. They allowed choosing more than one answer to this question. The outcomes can be seen in Table 4.6.

Table 4.6

List of department

Departments	frequency	percentage
Financial department	15	42.9
IT department	27	77.1
IT stakeholder	23	65.7
Purchasing department	15	42.9
Planning and strategic department	16	45.7
Other (Company owner/administrative department/director)	3	8.6

Most of them were familiar with the IT department (77.1%) and IT stakeholder (65.7%), followed by the planning and strategic department (45.7%). There were two similar departments: the financial and purchasing department accounted for 42.9% equally. The rest of them was the company owner/administrative department/director (8.6%).

4.4.2.2 Decision-making structure selected

The respondents were asked about the decision structure used in the supplier selection problems. Table 4.7 illustrates the analysis result.

Table 4.7

Decision structures

Decision making structures	frequency	percentage
Independent structure	4	11.4
Dependent structure	21	60.0

Only cost-benefit / financial	10	28.6
Total	35	100.0

The decision dependence structure was adopted as the majority of them (60.0%), while 28.6% concerned on the cost-benefit/financial. Only 11.4% used the independent structure.

4.4.2.3 Decision-making methods selected

The respondents were asked about the decision-making methods to proceed in the supplier selection problems. The outcomes can be reported in Table 4.8.

Table 4.8

Decision methods

Decision making methods	frequency	percentage
Grey	5	14.3
ANP	4	11.4
TOPSIS	5	14.3
PROMETHEE	9	25.7
Other	12	34.3
Total	35	100

The majority of respondents focused on primitive methods (i.e. committee suggestion, familiarity with a supplier, and low price bidding) which accounted into 34.4%. 25.7% of respondents preferred the PROMETHEE method as followed by using TOPSIS and Grey methods approximately 14.3% equally. The rest of the respondent (11.4%) used the ANP method.

4.4.2.4 Year of experience participating supplier selection process

The respondents were asked about their year of experience in participating supplier selection problems. The majority of them (29%) had between 9 and 12 years of experiences as followed 13 and 20 years, 26%. Whilst 14% had equally experience in two periods as between 2 and 8 years and more than 20 years. Only 3% had experience less than 2 years. These details are illustrated in Figure 4.1.

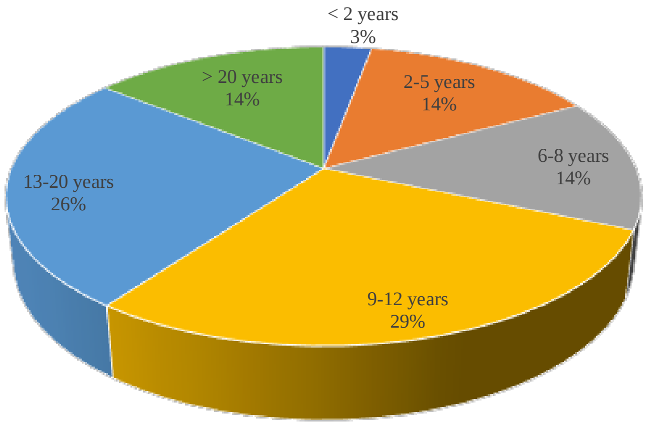

Figure 4.1

Year of experience

4.4.3 Current Practices of the Sustainability Dimensions, Evaluation Criteria, and Risk Factors Adopted

The section investigates the current practices being used the sustainability dimensions, evaluation criteria, and risk factors in supplier selection problems. The respondents identified the frequency used by using the contribution number in sustainability dimensions, evaluation criteria, and risk factors.

4.4.3.1 Frequency of sustainability aspects adopted

The respondents were asked about the sustainability perspectives to implement the supplier selection problems in ITO. The majority of respondents had selected technology sustainability (34 times) as important in ITO. 24 times concerned in economic sustainability used as second-order. The rest of sustainability (environment and social) was only selected 7 and 8 times (see Figure 4.2).

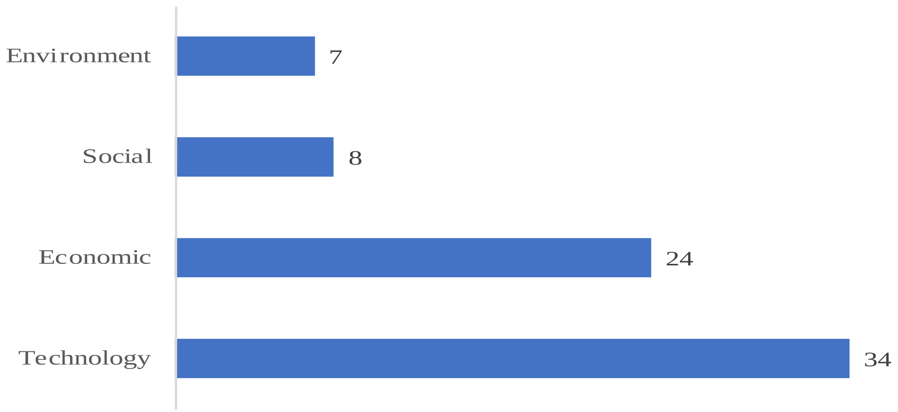

Figure 4.2

Sustainability dimensions favor used

4.4.3.2 Frequency of evaluation criteria adopted

Figure 4.3 shows the evaluation criteria that the respondents were familiar with. They were allowed to choose more than one answer for this question. Most of them were familiar with three criteria were quality, service and cost/price that strongly highlighed from the respondents accounted into 33, 32 and 30 times respectively, followed by seven criteria. Seven criteria were performance (29 times), technology capability and experts (28 times), experience (26 times), delivery (24 times), information and system security (23 times), reliability/usability (23 times) and satisfaction/responsiveness (22 times). The rest of evaluation criteria had a contribution number less than 20 times. Surprisingly, the social and culture were somewhat neglected from respondents.

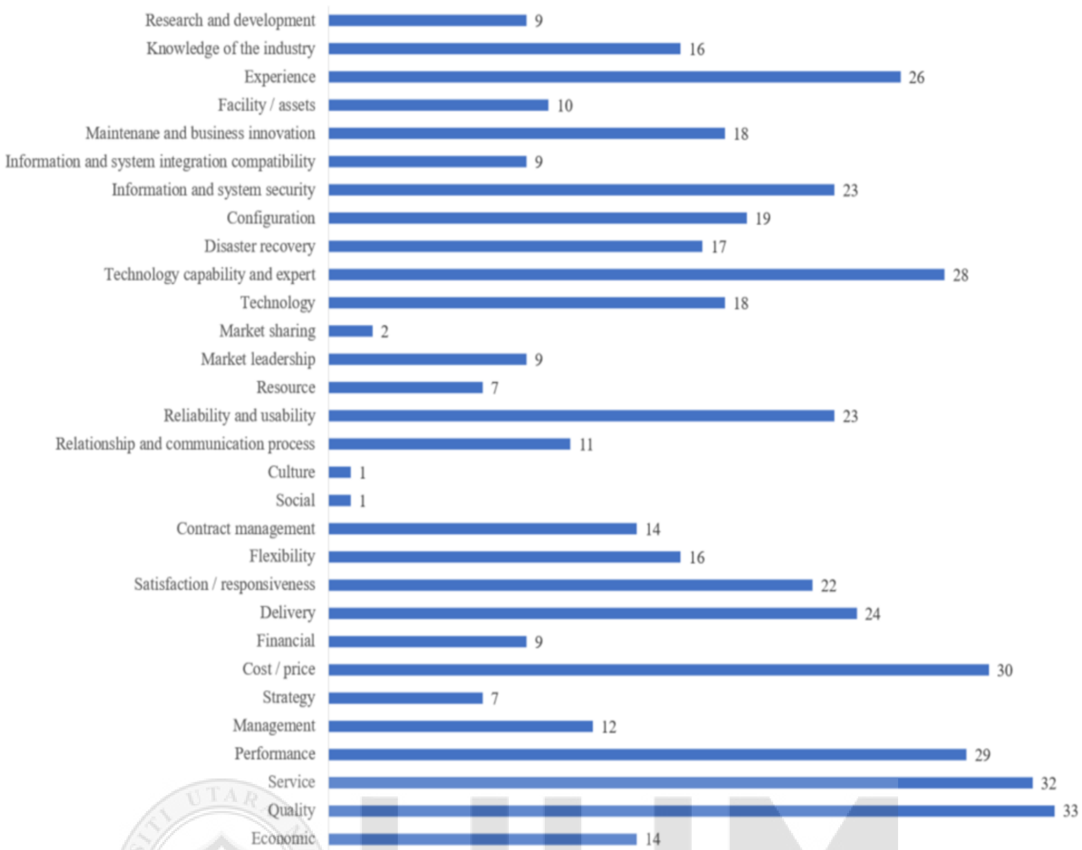

Figure 4.3

Evaluation criteria favor used

4.4.3.3 Frequency of risk factors adopted

Additionally, the respondents were asked about the risk factors that they adopted in the supplier selection problems of ITO. This question allowed multiple answers. It is apparent from Figure 4.4 that most of the respondents concerned four risk factors as significant aspects in supplier selection of ITO. These risk factors consisted of quality of IT products and services (25 times), cost management and unexpected cost (25 times), security of data accessibility (24 times), knowledge of business processes and new technology (22 times). The rest of the risk factors had a contribution number less than 20 times. Particularly, the organization’s culture and language were chosen only 5 times by respondents.

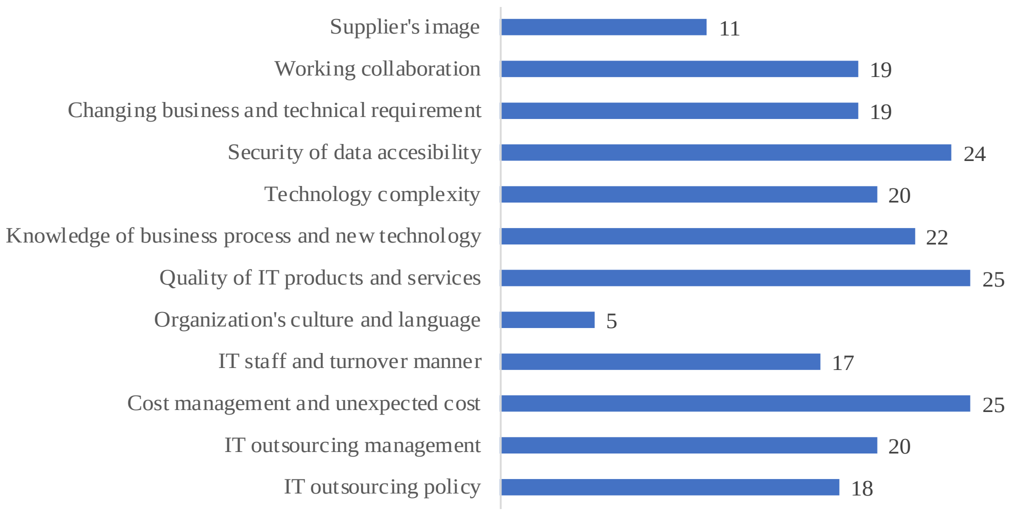

Figure 4.4

Risk factors favor used

4.4.4 Evaluation Criteria Associated with the Sustainability

The respondents were asked about what the evaluation criteria associated with the sustainability dimensions. This question could be answered in many multiple choices. The study had adopted Chi-Square technique to investigate the associated among them. The acceptance value should be less than 0.05 (Gorla & Somers, 2014). The majority of evaluation criteria had the Chi-Square equal/close to the zero (see Table 4.9). This demonstrated that most of the evaluation criteria could be associated on sustainability dimensions. Noteworthy there were only the contract management criterion which was close to 0.05.

Table 4.9

Chi-square of evaluation criteria

Evaluation criteria	chi-square
Economic	0.000
Quality	0.000
Service	0.000
Performance	0.000

Evaluation criteria	chi-square
Management	0.021
Strategy	0.005
Cost/price	0.000
Financial	0.000
Delivery	0.002
Satisfaction/responsiveness	0.000
Flexibility	0.000
Market leadership	0.000
Market Sharing	0.000
Contract management	0.047
Social	0.000
Culture	0.000
Relationship and communication process	0.000
Reliability and usability	0.000
Resource	0.005
Technology	0.000
Technology capability and experts	0.000
Configuration	0.000
Disaster recovery	0.000
Information and system security	0.000
Information and system integration compatibility	0.000
Maintenance and business innovation	0.000
Facility/assets	0.000
Experience	0.000
Knowledge of the industry	0.001
Research and development	0.003

n = 35 respondents

The cross-tabulation analysis indicated the most selected answer in the percentage of the evaluation criteria associated with each sustainability dimension. Table 4.10 shows the evaluation criteria associated with the sustainability dimensions.

Table 4.10

Contribution number of evaluation criteria on the sustainability

Evaluation criteria	sustainability			
	economic	social	technology	environment
Economic	22 (62.9%)	5 (14.3%)	19 (54.3%)	4 (11.4%)
Quality	14 (40.0%)	7 (20.0%)	30 (85.7%)	7 (20.0%)
Service	12 (34.3%)	20 (57.1%)	22 (62.9%)	5 (14.3%)
Performance	15 (42.9%)	11 (31.4%)	25 (71.4%)	2 (5.7%)
Management	19 (54.3%)	15 (42.9%)	17 (48.6%)	7 (20.0%)
Strategy	15 (42.9%)	9 (25.7%)	19 (54.3%)	6 (17.1%)
Cost/price	25 (71.4%)	7 (20.0%)	16 (45.7%)	4 (11.4%)
Financial	29 (82.9%)	4 (11.4%)	15 (42.9%)	6 (17.1%)
Delivery	11 (31.4%)	11 (31.4%)	21 (60.0%)	6 (17.1%)
Satisfaction/responsiveness	11 (31.4%)	22 (62.9%)	19 (54.3%)	6 (17.1%)
Flexibility	10 (28.6%)	19 (54.3%)	18 (51.4%)	6 (17.1%)
Market leadership	14 (40.0%)	10 (28.6%)	22 (62.9%)	5 (14.3%)
Market Sharing	19 (54.3%)	11 (31.4%)	17 (48.6%)	2 (5.7%)
Contract management	15 (42.9%)	15 (42.9%)	9 (25.7%)	6 (17.1%)

Evaluation criteria	sustainability			
	economic	social	technology	environment
Social	5 (14.3%)	23 (65.7%)	6 (17.1%)	9 (25.7%)
Culture	5 (14.3%)	25 (71.4%)	12 (34.3%)	5 (14.3%)
Relationship and communication process	5 (14.3%)	24 (68.6%)	14 (40.0%)	6 (17.1%)
Reliability and usability	14 (40.0%)	21 (60.0%)	22 (62.9%)	4 (11.4%)
Resource	7 (20.0%)	18 (51.4%)	16 (45.7%)	7 (20.0%)
Technology	10 (28.6%)	5 (14.3%)	28 (80.0%)	7 (20.0%)
Technology capability and experts	9 (25.7%)	11 (31.4%)	29 (82.9%)	6 (17.1%)
Configuration	11 (31.4%)	6 (17.1%)	30 (85.7%)	4 (11.4%)
Disaster recovery	8 (22.9%)	7 (20.0%)	27 (77.1%)	7 (20.0%)
Information and system security	11 (31.4%)	9 (25.7%)	30 (85.7%)	4 (11.4%)
Information and system integration compatibility	10 (28.6%)	8 (22.9%)	30 (85.7%)	6 (17.1%)
Maintenance and business innovation	14 (40.0%)	10 (28.6%)	27 (77.1%)	7 (20.0%)
Facility/assets	11 (31.4%)	8 (22.9%)	26 (74.3%)	6 (17.1%)
Experience	9 (25.7%)	18 (51.4%)	27 (77.1%)	10 (28.6%)
Knowledge of the industry	10 (28.6%)	18 (51.4%)	24 (68.6%)	9 (25.7%)
Research and development	14	14	24	9

Evaluation criteria	sustainability			
	economic	social	technology	environment
	(40.0%)	(40.0%)	(68.6%)	(25.7%)

n = 35 respondents

Most criteria were obviously associated with the technology sustainability as suggested by respondents (see Table 4.10). This is because these criteria can measure the supplier's capability in developing and maintaining the ITO. Most respondents highlighted four evaluation criteria (quality, configuration, Information and system security as well as information and system integration compatibility) comprising 80% highly associated the technology sustainability. There were three criteria as economic (62.9%), cost/price (71.4%), and financial (82.9%) associated to the economic sustainability. Particularly, the financial criterion was highly selected than other criteria in this sustainability. Social sustainability indicated the working coordination such as satisfaction/responsiveness (62.9%), culture (71.4%), relationship and communication process (68.6%), and reliability/usability (60.0%). Few respondents focused on the evaluation criteria associated with environmental sustainability. This was indicated only approximately 20% compared to other sustainability dimensions.

4.4.5 Evaluation Criteria Influncing the Sustainability

Additionally, the respondents were further inquired about the evaluation criteria influencing sustainability. These evaluation criteria were categorized into economic, social, and technology sustainability (see Table *2.6*). The mean value ($\bar{x}$) for each criterion was obtained from the analysis; it represents the most selected answers. The Likert's scale (5 scale) was used in this question ranging from '*Not Importance*' to '*Very Importance*'. The scale was then mapped to equal intervals. The interval sizes were calculated by following formula in Equation 4.1 referring to study of Raisian et al. (2017).

$$Interval\ values = \frac{n-1}{n} \tag{4.1}$$

where n was the maximum number in the scale. In this case, it was equal 5. Thus, the interval size in each level was 0.80 as depicted in Table 4.11.

Table 4.11

The interval values

Degree of Importance (DI)	interval values
Not Importance (NI)	1.00 – 1.80
Less Importance (LI)	1.81 – 2.60
Moderately Importance (MI)	2.61 – 3.40
Importance (I)	3.41 – 4.20
Very Importance (VI)	4.21 – 5.00

Table 4.12 exhibits the mean value in each evaluation criterion influencing the sustainability dimension. The outcomes in this finding showed that most evaluation criteria obtained high influencing whereby DI was in the range of '*Importance (I)*' to '*Very Importance (VI)*'. Notably, there were only five criteria (i.e. market leadership, market sharing, contract management, social and culture) that obtained the '*Moderately Importance*'.

Table 4.12

The degree of importance for evaluation criteria practices

Sustainability	evaluation criteria	mean	DI
Economic	Economic	3.77	I
	Quality	4.43	VI
	Service	4.43	VI
	Performance	4.29	VI
	Management	3.97	I
	Strategy	3.66	I
	Cost/price	4.29	VI
	Financial	4.14	I

Sustainability	evaluation criteria	mean	DI
	Delivery	4.09	I
	Satisfaction/responsiveness	4.14	I
	Flexibility	3.74	I
	Market leadership	3.37	MI
	Market sharing	3.11	MI
	Contract management	3.40	MI
Social	Social	2.77	MI
	Culture	2.77	MI
	Relationship and communication process	3.57	I
	Reliability and usability	4.29	VI
	Resources	3.74	I
Technology	Technology	4.26	VI
	Technology capability and experts	4.54	VI
	Configuration	4.29	VI
	Disaster recovery	4.17	I
	Information and system security	4.49	VI
	Information and system integration compatibility	4.09	I
	Maintenance and business innovation	4.03	I
	Facility/assets	3.89	I
	Experience	4.26	I
	Knowledge of the industry	4.09	I
	Research and development	3.66	I

Noted that:

VI:- Very Important

I :- Important

MI:- Moderately Important

4.4.6 Risk Factors Associated with the Sustainability

The respondents were also asked about the associated risk factors to the sustainability dimensions. Majority of risk factors associated the sustainability dimensions because the Chi-Square value was close to zero, excepted ITO management because the significance value exceed 0.05 (see Table 4.13).

Table 4.13

Chi-square of risk factors

Risk factors	chi-square
ITO policy	0.001
ITO management	0.061
Cost management and unexpected cost	0.000
IT staff and turnover manner	0.000
Organization’s culture and language	0.000
Quality of IT products and services	0.000
Knowledge of business process and new technology	0.000
Technology complexity	0.000
Security of data accessibility	0.000
Changing business and technical requirement	0.000
Working collaboration	0.000
Supplier’s image	0.000

n = 35 respondents

When further investigated with the cross-tabulation analysis, the result revealed that the majority of the respondents selected risk factors associated with three sustainability dimensions namely economic, social and technology (see Table 4.14).

Table 4.14

Contribution number of risk factors in sustainability

Risk factors	sustainability			
	economic	social	technology	environment
ITO policy	19 (54.3%)	15 (42.9%)	20 (57.1%)	5 (14.3%)
ITO management	13 (37.1%)	18 (51.4%)	17 (48.6%)	8 (22.9%)
Cost management and unexpected cost	29 (82.9%)	6 (17.1%)	16 (45.7%)	2 (5.7%)
IT staff and turnover manner	15 (42.9%)	25 (71.4%)	14 (40.0%)	6 (17.1%)
Organization's culture and language	2 (5.7%)	28 (80.0%)	3 (8.6%)	7 (20.0%)
Quality of IT products and services	18 (51.4%)	7 (20.0%)	31 (88.6%)	5 (14.3%)
Knowledge of business process and new technology	10 (28.6%)	10 (28.6%)	28 (80.0%)	5 (14.3%)
Technology complexity	7 (20.0%)	10 (28.6%)	29 (82.9%)	4 (11.4%)
Security of data accessibility	12 (34.3%)	15 (42.9%)	28 (80.0%)	3 (8.6%)
Changing business and technical requirement	18 (51.4%)	17 (48.6%)	26 (74.3%)	7 (20.0%)
Working collaboration	8 (22.9%)	29 (82.9%)	15 (42.9%)	8 (22.9%)
Supplier's image	11 (31.4%)	22 (62.9%)	16 (45.7%)	5 (14.3%)

n = 35 respondents

The respondents considered the cost management and unexpected cost (82.9%) became a high risk associated the economic sustainability. Similarly, the working collaboration (82.9%) and organization's culture and language (80.0%) were highly associated with social sustainability. While technology sustainability faced the risk associated with the quality of IT products and services, technology complexity, security of data accessibility as well as knowledge of the business process and new technology. Four of them obtained the percentage of the contributed number more than 80%; it was highlighted that they were highly associated with this sustainability. Only 20% of respondents considered the evaluation criteria being associated the environmental sustainability.

4.4.7 Risk Factors Influencing the Sustainability

Additionally, the respondents were asked about the risk factors influencing the sustainability dimensions. These risk factors could be categorized into three sustainability dimensions covering economic, social and technology. The analysis is similar in section 4.4.5 by using Linkert's scale (5 scales) in this question. The mean score in each risk factor was mapped in the intervals level as shown in Table 4.11. The results became the degree of importance as depicted in Table 4.15.

Table 4.15

The degree of importance for risk factors practices

Sustainability	risk factors	mean	DI
Economic	ITO policy	3.83	I
	ITO management	4.03	I
	Cost management and unexpected cost	4.03	I
	IT staff and turnover manner	3.91	I
	Organization's culture and language	3.03	MI
	Quality of IT products and services	4.40	VI
	Knowledge of business process and new technology	4.11	I
	Technology complexity	4.11	I
	Security of data accessibility	4.29	VI

Sustainability	risk factors	mean	DI
	Changing business and technical requirement	4.03	I
	Working collaboration	3.80	I
	Supplier’s image	3.40	MI
Social	ITO policy	3.20	MI
	ITO management	3.17	MI
	Cost management and unexpected cost	3.31	MI
	IT staff and turnover manner	3.43	I
	Organization’s culture and language	2.97	MI
	Quality of IT products and services	3.94	I
	Knowledge of business process and new technology	3.60	I
	Technology complexity	3.54	I
	Security of data accessibility	4.06	I
	Changing business and technical requirement	3.46	I
	Working collaboration	3.60	I
	Supplier’s image	3.26	MI
Technology	ITO policy	3.63	I
	ITO management	3.69	I
	Cost management and unexpected cost	3.86	I
	IT staff and turnover manner	3.69	I
	Organization’s culture and language	2.91	MI
	Quality of IT products and services	4.40	VI
	Knowledge of business process and new technology	4.09	I
	Technology complexity	4.03	I
	Security of data accessibility	4.34	VI
	Changing business and technical requirement	3.86	I
	Working collaboration	3.80	I
	Supplier’s image	3.49	I

Sustainability	risk factors	mean	DI

Noted that:

VI:- Very Importance

I :- Importance

MI:- Moderately Importance

Table 4.15 shows that most risk factors obtained the high-level influencing sustainability, whereby the DI was range of ‘*Important*’ to ‘*Very Important*’. There were two risk factors (quality of IT products and services and security of data accessibility) as highest influencing (DI = ‘*Very Important*’) in economic and technological sustainability. Notably, all sustainability dimensions faced the risk of the organization’s culture and language. However, this risk was only at the ‘*Moderately Important*’ level.

4.4.8 The Priority of Implemented Evaluation Criteria

The respondents were asked about the priority of evaluation criteria. The priority obtained mean score in each criterion by the descriptive analysis. The priority could capture the decision-makers’ opinion, besides, the indicated important level was used as the supplier assessment. This was discussed studied of Ahmad et al. (2014). Therefore, Table 4.16 shows the priority of evaluation criteria based on mean score.

Table 4.16

The evaluation criteria ranking

Evaluation criteria	mean	priority
Economic	6.63	26
Quality	8.49	1
Service	8.40	2
Performance	7.91	9
Management	7.23	19
Strategy	6.74	23

Evaluation criteria	mean	priority
Cost/price	8.03	6
Financial	7.29	18
Delivery	7.94	7
Satisfaction/responsiveness	8.09	5
Flexibility	7.63	14
Market leadership	6.20	27
Market sharing	5.57	28
Contract management	6.97	21
Social	5.40	29
Culture	5.03	30
Relationship and communication process	6.71	24
Reliability and usability	7.94	7
Resources	6.69	25
Technology	7.63	14
Technology capability and experts	8.11	4
Configuration	7.71	12
Disaster recovery	7.77	11
Information and system security	8.20	3
Information and system integration compatibility	7.69	13
Maintenance and business innovation	7.31	17
Facility/assets	7.14	20
Experience	7.80	10
Knowledge of the industry	7.49	16
Research and development	6.80	22

The result in Table 4.16 describes that the quality criterion obtained the highest importance from decision-makers. The respondents highlighted the high quality of the supplier to reflect the efficient ITO. On contrary, the culture criterion obtained the lowest priority. Because the decision-makers hardly paid attention to consider this criterion for supplier selection of ITO. Therefore, these criteria prioritization captured the decision-makers opinion. It also could be the guideline for the weight allocation of each criterion in the supplier assessment.

4.4.9 The Priority of Implemented Risk Factors

The respondents were also asked about the priority of risk factors. Similar to Section 4.4.8, the mean score was calculated to assign the priority of risk factors. Table 4.17 illustrated the priority of risk factors.

Table 4.17

The risk factors ranking

Risk factors in practices	mean	priority
ITO policy	6.97	10
ITO management	7.20	6
Cost management and unexpected cost	7.37	3
IT staff and turnover manner	7.03	9
Organization's culture and language	5.60	12
Quality of IT products and services	8.09	1
Knowledge of business process and new technology	7.29	4
Technology complexity	7.23	5
Security of data accessibility	8.06	2
Changing business and technical requirement	7.17	7
Working collaboration	7.17	7
Supplier's image	6.29	11

The result in Table 4.17 indicates that the decision-makers concerned about the quality of IT products and services as first priority. The risk factor highly impacting the supplier assessment in the selection process followed by the security of data accessibility and cost management and unexpected cost. Surprisingly, there were two risk factors obtaining the same priority; they were changing business and technical requirements and working collaboration.

4.5 Discussion

This study has investigated several issues to the construction of the evaluation criteria and risk factors on sustainable ITO for supplier selection model. The findings of the study will be discussed in the next subsection according to the objectives of the exploratory study.

Objective 1: To study the current practices of supplier selection process for ITO among Thailand practitioners

- **Exposure on supplier selection process**

Most of the respondents had 9 years to 20 years' experiences as refer to Figure 4.1. Only 14% of respondents obtained high experience (more than 20 years) on the supplier selection problems for ITO. The result was different from the study of Secundo et al. (2017) who mentioned that the suitable experience of decision-makers is 7.5 years. This highlight to supplier selection problems in Thailand required the decision-makers highly experience a minimum of 9 years. This outcome was consistent with the studies of Chen and Wang (2009); Faisal and Raza (2016); Rabbani et al. (2017); Ramanathan and Krishnan (2015). In addition, the majority of the respondents were in the high position of each organization (refer to Table 4.4). The study by Liu et al. (2016); Thakur and Anbanandam (2015) supports this. It indicates that the procurement committee in Thai organizations required decision-makers who had highly IT knowledge and experience in supplier selection problems.

- **The departments' involvement in purchasing committee**

Most respondents worked in the IT department (77.1%) and IT stakeholders (65.7%) that were selected to be a part of the committee (referring to Table 4.3). This is consistent with the previous study in Faisal and Raza (2016) whereby the organization selected a committee that had IT knowledge for supplier selection problems. However, the committee should consist of various knowledge, not only IT. This is essential for supplier selection as it involved the finance and the organization's strategy. Having various knowledge in committee will incur the right supplier selection (Liu et al., 2016).

- **Decision structure implementation**

Many respondents selected the dependent structure (60%) (See Table 4.7) as a suitable adopt in the supplier selection problems of ITO. In contrast, Mardani et al. (2015) stated that the independent structure preferred in supplier selection problems similar to the work of Efe (2016); Mukherjee and Mukherjee (2015); Nazari-Shirkouhi et al. (2017); Repschlaeger et al. (2014). Unfortunately, the independent structure is insufficient for real practice implementation (Gölcük & Baykasoğlu, 2016). This is consistent with the respondents selected. Added to this, the concept of sustainability requires balancing various evaluation criteria (Azimifard et al., 2018; Fallahpour et al., 2017; Rao, Goh, et al., 2017). Therefore, sustainability incurred the interrelationship among evaluation criteria for supplier selection problems. Nevertheless, 28.6% of the respondents used only one criterion (cost-benefit/financial) consideration to select the supplier.

- **Decision method implementation**

Most of the respondents were familiar with the primitive method (34.3%) (i.e. committee suggestion, familiarity with a supplier, and low price bidding) referring to Table 4.8. The result was opposed to many works of Efe (2016); Kilic et al. (2015); Mukherjee and Mukherjee (2015); Nazari-Shirkouhi et al. (2017); Uygun et al. (2015) who used the scientific method in the supplier selection problem. One of the scientific methods widely used ANP methods as reported in the studies of Zavadskas et al. (2016). The method also supported solving real-world decision-making problems (Gölcük &

Baykasoğlu, 2016) because it was to synthesize complex decision problems, in accordance with studies of Kilic et al. (2015); Uygun et al. (2015). Unfortunately, the respondents used this method in their supplier selection problems only 11.4%.

Objective 2: To investigate the practitioners' opinion on the evaluation criteria and risk factors used in supplier selection of ITO that lead to the sustainability.

- **Priority of sustainability perspectives usability**

Generally, sustainability is the social responsibility and environmental awareness based on economic growth (Rao, Goh, et al., 2017). In this way, sustainability is a crucial part of the supplier selection process. Furthermore, sustainability becomes important to technology. The technology has also increased the ability of business competition and customer satisfaction (Thakur & Anbanandam, 2015). Technology sustainability was chosen as a first priority by the respondents of this study. Furthermore, towards ensuring a positive impact on the environment, environmental sustainability was chosen by the respondents only 7 times. This is different in many works mentioning that supplier selection problems had paid attention to environmental sustainability (Fallahpour et al., 2017; Luthra et al., 2017; Rabbani et al., 2017).

Moreover, the technology builds the maximum profit and increases revenue to the organization due to having new products and services respond to the customer needs such as online travel booking (Lin, 2016), digital banking (Thakur & Anbanandam, 2015) and digital tools up-to-date (Faisal & Raza, 2016). These services have increased the organizations' revenue and positively affect the shareholder wealth and incurs reinvestment. With these reasons, economic sustainability was chosen as the second priority (24 times). This is also supported in existing studies of the sustainable supplier selection used this sustainability to assess the suppliers' capability (Fallahpour et al., 2017; Luthra et al., 2017; Rabbani et al., 2017).

In addition, emphasizing social communication in the working space is to increase mutual trust and good relationships in the working collaboration. The relationship and communication are a crucial part of working for ITO success between organization and supplier as stated in the studies of Alexandrova (2012); Khan et al. (2010); Kronawitter et al. (2013). Fallahpour et al. (2017); Rao, Goh, et al. (2017) highlighted the humans' welfare in social sustainability for supplier selection problems. Surprisingly, only 8 times were chosen for social sustainability being used in the supplier selection problems for ITO. This is obvious that most respondents highlighted two sustainability dimensions (economic and technology) in supplier selection problems of ITO.

- **Priority of evaluation criteria usability**

Most evaluation criteria emphasized assessing the suppliers' capability in the supplier selection problems of ITO. The evaluation criteria were gathered from the review of the literature even domain expert suggestions (Khan & Faisal, 2015; Mukherjee & Mukherjee, 2015; Thakur & Anbanandam, 2015). These evaluation criteria did not only highlight price but also mentioned the other evaluation criteria, especially qualitative (immeasurable) criteria. Based on the review literature in this study, the quality criterion became the first priority adopt in the supplier selection of ITO. Similarly, the respondents chose the quality (33 times) as the highest priority followed by services (32 times) and cost/price (30 times) criteria (see Figure 4.3). In addition, they highlighted the technical criteria such as technological capability and experts, experience, information and system security, disaster recovery and configuration 20 times approximately.

Accordingly, most decision-makers selected these evaluation criteria as the first priority in supplier selection problems similar to the studies of Cao et al. (2012); Chang et al. (2012); Kahraman et al. (2009); Morais et al. (2014). This was shown that most decision-makers did not only choose the price in making the decision, but also paid attention to the other evaluation criteria. However, the cost/price was also the third priority of evaluation criteria in the supplier selection problem. Khan and Faisal (2015); Lin, Chen, and Ting (2011); Thakur and Anbanandam (2015) stated that supplier selection needed to decide based on a reasonable cost/price. Surprisingly, the social and culture was chosen only 1 time by the respondents. It is not different from the existing studies in ITO problems that were not mentioned the the social and cultural criteria (Nazari-Shirkouhi et al., 2017; Qiang & Li, 2015; Thakur & Anbanandam, 2015). On contrary, it was different from the studies of Mukherjee and Mukherjee (2015). They concerned about the different cultures and languages in working collaboration for the off-shoring supplier selection. Consequently, most evaluation criteria used in supplier selection on domain experts' perspective reflected the obtaining benefits and technical improvement by the supplier.

- **Priority of risk factors usability**

The risk factors in supplier selection were different than those in the evaluation criteria. The risk factors attempted to control and monitor the undesirable outcomes' occurrence; it involved the risk management of both supplier and ITO (Rao, Xiao, et al., 2017; Samantra et al., 2014). Varajão et al. (2017) reported that the loss of control in the business was highlighted rather than the unexpected cost and decreased quality. This is a difference in this study, in which the respondents focused on the quality of IT products and services (25 times) as a highly important risk similar to the cost management and unexpected cost (25 times) followed by security of data accessibility

(24 times), knowledge of business process and new technology (22 times), technology complexity (20 times) and ITO management (20 times). On top of this, Hodosi and Rusu (2019) stated that outsourcing had a high risk because of notable hidden costs. It was similar to the respondents' suggestion. They selected the risk of cost management and the unexpected cost as a high priority. Since the cost management and unexpected cost involved the various risk aspects such as lack of planning budget, ineffective IT infrastructure investment and hidden cost. Particularly, the hidden cost incurs budget overrun that does not appear in the ITO contract (González et al., 2016).

Next, most respondents also concerned about the security of data accessibility in third priority. ITO occurred from working between two parties namely organization and supplier. Normally, the supplier could access the systems and data of the organization even some confidential information. It is possible that the information can even be a leak to the competitors by the supplier (González et al., 2016). In addition, the risk in ITO might arise from instability business processes, due to high competition of business. It impacts the ITO operation change (Fan et al., 2012). It affected the respondents who were somewhat highly anxious about the supplier's capability to deal with this risk. This also involved the technical complexity that might be an obstacle to the ITO accomplishment. The study of Fan et al. (2012) had identified these risks in the risk management of ITO.

In addition, the risk of the working collaboration should be concerned in the supplier selection of ITO. This risk gained somewhat high consideration in this study (19 times). Similarly, the study by Alikhani et al. (2019) reported that the risk also obtained quite high anxiety from domain experts' opinions. At the same time, the risk directly affected ITO success that involved the efficient communication between staff and management team for two parties in ITO (Ismail & Razali, 2014; Kronawitter et al., 2013; Smuts et al., 2010). It is different in this study of Thakur and Anbanandam (2015) which never considered the risk of working collaboration factors. Furthermore, the staff turnover rate became an obstacle to the performed ITO continuous. If staff had the poor morale during the contract (González et al., 2016); it might incur ITO unsuccess. Consequently, the respondents concerned these risks in the high priority for supplier selection problems of ITO.

- **The selected evaluation criteria associated with the sustainability dimensions**

The corresponding evaluation criteria in each sustainability dimension became a key challenge for supplier selection leading to sustainable ITO. Sustainability incured the balancing of evaluation criteria such as in studies of Azimifard et al. (2018); Fallahpour et al. (2017); Girubha et al. (2016); Luthra et al. (2017); Rabbani et al. (2017). Table 4.10 has highlighted to the evaluation criteria associated in three sustainability dimensions. The study chose the corresponding criteria in each sustainability dimension on the percentage of contribution number when the value was more than 60%. The value was referred from the study of Amini, Hosseinalipour, and Monavvarian (2017). The selection outcomes can be shown in Table 4.18.

Table 4.18

The evaluation criteria associated sustainability

Sustainability	evaluation criteria	Percentange (%)
Economic	Economic	62.9
	Cost/Price	71.4
	Financial	82.9
Technology	Quality	85.7
	Service	62.9
	Performance	71.4

Sustainability	evaluation criteria	Percentange (%)
	Market leadership	62.9
	Reliability and usability	62.9
	Technology	80.0
	Technology capability and experts	82.9
	Disaster recovery	77.1
	Configuration	85.7
	Information and system security	85.7
	Information and system integrated compatibility	85.7
	Maintenance and business innovation	77.1
	Facility/assets	74.3
	Experience	77.1
	Knowledge of the industry	68.9
	Research and development	68.9
Social	Satisfaction/responsiveness	62.9
	Social	65.7
	Culture	71.4
	Relationship and communication process	68.6

n = 35 respondents

Noteworthy the evaluation criteria had no correlated into environmental dimension significantly since percentage of contribution number was less than 60%, so the evaluation criteria were not selected. Consequently, the evaluation criteria only were associated three sustainability dimensions namely economic, social and technology. The detailed explanations in the corresponding criteria in each sustainability dimension will be discussed below.

Evaluation criteria and economic sustainability

The respondents recommended three criteria as economic, cost/price, and finance associated the economic sustainability. Generally, the economic criterion not only aimed at the investment reduction for IT system development and maintenance but also aimed to retain the IT system efficiency and effectiveness (Nazari-Shirkouhi et al., 2017). Therefore, the supplier was hired from the organization based on a reasonable price. The reasonable price was also related to the quality of products and services supplied by the supplier (Fallahpour et al., 2017). The results of the organization showed the variable cost instead of fixed cost from IT staffs' wages (Faisal & Raza, 2016) along with the organization to reduce the expenditure for IT system development and maintenance (Liu et al., 2016). In addition, the finance criterion had referred to financial stability; it was consistent with the earning, profitability, compound annual growth, and the size of cash reserves as addressed in the study of Mukherjee and Mukherjee (2015). This reflects the financial capability of the supplier to support the supplier's staff wages and new IT system investment throughout the contract. Accordingly, three evaluation criteria have associated the economic sustainability.

Evaluation criteria and technology sustainability

Technology sustainability directly involved with the supplier's capability because the supplier could provide both experts and new technology to improve the IT system supporting the digital business in accordance to studies of Faisal and Raza (2016); Thakur and Anbanandam (2015). The respondents supported this whereby most evaluation criteria associated the technology sustainability, especially technology, technology capability and experts, quality, configuration, information and system security, and information and integrated system compatibility. Many existing studies adopted these evaluation criteria to assess the supplier capability in both system development and maintenance (Chang et al., 2012; Kahraman et al., 2010; Liu & Quan, 2013; Nazari-Shirkouhi et al., 2017; Thakur & Anbanandam, 2015). Also, the facility/asset criterion has been highlighted that the supplier had to supply the modern

IT infrastructure to support new business (i.e. electronic banking) as followed in the study of Thakur and Anbanandam (2015). These were consistent with the study of Amri and Saoud (2014); Betz and Caporale (2014) who focused on software system survivability of even business processes changed with development and maintenance.

Evaluation criteria and social sustainability

Generally, ITO is a working collaboration between the organization and supplier. Thus, the supplier should understand the culture and language to the communication between two parties in the working society. The respondents supported this whereby they selected four criteria covering satisfaction/responsiveness, social, culture, and relationship and communication process associated with social sustainability. In addition, these criteria were associated the social and individual dimensions in software sustainability, in accordance with studies of Amri and Saoud (2014); Raisian et al. (2017). They pointed out the staffs welfare, participation, communication, and interaction for the requirement collection should become consideration. Consequently, these were associated with the supplier's capability in terms of social sustainability in supplier selection for sustainable ITO.

- **The selected evaluation criteria influencing the sustainability dimensions**

The evaluation criteria have been grouped into three sustainability dimensions as economic, social and technology based on the review of the literature (see Table 2.6). In order to ensure that these evaluation criteria influence the sustainability dimension significantly, this study adopted the degree of importance (DI) to choose the evaluation criteria. The evaluation criteria were selected when DI obtained at least '*Importance*' level. This value was suggested by Kucukaltan, Irani, and Aktas (2016). The outcomes can be shown in Table 4.19.

Table 4.19

The evaluation criteria influencing sustainability

Sustainability	influenced evaluation criteria	DI
Economic	Quality	VI
	Service	VI
	Performance	VI
	Cost/price	VI
	Economic	I
	Management	I
	Strategy	I
	Financial	I
	Delivery	I
	Satisfaction/responsiveness	I
	Flexibility	I
Technology	Technology	VI
	Technical capability and experts	VI
	Configuration	VI
	Information and system security	VI
	Disaster recovery	I
	Information and system integration compatibility	I
	Maintenance and business innovation	I
	Facility/assets	I
	Experience	I
	Knowledge of the industry	I
	Research and development	I
Social	Reliability and usability	VI
	Relationship and communication process	I
	Resources	I

Noted that:

VI:- Very Importance

I :- Importance

MI:- Moderately Importance

The majority of the evaluation criteria significantly influenced the sustainability dimension with '*Importance*' level. There were four criteria in both economic and technology sustainability as highly influencing in the '*Very Importance*' level. Only one criterion (reliability and usability) highly influenced the social sustainability. Unfortunately, the social criterion was not chosen because DI value was equal '*Moderately Importance*'. A detailed explanation of criteria influencing each sustainability dimension will be addressed subsequently.

Evaluation criteria and economic sustainability

Economic dimension is a crucial part of IT system survivability because the dimensions focus on the capital and added value that comprise wealth creation, profitability, capital investment and income (Venters et al., 2018). These were associated with the organization's shareholders in the reinvestment to improve the IT system throughout the business change. The respondent supported this whereby they selected eleven criteria that significantly influenced this dimension. There were four criteria (quality, service, performance and cost/price) obtaining the '*Very Importance*', while the rest of them obtained the '*Importance*'. These criteria could reflect the profitability, reasonable capital investment and increasing income from IT system development and maintenance through the supplier. The existing studies have adopted these criteria to assess the supplier's capability to improve the IT system and support the business changed to the digital era such as digital banking (Thakur & Anbanandam, 2015), travel booking online (Lin, 2016), digital education (Faisal & Raza, 2016) and bookstore online (Nazari-Shirkouhi et al., 2017). This was obvious that IT system was able to increase the potential business competition. Also, the high-efficiency IT system directly affected the profit and revenue increases as addressed in the work of Thakur and

Anbanandam (2015). Obviously, these criteria significantly influenced the economic sustainability in supplier selection problem for ITO.

Evaluation criteria and technology sustainability

Technology sustainability is aimed at the survivability and perdurability of IT systems both software and hardware (IT infrastructure). Thus, the development and maintenance phase is highly important for the IT system, if the organization's business and policy change. This made the respondents selecting eleven criteria to sustain the longevity of IT system implementation when the system was outsourced. In other words, all eleven criteria indicated the supplier's technical capability to support the development and maintenance of IT systems. Therefore, these criteria were adopted in the studies of Khan and Faisal (2015); Nazari-Shirkouhi et al. (2017); Secundo et al. (2017); Thakur and Anbanandam (2015) to assess the supplier's technical capability to improve the IT system; including IT infrastructure. This is because business requirements changed such as the work of Thakur and Anbanandam (2015). They improved the IT infrastructure to support customer satisfaction for using digital banking. Consequently, these criteria influenced the survivability and perdurability of IT systems whereby Amri and Saoud (2014); Betz and Caporale (2014) stated that technology sustainability indicated the incessant technology evolution with development and maintenance based on organization business changing.

Evaluation criteria and social sustainability

The survivability and perdurability of IT systems, that are outsourced, do not only depend on economic and technology sustainability but also involve social sustainability. This is because ITO is relevant to the working society between the organization and the supplier (Thakur & Anbanandam, 2015). It reflects the two sustainability aspects of the software namely social and individual (Amri & Saoud, 2014; Raisian et al., 2017). Therefore, the respondent chose three criteria as reliability and usability, relationship and communication process and resources criteria influencing the social sustainability. This was because these criteria indicated the ability to work collaboration and staffs well-being, which was consistent with the study of Amri and Saoud (2014). A good relationship and communication were important in the ITO workspace. Mukherjee and Mukherjee (2015) supported this by mentioned that high-quality communication kept working collaboration better along with exchange important information between partners. In addition, trustiness incured confidence in the working collaboration, which become another key for requirement collection in ITO. Whilst the staffs' welfare (i.e. payment, health insurance as well as number of working hours) should take into accout because it involved the job security and morale of staffs (Amri & Saoud, 2014; Venters et al., 2018) throughout ITO contract. Accordingly, three criteria significantly influenced social sustainability.

- **The selected risk factors associated with sustainability dimensions**

The risks become significant issues in the supplier selection to lead sustainable ITO. Gold and Awasthi (2015) considered the risks relevant in three sustainability dimensions (i.e. economic, social and technology) for supplier selection problems. Table 4.14 reported that the risk factors in ITO could be associated with sustainability dimensions. On top of this, the study chose the risk factors in each sustainability dimension by using a similar condition in the selection of evaluation criteria on sustainability. The results have been presented in Table 4.20.

Table 4.20

The risk factors associated sustainability

Sustainability	risk factors	percentage (%)
Economic	Cost management and unexpected cost	82.9
Technology	Quality of IT products and services	88.6
	Knowledge of business process and new technology	80.0
	Technology complexity	82.9
	Security of data accessibility	80.0
	Changing business and technical requirement	74.3
Social	IT staff and turnover manner	71.4
	Organization's culture and language	80.0
	Working collaboration	82.9
	Supplier's image	62.9

n = 35 respondents

Importantly, the risk factors could not be associated into environmental dimension significantly because the percentage of contribution number did not exceed 60% so the risk factors were not selected. Nevertheless, the risk factors were also relative to the environmental sustainability based on IT infrastructure as stated in the study of (Marnewick, 2017). Consequently, the risk factors could be associated with three sustainability dimensions. The detailed explanations of the corresponding risk factors in each sustainability dimension are discussed below.

Risk factors and economic sustainability

The respondents only selected the risk of cost management and unexpected cost associated the economic sustainability. The cost became an issue in the ITO unsuccess (Hodosi & Rusu, 2019) which consisting of various perspectives. They were hidden costs, inefficient investment in IT infrastructure, lack of cost management and planning as well as hiring incompetent experts (González et al., 2016; Martens & Teuteberg, 2009; Samantra et al., 2014). These should be controlled and monitored throughout the supplier's operation and development in ITO. Particularly, the hidden cost did not appear during the contract such as communication cost and post-outsourcing cost (González et al., 2016; Nduwimfura & Zheng, 2015b), which became the main issues affecting overbudget. Moreover, the stock market fluctuation might impact cost management and planning due to currency values affecting the IT infrastructure investment. A study by Gold and Awasthi (2015) determined the currency risk in considering the sustainable supplier selection.

Risk factors and technology sustainability

ITOs have become an organizations' strategy in the business competition so IT system stability is important. It reflects the organization's need for the sustainability of IT system. On contrary, ITO might cause undesirable outcomes and negatively impact the IT system stability by the supplier. The risk identification became one of the risk management for ITO proposed by Fan et al. (2012); Martens and Teuteberg (2009); Samantra et al. (2014) and González et al. (2016) in their studies. Similarly, the respondents identified the risk factors associated with technology sustainability in this study.

In order to deal with undesirable outcomes occurring in the supplier's operation and development, there were five risk factors namely quality of IT products and services (88.6%), technology complexity (82.9%), knowledge of business process and new technology (80%), security of data accessibility (80%) and changing business and technical requirement (74.9%). Most respondents were highly anxious about the quality of IT products and services followed by technical complexity. This might negatively impact the unexpected business competition if IT system occurred instability. Fan et al. (2012) identified that the incompetent supplier(s) affected the poor quality outcome and unable to troubleshoot the technical complexity. It revealed in the respondents' concerns about the lack of knowledge on the business process and new technology to respond to the changing business requirements. Martens and Teuteberg (2009) also identified to the lack of privacy/data security because the organizations' fear lost the confidential information. This was reported by Alexandrova (2015) stating that security risk was a higher protection level for the organization. The practice in this study was supported by the respondents. These risks were obvious to associate with the technology sustainability dimensions.

Risk factors and Social sustainability

ITOs involve the working collaboration between two parties as organization and supplier. The working collaboration might naturally occur the risk in various perspectives such as miscommunication, conflict relationship and unconfident ability. These will be eliminated by mutual trust which became an important component in successful working collaboration (Alexandrova, 2015). If lack of trustiness in the teams' workers (organization and supplier), it negatively impacted the ITO projects. On top of this, the obstacle in mismatches organizations' culture in the offshore context (Alexandrova, 2015) impacted the capturing requirements in the outsourcing project. Due to the different language between organization and supplier used; it resulted in a misunderstanding to the communication process. It also affected the successful ITO because the communication process was important in ITO as addressed in studies of success factors in ITO (Alexandrova, 2015; Khan et al., 2010; Kronawitter et al., 2013; Smuts et al., 2010). These were the risk associated the social sustainability, which was consistent with the respondent answer.

Furthermore, the staff is another one of the risks in the working between organization and supplier. If the supplier does not take into account the well-being of staff; it might incur turnover staffs. According to González et al. (2016), the loss of motivation and poor morale impact inefficient working collaboration in ITO. Moreover, the higher turnover staffs have no continuity in ITO implementation. It might be addressed that this risk is associated the social sustainability similar to the respondents' mentioned.

- **The selected risk factors influencing the sustainability dimensions**

The risk factors have investigated the influence on three sustainability dimensions with the degree of importance (DI). Similarly, the selection of evaluation criteria influencing sustainability. Table 4.21 depicts the DI value of each risk factor that influenced three sustainability dimensions.

Table 4.21

The risk factors influencing sustainability

Sustainability	Influenced risk factors	DI
Economic	Quality of IT products and services	VI
	Security of data accessibility	VI
	ITO policy	I
	ITO management	I
	Cost management and unexpected cost	I
	IT staff and turnover manner	I
	Knowledge of business process and new technology	I
	Technology complexity	I
	Changing business and technical requirement	I
	Working collaboration	I
Technology	Quality of IT products and services	VI

Sustainability	Influenced risk factors	DI
	Security of data accessibility	VI
	ITO policy	I
	ITO management	I
	Cost management and unexpected cost	I
	IT staff and turnover manner	I
	Knowledge of business process and new technology	I
	Technology complexity	I
	Changing business and technical requirement	I
	Working collaboration	I
	Supplier's image	I
Social	IT staff and turnover manner	I
	Quality of IT products and services	I
	Knowledge of business process and new technology	I
	Technology complexity	I
	Security of data accessibility	I
	Changing business and technical requirement	I
	Working collaboration	I

Noted that:

VI:- Very Important

I :- Important

MI:- Moderately Important

Obviously, most risk factors notably influenced more than one dimension. There are two risk factors obtained DI value as '*Very Important*'. In the other words, two risk factors pointed to the highly undesirable outcomes by influencing economic and technological sustainability. The rest of the risk factors also influenced three sustainability in the '*Important*' level. More details on risk factors influencing each dimension are discussed below.

Risk factors and economic sustainability

ITO has influenced not only the cost reduction in the IT system development and maintenance but also increasing revenue for the organizations such as changing traditional to digital business (Thakur & Anbanandam, 2015). The organization might necessarily reinvest in the ITO to sustain the IT system in the business environment change. However, ITO must also face many hazards such as cost management, incompetent supplier as well as low-quality products. Decreasingly, these impact the organization's income. Alikhani et al. (2019) reported that quality risk was concerned in high level on supplier selection problems. It is similar to the respondents that focused on the risk of quality of IT products and services in the '*Very Important*' level. These had an influence on this sustainability. If IT system had the low performance then the customer might repeal the products and services; it caused revenue decreasing significantly.

Furthermore, ITO must face the risk of data accessibility because working of supplier necessary was able to access the system and information of the organization. Perhaps, the supplier might keep the confidential information and leak it to the other organization (González et al., 2016). This might incur a loss in the business competition; it leads to the organization's revenue decreasingly. Therefore, DI level of security of data accessibility is also in the '*Very Important*' level. This is opposed to the study of risk management by Samantra et al. (2014) reported that the security risk had a low influence in ITO. The rest of risk factors also influenced this sustainability at the '*Importance*' level. For example, ITO policy, ITO management, cost management and unexpected cost and so on (see Table 4.21). Surprisingly, the risk of cost management and unexpected cost only obtained the '*Important*' level that influenced this dimension. A study by Varajão et al. (2017) highlighted the fear of unexpected costs affecting the decreasing quality of products and services. Similarly, the supplier selection in the study of Alikhani et al. (2019) highlighted the cost risk at a high level. This occurred from economic fluctuations, procurement-related costs and hidden cost (González et al., 2016; Nduwimfura & Zheng, 2015b), which might be crucial factors affecting the economic sustainability for ITO.

Risk factors and technology sustainability

Accordingly, the risks factors also attained either '*Very Important*' or '*Important*', which indicated crucial influencing toward technology sustainability. Particularly, the risk of quality of IT products and services and security of data accessibility highly were influenced this sustainability similar the economic sustainability. The insufficient quality in products and services can be reflected from the lack of supplier's capability (Rao, Xiao, et al., 2017) in various perspectives such as misunderstanding in business process (Fan et al., 2012) and inability to adapt new technologies (Martens & Teuteberg, 2009). In addition, system security is also one of the risks in ITO. However, the practical study of Alexandrova (2015) pointed out that the security problem was not somewhat attention in the ITO similar to the work of Samantra et al. (2014). This is different from the respondents that identified the high influence on the technology sustainability

Other risks in ITO might occur from working collaboration between organization and supplier. The organization's team worker might be unconfident with the supplier's capability. It impacts to no proper information sharing (Alikhani et al., 2019) which is relevant to the IT system to the supplier. This negative affects the developing and maintaining IT system of the organization. In addition, another risk is experts that arise the turnover situation. González et al. (2016) identified that loss of motivation and poor morale as well insecurity jobs were the driving force to the turnover staffs. This had an influence on technology sustainability as follows the respondent mentioned in the '*Important*' level because ITOs rely on the expertise from the supplier as stated in the study of Faisal and Raza (2016).

Risk factors and social sustainability

Social community is crucial in the working collaboration between the organization and supplier for ITO. The community highlighted two perspectives namely technical community and users (Amri & Saoud, 2014). However, both perspectives might incur conflict in working collaboration in terms of getting the users' requirement (business and technical). A study by Fan et al. (2012) identified the risk factors relevant to the working collaboration for ITO. They mentioned the unreliable requirements, different cultures and coordination of ITO operation. This is consistent with the respondents who highlighted that '*Important*' level on these risk factors influenced social sustainability. In addition, if staffs' unwell being occurred in working space, this might affect high turnover of the staffs and lost productivity in the working as addressed in the studies of González et al. (2016). This is also reflected social sustainability in terms of individual sustainability. Individual sustainability was highlighted in software sustainability, which mentioned the mental and staff well-being (Venters et al., 2018).

<u>Objective 3:</u> To analyze the interrelation and prioritization of evaluation criteria and risk factors on sustainability.

- **Analysis of the interrelated evaluation criteria and risk factors**

The evaluation criteria and risk factors being used in the analysis of Pearson Correlation Coefficient (PCC) were selected under two conditions: 1) percentage of contribution number in terms of associated > 60% and 2) degree of importance (DI) in terms of influencing > 3.5 (referring to '*Important*' level or above). The result that has twenty-one (21) evaluation criteria and eight (8) risk factors. The relationship was accepted when the significant value (ρ-value) did not exceed 0.01. This was supported in the study of Qi and Chau (2015). The outcomes from the PCC analysis can be seen in Appendix C. Additionally, the detailed explanations of the relationship among criteria and risk factors of each sustainability dimension will be further discussed subsequently.

Evaluation criteria of economic sustainability

This study found that there were six (6) evaluation criteria, and one (1) risk factor that had a relationship in the economic sustainability dimension. This was different from the sustainable supplier selection problem, whereby it emphasized the evaluation criteria without combining the risk factors (Azimifard et al., 2018; Fallahpour et al., 2017; Luthra et al., 2017). Gold and Awasthi (2015) argued that economic sustainability should not only consider evaluation criteria, but also take into account risk factors. This reflected the supplier's capability of handling the undesirable ITO throughout the contract. Additionally, the respondents highlighted other relationships of evaluation criteria under sustainability dimensions namely configuration, information and system security, disaster recovery as well as facility/assets. These criteria indicated the supplier's capability of ITO development and maintenance sustaining IT system long-run and perdurability when organization's business changed. It was similar to the study of Thakur and Anbanandam (2015) who adopted these evaluation criteria in the supplier selection problem to improve the IT system for supporting the digital banking on value-added in business.

Furthermore, economic sustainability considered risk factors, especially cost management and unexpected cost because cost might occur not only in IT system investment but also from organization-supplier coordination (González et al., 2016). This might become another reason why budget is overrun and impacts the supplier cancels the contract before the end of the contract (Faisal & Raza, 2016). There were also two risk factors on technology sustainability namely the quality of IT products and services as well as changing business and technical requirements relevant to economic sustainability. These risks might occur the loss of quality and service in IT systems which negatively affected the organization revenue decreasingly. This is supported by Nduwimfura and Zheng (2015b). Therefore, the relationship among criteria and risk factors influenced economic sustainability both internal and external dimension.

Evaluation criteria of technology sustainability

The relationship between evaluation criteria found in technology sustainability involved the supplier's technical skill to support the survivability and perdurability of IT system when organization business changed. The existing studies by Liu et al. (2016); Thakur and Anbanandam (2015) adopted the evaluation criteria to assess the supplier's technical skill to improve their IT system supporting the modern business (i.e. digital banking and online booking). This highlighted the supplier's capability on the IT system development. In this context, there were existing study mentioning sustainability in software engineering to improve the IT system including the IT infrastructure responding to the organization with business changes (Amri & Saoud, 2014; Becker et al., 2016; Betz & Caporale, 2014; Cevere & Gailums, 2017; Raisian et al., 2017; Venters et al., 2018). This is the survivability of IT system to support the business of the organization.

In addition, the relationship involved the risk factors to avoid the undesirable outcome from the supplier. There are existing works mentioning that supplier was a hazard to the ITO success (Nduwimfura & Zheng, 2015b; Samantra et al., 2014). This might make IT system instability from the insufficient capability of the supplier. This was because a lack of technical knowledge to solve the problem (i.e. technology complexity, security of data accessibility) impacted the quality of IT products and services including changing business and technical requirements (González et al., 2016; Nduwimfura & Zheng, 2015b). These risks were an obstacle in the maintainability and sustain perdurability of IT system when outsourced to the supplier. Consequently, the relationship among criteria and risk factors significantly influenced technology sustainability.

Evaluation criteria of social sustainability

The working society became a crucial aspect in ITO. Kronawitter et al. (2013) stated that the relationship and effective communication between organization and supplier was mandatory for ITO success. This was also found in the study that the relationship among criteria and risk factors influenced social sustainability involving the working collaboration due to supplier need to the requirement collection from organization to develop and maintain the IT system. This was highlighted in the study of Amri and Saoud (2014); Raisian et al. (2017). The working collaboration needed the confidence and trustiness between organization and supplier. If staff in the organization had negative thinking that supplier was hazardous to their job (González et al., 2016) , this would incur risks in the working collaboration which was negatively impacted the success ITO. Moreover, suppliers' staff welfare should be considered, the good welfare might impact staff turnover reduction along with morale (Fan et al., 2012; González et al., 2016). It directly involved the social sustainability for ITO.

Finally, the outcomes from statistic analysis identified 19 criteria and 7 risk factors that had relationships on three sustainability dimensions. These evaluation criteria and risk factors were related to the inner and outer dimensions as shown in Figure 4.5

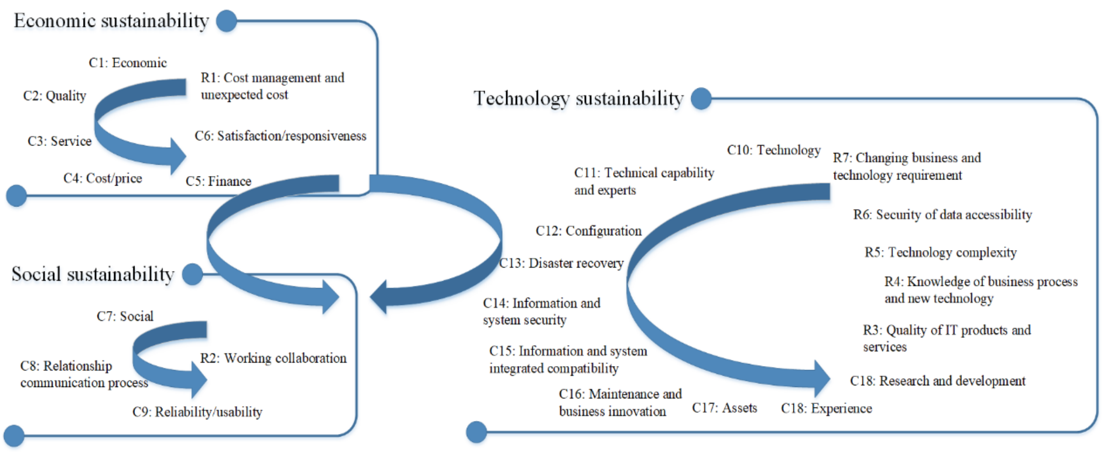

Figure 4.5

The relationships of evaluation criteria and risk factors

Furthermore, the linking represented the relationship either internal or external. An internal linkage represented the relationship within each sustainability dimension for example, technology, criteria(C_{10}) related to the technical capability and expert(C_{11}), configuration(C_{12}) and information and system integration compatibility(C_{15}). On top of this, the evaluation criteria in technology sustainability also had an external relationship to economic sustainability such as quality(C_2) related to the assets(C_{17}) criteria. The external linkage presented with circle in solid lines.

- **The prioritized evaluation criteria and risk factors**

The evaluation criteria and risk factors were obtained from the statistical analysis (see Figure 4.5). It was adopted to the supplier selection problem for sustainable ITO, especially Thai organizations. In addition, these evaluation criteria and risk factors had a different priority in the supplier assessment. Table 4.22 shows the priority of evaluation criteria and risk factors. The priority was determined by using the mean score ($\bar{x}$) value from Table 4.16 and Table 4.17 respectively. Each priority had become the guideline to allocate the weight values in the supplier selection problems.

Table 4.22

The prioritization of evaluation criteria and risk factors

Sustainability	IDs	evaluation criteria and risk factors	$\bar{x}$	priority
Evaluation criteria and risk factors of economic sustainability	C1	Economic	6.63	24
	C2	Quality	8.49	1
	C3	Service	8.40	2
	C4	Cost / Price	8.03	8
	C5	Finance	7.29	17
	C6	Satisfaction / Responsiveness	8.09	5
	R1	Cost management and unexpected cost	7.37	15
Evaluation criteria and risk factors of social sustainability	C7	Social	5.40	25
	C8	Relationship / communication process	6.71	23
	C9	Reliability / Usability	7.94	9
	R2	Working collaboration	7.17	19
Evaluation criteria and risk factors of technology sustainability	C10	Technology	7.63	14
	C11	Technical capability and experts	8.11	4
	C12	Configuration	7.71	12
	C13	Disaster recovery	7.77	11
	C14	Information and system security	8.20	3
	C15	Information and system integrated compatibility	7.69	13
	C16	Maintenance and business innovation	7.31	16
	C17	Facility / asset	7.14	21
	C18	Experience	7.80	10
	C19	Research and development	6.80	22
	R3	Quality of IT products and services	8.09	5

Sustainability	IDs	evaluation criteria and risk factors	$\bar{x}$	priority
	R4	Knowledge of business process and new technology	7.29	17
	R5	Technology complexity	7.23	18
	R6	Security of data accessibility	8.06	7
	R7	Changing business and technical requirement	7.17	19

Based on Table 4.22, there were five (5) criteria and two (2) risk factors obtained the high priority. Therefore, all of them should obtain a high important weight being used in the supplier selection model whereby quality and service criteria had important weight as first and second respectively. Similarly, the studies of Chang et al. (2012); Faisal and Raza (2016) pointed to the quality and service criteria which was significant in supplier selection of ITO. This was also highlighted that both evaluation criteria related to the economic sustainability.

There were also two criteria (information and system security, and technical capability and experts) and two risk factors (quality of IT products and services and security of data accessibility) that obtained high priority influence technology sustainability. This reflected the high capability of a supplier to develop and maintain IT system. However, the respondents also paid attention to two risk factors to prevent the undesirable outcome from a supplier in terms of quality of IT product and service as well as security of data accessibility because the undesirable outcomes may arise as a serious threat to the ITO (Samantra et al., 2014) which might impact the technology sustainability. Therefore, the criteria and risk factors should obtain a high weight value to the supplier assessment.

Surprisingly, most respondents somewhat neglected the evaluation criteria that influenced social sustainability (refer to Table 4.22). This was opposed in the study of

Azimifard et al. (2018) who considered the criteria in social be important for a sustainable supplier selection problem. They highlighted to the supplier’s staff welfare and morale for sustainable supplier. Besides that, Amri and Saoud (2014); Raisian et al. (2017) stated that social sustainability involved the effective working collaboration to the software system improvement. This reflected to the supplier's capability in the working collaboration with the organization to lead sustainable ITO.

4.6 Summary

This chapter describes the instrument design, sampling, pilot study, data collection, and analysis performed in the exploratory study. The study aimed to investigate the current practices of the supplier selection process. The current practice conducted tangible and intangible criteria relevant to sustainable ITO. The finding revealed the supplier selection problem in Thai organizations used the primitive methods (i.e. committee suggestion, familiarity with a supplier, and low price bidding) to the final decision in the supplier selection. In addition, the evaluation criteria and risk factors associated and influenced the three sustainability perspectives were revealed. On top of that, the relationship of the evaluation criteria and risk factors had been investigated along with identifying its priority. Accordingly, these findings determined 19 evaluation criteria and 7 risk factors along with the relationship construction among them to adopt in the supplier selection model. Existing supplier selection models relied on human involvement to allocate the weight values. Consequently, Enhanced Supplier Selection (ESS) model was proposed. The proposed model allocated the weight values without human involvement under the interrelationship of criteria in this chapter. More details of the ESS model construction will be discussed in the next chapter.

CHAPTER FIVE

ENHANCED SUPPLIER SELECTION MODEL DEVELOPMENT

5.1 Introduction

Based on the theoretical studies, it is noted that the limitations of supplier selection model for IT outsourcing (ITO) includes inconsistent use of evaluation criteria. Furthermore, existing studies have not considered risk factors which contribute to the sustainability of ITO. On top of that, the use of Multi-Criteria Decision-Making (MCDM) in supplier selection is subjective to human (i.e. expert) judgment. Different evaluation made by the experts may lead to a different outcome. In this chapter, the solution for the shortcomings are presented as an enhanced supplier selection model (ESS) where it contains the identified evaluation criteria and a new MCDM method, known as Analytic Network Process (ANP) and Firefly Algorithm (FA) termed as ANP-FA.

The chapter starts by the overview of the ESS model in Section 5.2. The preliminary study is described on the experiment in Section 5.3. The following Section 5.4 explains the construction of weight determination method in details. Section 5.5 provides the discussion related to the ESS model development and Section 5.6 ends the chapter with a summary.

5.2 Overview of Enhanced Supplier Selection Model

The aim of the proposed ESS model is to evaluate ITO projects without relying on human judgment. Furthermore, the deployed evaluation criteria includes risk factors that are important to sustain ITO. Thus, ESS model (as in Figure 5.1) adapts supplier selection framework from De Boer et al. (2001); Fallahpour et al. (2017); Kilic et al. (2015); Rabbani et al. (2017) and quip it with an optimized inconsistency of Pairwise

Comparison Matrix (PCM), in accordance with Girsang et al. (2015). The ANP method is deployed to allocate relevant weight values to represent relationships between evaluation criteria.

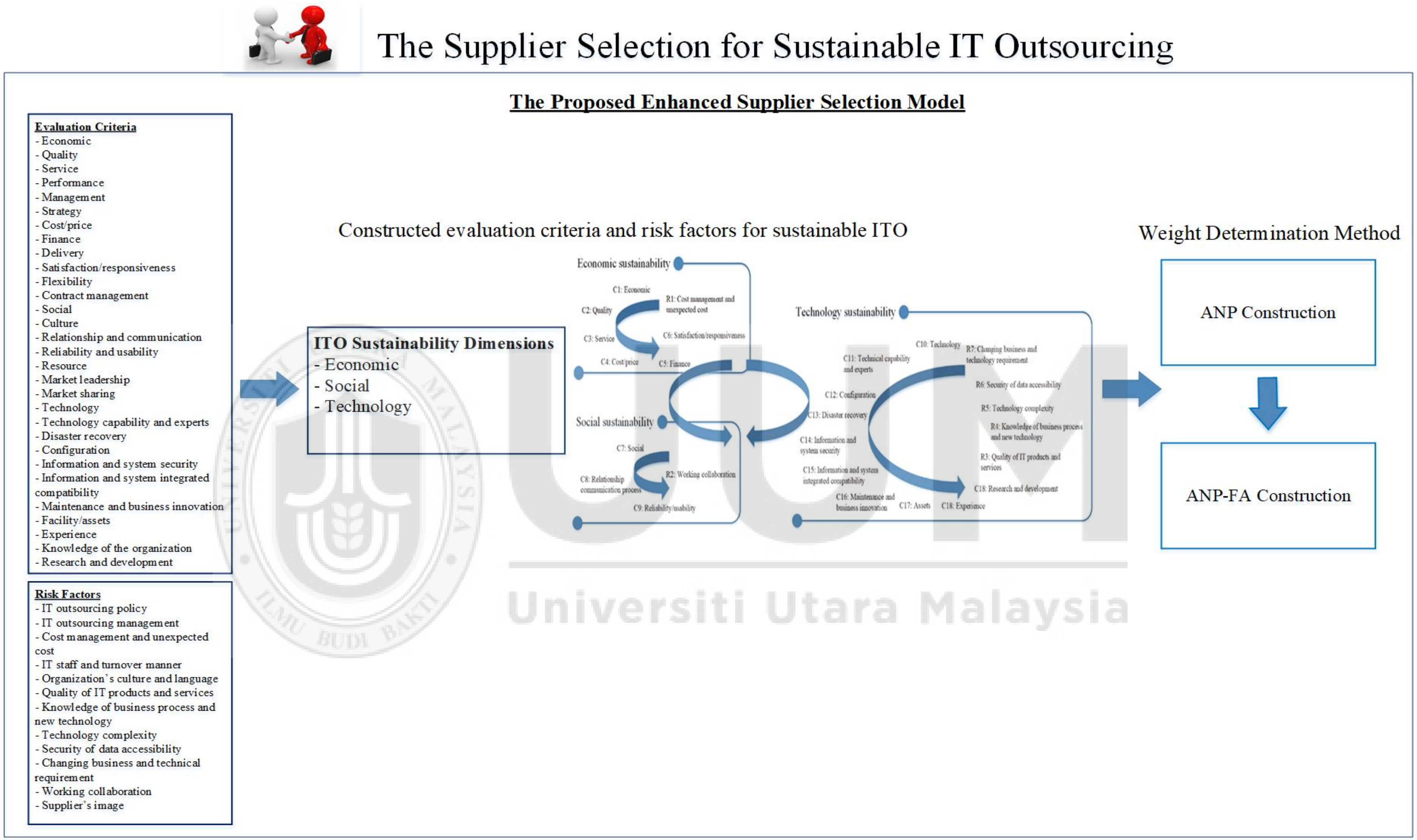

Figure 5.1

The proposed ESS model

ESS model is adapted from the supplier selection model where it includes the criteria and risk factors. Nevertheless, existing supplier selection models have not mapped the criteria and factors onto sustainable dimensions for ITO. Existing supplier selection models have identified the criteria relevant to sustainability that includes economic, social and environmental (Fallahpour et al., 2017; Luthra et al., 2017; Rao, Goh, et al., 2017). However, it does not include the technology sustainability to sustain ITO. Technology is an important part of IT system both experts' technical knowledge and IT infrastructure (i.e. computer, server and network equipment). Existing studies in ITO have identified criteria relevant to the technical capability (Ebrahimnejad et al., 2017; Mukherjee & Mukherjee, 2015; Nazari-Shirkouhi et al., 2017; Thakur & Anbanandam, 2015). These criteria do not state to sustain the environment. Thus, the study identified the criteria relevant to three dimensions as economic, social, and technology. Nevertheless, Marnewick (2017) addressed that the concept of green IT should be included in the IT infrastructure to reduce greenhouse gas emissions and harmful materials as well as to sustain its performance efficiency. This is why environmental sustainability has been implicitly mentioned in the technology dimension. For these reasons, the relationship between criteria is only relevant to three sustainability dimensions including economic, social and technology. This study called the relationship as ANP structure.

ANP-FA construction is not only adapted from the ANP methods, but it is also relevant to the other studies as Ahmad et al. (2014); Girsang et al. (2015); Lin, Kou, and Ergu (2014). ANP-FA eliminates the human involvement to allocate the optimized weight value on the ANP structure. The method significantly reflects to the human prejudices reduction. In order to ensure that ESS model is valid, this study has adopted a case study to evaluate the model. A details explanation will be described in Chapter 6.

5.3 Preliminary Study

The ANP method is appropriate to adopt in the real-world decision-making problem, especially weight allocation (Gölcük & Baykasoğlu, 2016). Existing studies of ANP integrated with other approaches have proven to overcome the uncertainty and vagueness of human preference (Özdemir & Tüysüz, 2017; Uygun et al., 2015). Hence, this study deploys FA instead of human to adjust the judgment value in PCM. The undertaken experimental approach is shown in Figure 5.2.

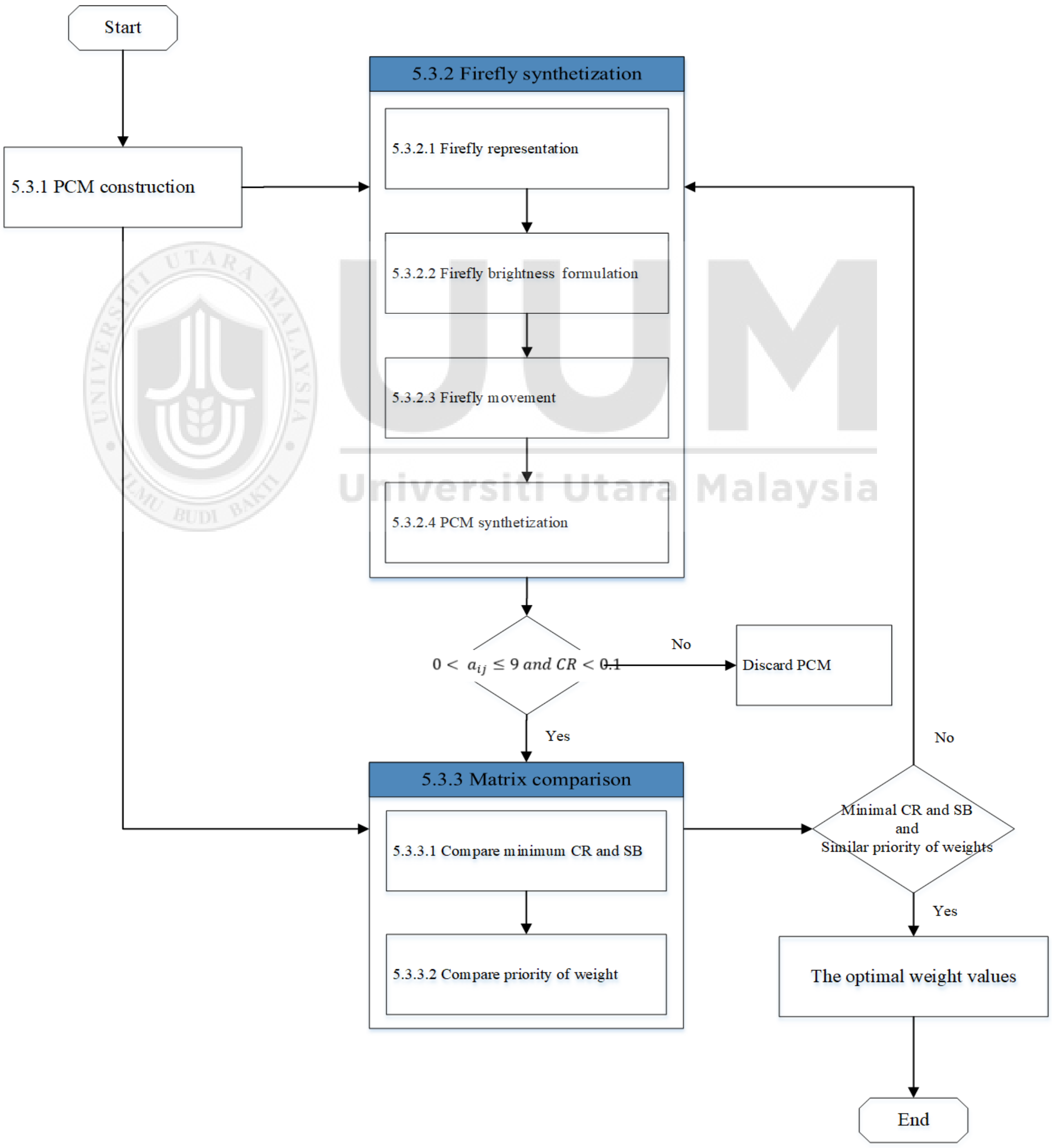

Figure 5.2

Flowchart of ANP-FA

There are three main steps required in deploying FA eliminating human involvement in ANP. PCM construction, firefly synthetization and matrix comparison. Detials for each of the step is discussed in the upcoming subsections.

5.3.1 Pairwise comparison matrix construction

PCM is an important component of an ANP as it synthesizes the criteria weight values to represent relationship among criteria (Saaty, 2004). Thus, it indicates the relationship of one criterion to another (i.e. target/evaluation criteria/alternative) (Saaty, 1980). PCM is organized in the square matrix whereby the compared criteria are sorted vertically in the first column; and horizontally in the first row of the matrix, as depicted in Table 5.1. The evaluation criteria can be represented the $(C_i \dots C_n)$. The relative importance of each C_i in the column compares to the C_j in the row, represented by judgment value $\left(a_{ij}\right)$ as followed the Saaty's rules. Where $a_{ji} = \frac{1}{a_{ij}}$ when $i \neq j$, and $a_{ij} = 1$ when $i = j$.

Table 5.1

PCM structure

Criteria	$\boldsymbol{C_{i+1}}$	$\boldsymbol{C_2}$	**…**	**…**	$\boldsymbol{C_n}$
$\boldsymbol{C_{j+1}}$	1	a_{12}	.	.	a_{1n}
$\boldsymbol{C_2}$	a_{21}	1	.	.	a_{2n}
.	.	.	1	.	.
$\boldsymbol{C_{n-1}}$	$a_{(n-1)1}$	.	.	1	$a_{(n-1)n}$
$\boldsymbol{C_n}$	a_{n1}	a_{n2}	.	.	1

This study collected PCMs from the review of the literature Bu and Xu (2009); Nazari-Shirkouhi et al. (2017); Yang and Huang (2000) as shown in Table 5.2. PCMs consisted of the same criteria namely management(C_1), strategy(C_2), economic(C_3), technology(C_4) and quality(C_5). In addition, the PCMs also included its judgment values. The priority of weight was also identified to be a guideline of FA to sustain human knowledge and opinion for the weight allocation.

Table 5.2

PCM collection

Authors	Criteria	C1	C2	C3	C4	C5	CR	Weight	Priority
Yang and Huang (2000)	C1	1	1	4	5	3		0.364	1
	C2	1	1	2	6	3		0.328	2
	C3	1/4	1/2	1	3	1	0.015	0.134	3
	C4	1/5	1/6	1/3	1	1/2		0.057	5
	C5	1/3	1/3	1	2	1		0.117	4
Bu and Xu (2009)	C1	1	1/3	1/5	5	3		0.134	3
	C2	3	1	1/3	7	5		0.260	2
	C3	5	3	1	9	7	0.053	0.503	1
	C4	1/5	1/7	1/9	1	1/3		0.035	5
	C5	1/3	1/5	1/7	3	1		0.068	4
Nazari-Shirkouhi et al. (2017)	C1	1	2	5	6	3		0.408	1
	C2	1/2	1	5	4	4		0.306	2
	C3	1/5	1/5	1	3	1/4	0.094	0.085	4
	C4	1/6	1/4	1/3	1	1/2		0.057	5
	C5	1/3	1/4	4	2	1		0.144	3

5.3.2 Firefly synthetization

The second step was to determine the optimized weight values from the feasibility space. The PCM was represented with a firefly instead of a human to adjust the judgment values. The firefly's behaviors have become an important part of modifying the judgment value. There were four steps to perform; firefly representation, firefly brightness formulation, firefly movement and PCM synthetization. Detailed explanations of each step are presented in sections 5.3.2.1, 5.3.2.2, 5.3.2.3 and 5.3.2.4.

5.3.2.1 Firefly representation

Generally, the procurement committee in an organization comprised of a group of decision-makers who have diverse knowledge, in accordance with studies of Banaeian et al. (2018); Nazari-Shirkouhi et al. (2017); Secundo et al. (2017). Therefore, the decision-maker can synthesize the criteria based on his/her knowledge and experience. Hence, it resulted multiple PCM to the weight allocation. Thus, in this study, a firefly (refer to decision-maker) represented PCM when the consistency ratio (CR) did not exceed 0.1 as mentioned in study of Saaty (2013). Table 5.3 denotes the relevant fireflies representing the PCM as reported in the relevant studies.

Table 5.3

Firefly that represented PCM

Authors	Yang and Huang (2000)					Bu and Xu (2009)					Nazari-Shirkouhi et al. (2017)				
Firefly	**FF1**					**FF2**					**FF3**				
Criteria	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
C1	1	1	4	5	3	1	1/3	1/5	5	3	1	2	5	6	3
C2	1	1	2	6	3	3	1	1/3	7	5	1/2	1	5	4	4
C3	1/4	1/2	1	3	1	5	3	1	9	7	1/5	1/5	1	3	1/4
C4	1/5	1/6	1/3	1	1/2	1/5	1/7	1/9	1	1/3	1/6	1/4	1/3	1	1/2
C5	1/3	1/3	1	2	1	1/3	1/5	1/7	3	1	1/3	1/4	4	2	1

5.3.2.2 Firefly brightness formulation

Biologically, each firefly has its brightness (I) to attract another firefly. In this study, the firefly brightness was relevant to the CR value where a perfect PCM consistency occurred when CR was close/equal to zero. In other words, the firefly brightness was computed with a reciprocal of CR value, in which, the value was called to be objective function as shown in Equation 5.1.

$$Objective\ function\ (I_i) = \frac{1}{CR} \tag{5.1}$$

Where:

I_i = Brightness intensity of a firefly

CR = Consistency Ratio

The brightness of fireflies included in Table 5.3 are then calculated base on Equation 5.1. The outcomes are as shown in Table 5.4.

Table 5.4

Firefly's brightness intensity

Authors	Firefly (PCM)	CR	Firefly brightness
Yang and Huang (2000)	FF1	0.015	66.667
Bu and Xu (2009)	FF2	0.053	18.868
Nazari-Shirkouhi et al. (2017)	FF3	0.094	10.638

5.3.2.3 Firefly movement

Whether a firefly should move or not depends on the brightness. A brighter firefly will attract the ones which are less bright. When the position of a firefly changes, so does the PCM judgment value. The new judgment values were determined using Equation 5.2.

$$a_{ij}^{f1'} = a_{ij}^{f1} + \beta_0 e^{-\gamma r^2_{a_{ij}^{f1}, a_{ij}^{f2}}} \left(a_{ij}^{f2} - a_{ij}^{f1}\right) + \alpha(rand - 1) \tag{5.2}$$

Where:

$a_{ij}^{f1'}$ = new judgment value of firefly $(f1)$

a_{ij}^{f1} = current judgment value of firefly $(f1)$

a_{ij}^{f2} = current judgment value of firefly $(f2)$

β_0 = current brightness value

γ = Light absorption coefficient

$r_{a_{ij}^{f1}, a_{ij}^{f2}}$ = Distance between two-fireflies

α = Randomization parameter

$rand$ = Random number uniformly distributed [0, 1].

Equation 5.2 can be divided into three parts separated by the plus sign's notation. The first part was the current position of a firefly $(f1)$ referring to the judgment values. The second part showed that the firefly $(f1)$ moved toward the strong brightness at a distance. The last part represented the firefly $(f1)$ move randomly. Figure 5.3 shows the flow of firefly's movement. Two processes are further described in this study: 1) attraction movement, and 2) random movement.

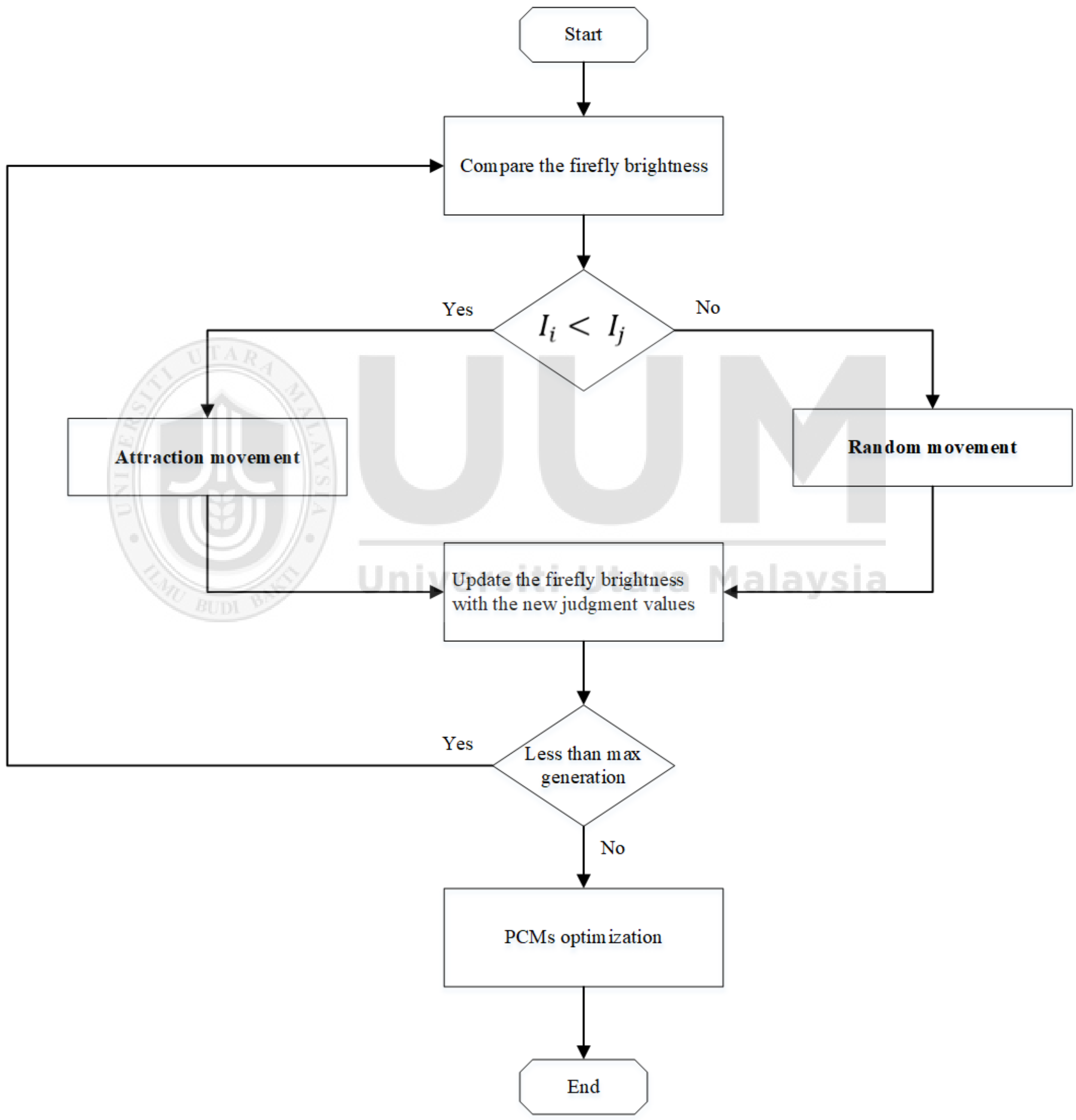

Figure 5.3

Flow of the firefly movement

- Attraction movement

A firefly moves towards the one with a stronger brightness. The result of a firefly movement is the change in judgment values in PCM. This study proposed an algorithm to compute the new judgment value based on the brightness attraction as shown in Figure 5.4. The algorithm consisted of three steps; 1) compute the light absorption coefficient, 2) compute the distance in-between pair fireflies' comparison, and 3) compute the new judgment values.

Step 1. Defined the dimension (n) of PCM
Step 2. Defined the weight (ω) values from Section 5.3.5.2
Step 3. Calculated the gramma parameter
    For i in range(0, n)
        For j in range(0, n)
            If i < j:

$$\delta_{ij} = a_{ij}\left(\frac{\omega_j}{\omega_i}\right) - 1$$

$$\gamma = \gamma + absoulute(\delta_{ij})$$

        End For:
    End For:
Step 4. Calculate the distance (r) of two weight vectors

$$r = \frac{\sum_{i=0}^{n} \omega_i^{f1}\, \omega_i^{f2}}{\sqrt{\sum_{i=0}^{n} \omega_i^{f1}}\, \sqrt{\sum_{i=0}^{n} \omega_i^{f2}}}$$

Step 5. Calculate the new position of a firefly
    For i in range(0, n)
        For j in range(0, n)
            If i < j:
                Step 5.1 Calculate the new judgment value (a_{ij})

$$a_{ij}^{f1'} = a_{ij}^{f1} + \beta_0 e^{-\gamma r^2}\left(a_{ij}^{f2} - a_{ij}^{f1}\right)$$

                Step 5.2 Assigned (a_{ij}) and (a_{ji}) = ($1/a_{ij}$) in PCM
        End For:
    End For:

Figure 5.4

Pseudocode of firefly attraction movement

Furthermore, the bias (δ) value was obviously assembled in each judgment value as mentioned in Equation 2.2. The bias value incurred the inconsistency in PCM and reflected the human prejudices. If bias value was close/equal to zero then PCM became the perfect consistency and without human prejudices. In other words, the Sum of Bias (SB) value was close/equal to zero as well. Therefore, the study adopted the SB value as a light absorption coefficient(γ) as shown in step 3. In addition, the distance(r) value was computed from the Cosine Similarity (CS) method. The method could measure the distance between two fireflies with the weight vector in step 4. At the end, the algorithm computed the new judgment value with two values: attractiveness and distance value. Then the firefly's brightness updated from Equation 5.1. For example, FF2 had brightness less than FF1 (see Table 5.4), then FF2 moving toward the FF1. Next, the judgment values in FF2 were modified along with updated the brightness of FF2. The outcomes are presented in Table 5.5.

Table 5.5

Judgment values based on firefly attractiveness

Position	judgment values	β_0	$\gamma = \sum\lvert\delta_{ij}\rvert$; i < j	r^2	outcomes
a_{12}	1/3				3.494
a_{13}	1/5				18.215
a_{14}	5				5.000
a_{15}	3				3.000
a_{21}	3				0.286
a_{23}	1/3				8.235
a_{24}	7	4.741	2.921	0.473	2.259
a_{25}	5				0.223
a_{31}	5				0.055
a_{32}	3				0.121
a_{34}	9				0.051
a_{35}	7				0.047
a_{41}	1/5				0.200
a_{42}	1/7				0.443

Position	judgment values	β_0	$\gamma = \sum\lvert\delta_{ij}\rvert$; i < j	r^2	outcomes
a_{43}	1/9				19.445
a_{45}	1/3				1.123
a_{51}	1/3				0.333
a_{52}	1/5				4.482
a_{53}	1/7				21.445
a_{54}	3				0.890

- Random movement

A firefly moves randomly when it has strong brightness compared to other firefly. In this case, the study proposes an algorithm to support the firefly movement as shown in Figure 5.5. The bias value was adopted in the randomization parameter (α) to modify the judgment values when a firefly moves randomly.

Step 1. Defined the dimension (*n*) of PCM
Step 2. Defined the weight (ω) values from Section 5.3.5.2
Step 3. Defined the *Rand* value in uniformly distributed [0, 1] by random
Step 4. Calculate the new position of a firefly
For i in range(0, *n*):
For j in range(0, *n*):
If i < j:
Step 4.1 Randomization parameter (α)

$$\alpha = \delta_{ij} = a_{ij} * \left(\frac{\omega_j}{\omega_i}\right) - 1$$

Step 4.2 Calculated new judgement value (a_{ij})

$$a_{ij}^{f1'} = a_{ij}^{f1} + \alpha(rand - 1)$$

Step 4.3 Assigned (a_{ij}) and (a_{ji}) by 1/(a_{ij}) in PCM
End For:
End For:

Figure 5.5

Pseudocode of firefly random movement

For example, the brightness of FF1 (66.667) was compared with the brightness of FF3 (10.638). FF1 was brighter than FF3 so the FF1 moved randomly. The result in Table 5.6 shows the new judgment value from the movement of firefly.

Table 5.6

Judgment values based on firefly random movement

Position	judgment values	randomization parameter (α) $\alpha = \delta_{ij} = a_{ij} * \left(\frac{\omega_j}{\omega_i}\right) - 1$	$rand$ $[0, 1]$	outcomes
a_{12}	1	0.100	0.196	0.920
a_{13}	4	0.474		3.619
a_{14}	5	0.217		4.826
a_{15}	3	0.034		2.973
a_{21}	1	0.110		1.087
a_{23}	2	0.181		1.854
a_{24}	6	0.044		5.965
a_{25}	3	0.073		2.941
a_{31}	1/4	0.322		0.276
a_{32}	1/2	0.222		0.539
a_{34}	3	0.275		2.779
a_{35}	1	0.126		0.899
a_{41}	1/5	0.277		0.207
a_{42}	1/6	0.042		0.168
a_{43}	1/3	0.216		0.360
a_{45}	1/2	0.028		0.477
a_{51}	1/3	0.035		0.336
a_{52}	1/3	0.068		0.340
a_{53}	1	0.144		1.113
a_{54}	2	0.027		2.095

The outcomes of the firefly movement is shown in Table 5.7. However, to ensure that the outcomes were consistent; they needed to be verified following to Saaty's rule

(Saaty, 2013). In addition, the outcomes should be similar to the ones produced by human where the weight priority should be the same. These verifications are further explained in the next section.

Table 5.7

Outcome of firefly movement

		Original PCM							Optimizing PCM					
Authors		Criteria	C1	C2	C3	C4	C5		Criteria	C1	C2	C3	C4	C5
Yang and Huang (2000)	FF1	C1	1	1	4	5	3	OFF1	C1	1.000	1.065	1.252	8.839	2.271
		C2	1	1	2	6	3		C2	0.939	1.000	1.167	6.854	3.017
		C3	1/4	1/2	1	3	1		C3	0.799	0.857	1.000	6.411	2.544
		C4	1/5	1/6	1/3	1	1/2		C4	0.113	0.146	0.156	1.000	0.362
		C5	1/3	1/3	1	2	1		C5	0.440	0.331	0.393	2.764	1.000
Bu and Xu (2009)	FF2	C1	1	1/3	1/5	5	3	OFF2	C1	1.000	7.279	0.672	2.764	10.54
		C2	3	1	1/3	7	5		C2	0.137	1.000	1.587	2.003	1.307
		C3	5	3	1	9	7		C3	1.487	0.630	1.000	1.642	0.111
		C4	1/5	1/7	1/9	1	1/3		C4	0.362	0.499	0.609	1.000	4.030
		C5	1/3	1/5	1/7	3	1		C5	0.095	0.765	8.987	0.248	1.000
Nazari-Shirkouhi et al. (2017)	FF3	C1	1	2	5	6	3	OFF3	C1	1.000	1.632	2.210	29.48	9.566
		C2	1/2	1	5	4	4		C2	0.613	1.000	1.173	21.95	13.14
		C3	1/5	1/5	1	3	1/4		C3	0.453	0.853	1.000	16.87	9.002
		C4	1/6	1/4	1/3	1	1/2		C4	0.034	0.046	0.059	1.000	0.446
		C5	1/3	1/4	4	2	1		C5	0.105	0.076	0.111	2.245	1.000

5.3.2.4 Pairwise comparison matrix synthetization

In PCM synthetization, there were four values to be verified: judgment, CR, bias, and weight. These values indicated PCM consistency, elimination of human involvement and criteria prioritization by weight values. Detailed explanation of the four values are discussed subsequently.

- Judgment value

The judgment value should be in the range $(0, 9)$ as referenced in the study of Saaty (2013). The study developed method to analyze the judgment values as shown in Figure 5.6.

```
Step 1. Outcome from Section 5.3.4 is defined
        PCM = {PCM1, PCM2, PCM3, … PCMx}
        For k in range(0, x)
Step 2.   Defined the dimension (n) of PCM at k
Step 3. Investigate the judgment value (a)
          For i in range(0, n)
            For j in range(0, n)
                PCM is eliminate when have only one
                judgement value at (i, j) less than or equal
                zero or more than nine
            End For:
          End For:
        End For:
```

Figure 5.6

Pseudocode of judgment value analysis

Based on data in optimizing PCM (see in Table 5.7), it was learned that only OFF1 is accepted for further analysis (see in Table 5.8). This was because all of the judgment value did not exceed 9, and there was not any with less than or equal zero. On the contrary, OFF2 and OFF3 were eliminated due to some judgment values exceeding 9.

Table 5.8

PCM acceptance

OFF1					
Criteria	C1	C2	C3	C4	C5
C1	1.000	1.065	1.252	8.839	2.271
C2	0.939	1.000	1.167	6.854	3.017
C3	0.799	0.857	1.000	6.411	2.544
C4	0.113	0.146	0.156	1.000	0.362
C5	0.440	0.331	0.393	2.764	1.000

- Weight synthetization

The weight values were synthesized using the Additive Normalization (AN) method (Saaty, 1999). In order to deploy the AN in the study, a method was designed as denoted in Figure 5.7.

Step 1. Defined the dimension (n) of PCM
Step 2. Column normalization
    For i in range(0, n)
        sum = 0
        For j in range(0, n)
            Step 2.1 Sum judgment value in each column

$$sum = sum + a_{ij}$$

        End For:
        For j in range(0, n)
            Step 2.2 Normalized in each judgment value in each column

$$a'_{ij} = \frac{a_{ij}}{sum}$$

        End For:
    End For :
Step 3. Row normalization in order to determine the weight
    For i in range(0, n)
        sum = 0
        For j in range(0, n)
            Step 3.1 Sum normalized value in each column same as row

$$sum = sum + a'_{ij}$$

        End For:
            Step 3.2 Calculated weight in each row

$$\omega_i = \frac{sum}{n}$$

    End For:

Figure 5.7

Pseudocode of weight calculation

The implementation of the pseudocode was via column and row normalization. Each judgment value was divided with the sum of judgment in its column as known as column normalization. Whilst row normalization was the sum of judgment value in each row divided with number of criteria. The outcome in this algorithm was weight values. Therefore, the algorithm synthesized OFF1 to the weight allocation as shown in Table 5.9.

Table 5.9

Weight allocation

			OFF1			
Criteria	C1	C2	C3	C4	C5	weight
C1	1.000	1.065	1.252	8.839	2.271	**0.304**
C2	0.939	1.000	1.167	6.854	3.017	**0.293**

OFF1						
Criteria	C1	C2	C3	C4	C5	weight
C3	0.799	0.857	1.000	6.411	2.544	**0.254**
C4	0.113	0.146	0.156	1.000	0.362	**0.039**
C5	0.440	0.331	0.393	2.764	1.000	**0.109**

- Consistency synthetization

CR value was a crucial part in indicating PCM consistency before adopting weight values in the super matrix. The CR value incurred the bias acceptance in PCM which CR value should not exceed 0.1 as suggested by Saaty (2013). Hence, to compute the CR value, the following method was designed as shown in Figure 5.8.

```
Step 1. Determine the PCM
Step 2. Define the PCM dimension (n)
Step 3. Calculate the maximum eigenvalue
        Get eigen value by using linalg.eigvalus function
        Set maxeigvalue variable is equal to zero
        For each in eigvalues:
            If each.imag == 0:
                If each.real >= max:
                    Set maxeigvalue = each.real

Step 4. Calculated the consistency ratio (CR)
        Set RI value related to PCM dimension (n)
```

$$CR = \frac{maxeigvalue - n}{RI(n-1)}$$

Figure 5.8

Pseudocode of consistency synthesis

In order to verify the consistency, the algorithm synthesized the OFF1. The outcome highlighted that OFF1 was consistent because the CR value was equal to 0.004, whilst maximum eigenvalue (λ_{max}) is 5.018. Noticeable λ_{max} close to the number of criteria. This also indicated that the FA could reduce inconsistency in PCM.

- Bias synthetization

Generally, the bias value was assembled in the judgment value. This incured human prejudices to the decision-making as addressed in the study of Saaty (2013). Therefore, if the bias value was close to zero then the judgment value was without the human prejudices by referring to Equation 2.2. Hence, PCM could be without human prejudices when all bias values were close to zero. Figure 5.9 has shown the algorithm to compute the SB value.

Step 1. Defined the dimension (n) of PCM
Step 2. Defined the weight (ω) values from Section 5.3.5.2
Step 3. Calculate the sum bias value
sum = 0
For i in range(0, n)
For j in range(0, n)
If i < j
Step 3.1 Calculate the bias value in each judgment value

$$\delta_{ij} = a_{ij}\frac{\omega_j}{\omega_i} - 1$$

Step 3.2 Calculate the sum bias

$$sum = sum + absolute(\delta_{ij})$$

End For:
End For:

Figure 5.9

Pseudocode of bias calculation

OFF1 (see Table 5.8) computed the bias values and SB value. The result of bias value could be seen in Table 5.10.

Table 5.10

The bias values

	OFF1				
Criteria	C1	C2	C3	C4	C5
C1	0.000	0.027	0.046	0.131	0.185
C2	0.026	0.000	0.012	0.090	0.123
C3	0.044	0.011	0.000	0.019	0.092
C4	0.116	0.099	0.019	0.000	0.015

OFF1					
Criteria	C1	C2	C3	C4	C5
C5	0.227	0.110	0.085	0.015	0.000

Noticeably, bias values were in the upper and the lower triangle close to zero. In addition, SB value was close to each other, which accounted for 0.740 (upper triangle) and 0.752 (lower triangle) respectively. This reflected the increasing PCM consistency along with the prejudices reduction.

5.3.3 Matrix Comparison

The comparative approach has become an important part of verifying the optimal PCM (optimizing weight values) because the outcomes from firefly synthetization phase had a possibility that might have more than one optimal PCMs. The optimizing PCM should be selected considering two conditions: it had a minimum CR and SB values, and the priority of weight were similar to the PCM in firefly representation phase. Figure 5.10 illustrates the process of matrix comparison to determine the optimized weight values. There were two steps required, and they are discussed subsequently.

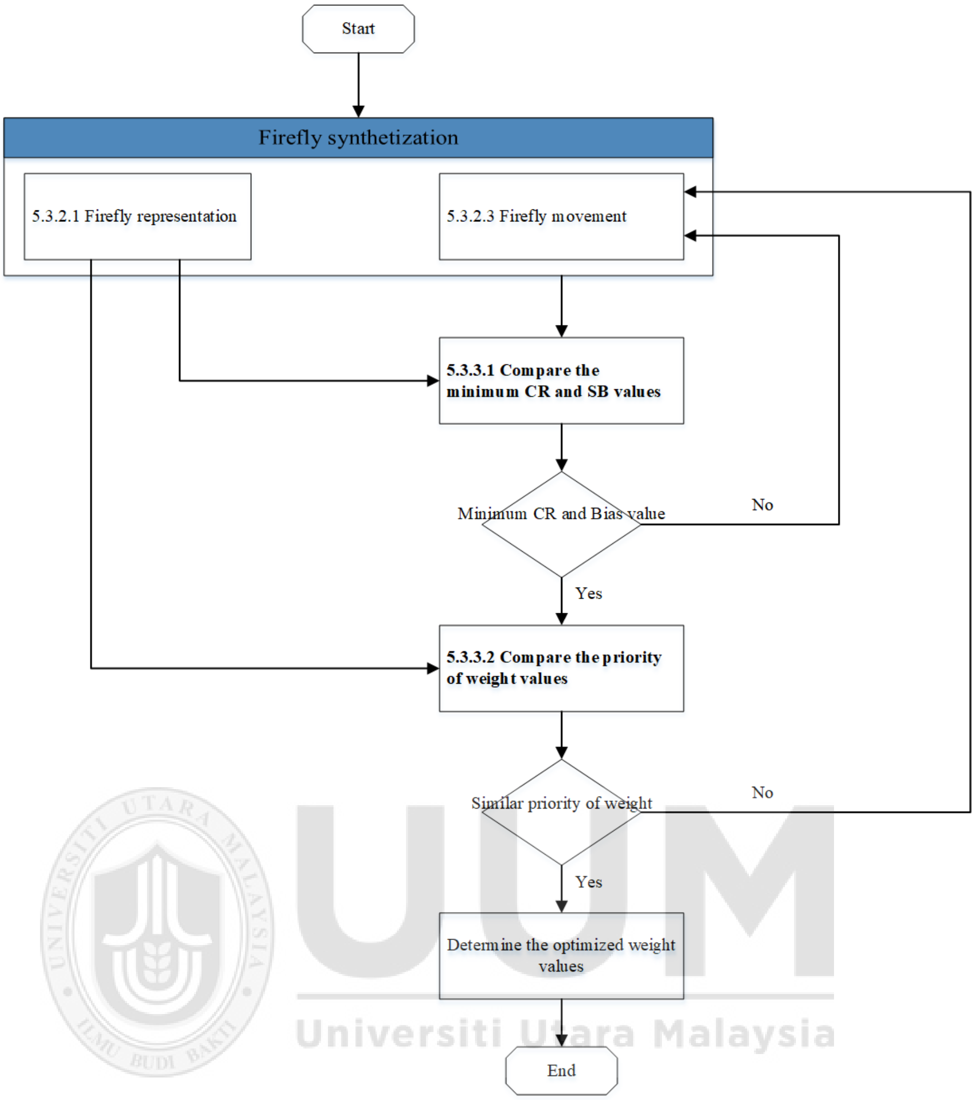

Figure 5.10

Flow chart of matrix comparison

5.3.3.1 Comparison of the minimum consistency ratio and sum of bias values

Both CR and SB values from the outcome of firefly synthetization needed to be analyzed. The optimized PCM was selected when the CR and SB values were at minimum stage when compared to the literature. This study developed the algorithm to compare the minimum CR and SB values as shown in Figure 5.11.

```
Step 1. Gathered PCMs from referenced literature
        Original PCM[x] = {PCM1, PCM2, …, PCMx}
Step 2. Outcomes from Section 5.3.4
        Optimal PCM[y] = {PCM1, PCM2, …, PCMy}
Step 3. PCMs Ranking that have minimal SBV and CR
        Step 3.1 Rank the SBV and CR by ascending of original
                 PCM
        Step 3.2 Rank the SBV and CR by ascending of optimal
                 PCM
Step 4. Compare the minimal sum of BV and CR value
        Step 4.1 Selected top one of the original PCM and optimal PCM
        Step 4.2 If SBV of optimal PCM < SBV of original PCM
                 and CR of optimal PCM < CR of original PCM:
                     A PCM is selected
                 else:
                     Go to the searching process
```

Figure 5.11

Pseudocode of CR and SB values comparison

In this case, the outcome of the firefly synthetization had only one PCM (OFF1). This was because OFF1 obtained the minimum for both the CR and the SB values when compared with PCM reported in the literature. It was obvious that SB value (0.740) of OFF1 was less than FF1 by nearly half, while CR of OFF1 was less than FF1 approximately 0.01. Hence, it demonstrated that FA eliminated human prejudice in the PCM.

5.3.3.2 Comparison of the priority of weight values

The priority of weight values could indicate to the human knowledge. According to Ahmad et al. (2014), the criteria prioritization lead to the weight allocation through the judgment value assignment. Thus, the study adopted the comparative approach to verify the priority of weight values of firefly synthetization outcome. Figure 5.12 shows the algorithm to the verification of similar priority of weight values.

```
Step 1. PCM outcome from Section 5.3.2 and 5.3.5.2
Step 2. PCM outcome from Section 5.3.4 and 5.3.6.1

Step 3. Determined the number of criteria ( n )
Step 4. Ranked weights of Step 1 and Step 2 by the descending
Step 5. Compared the priority similarity
        For i in range(0, n)
            If priority weight of optimal PCM( i )  != priority weight of
original PCM( i ):
                  Go to searching process
        End For:
Step 6. Determined the optimal weights
```

Figure 5.12

Pseudocode of weight priority comparison

The outcome from the algorithm is presented in Table 5.11. The priority of weight values (OFF1) had a similarity with the FF1. This could implicit that FA could allocate the optimized weight values without human involvement but also sustain human knowledge.

Table 5.11

The outcome of weight priority comparison

Criteria	FF1		OFF1	
	weight values	priority	weight values	priority
C1	0.364	1	0.304	1
C2	0.328	2	0.293	2
C3	0.134	3	0.254	3
C4	0.057	5	0.039	5
C5	0.117	4	0.109	4

To sum up, the preliminary study (experimental) reported that FA could eliminate human involvement because FA automatically adjusted the judgment values and reduced the human prejudices. In addition, the outcome (weight values) sustained human knowledge based on priority of criteria. The resulting from FA was to the optimized weight allocation without human involvement and sustained human knowledge.

5.4 Weight Determination

The proposed ESS model designed the novel weight determination method called ANP-FA method. The method allocated the weight values relevant to the relationship between criteria without human involvement. This design relied on the fundamental of ANP method as shown in Figure 5.13.

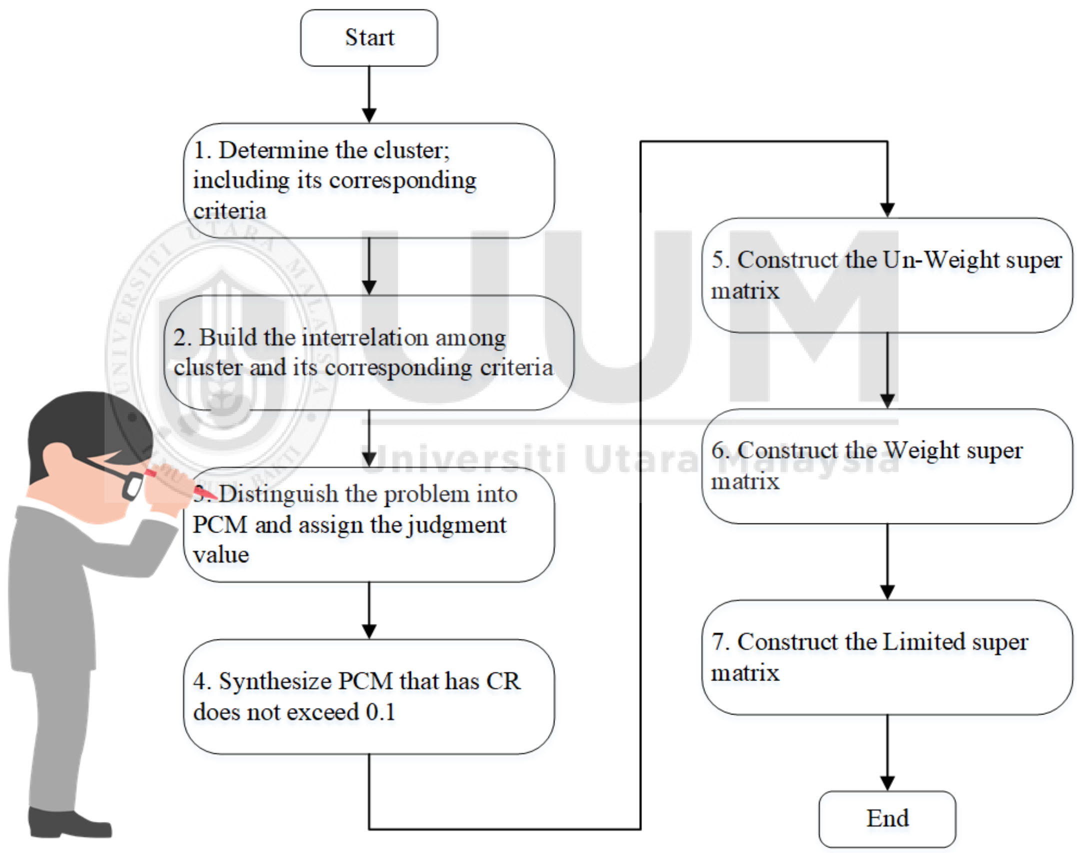

Figure 5.13

Flow of ANP method

Based on the steps of ANP method, the third (3) and fourth (4) steps were restructured to eliminate human involvement from the assignment of judgment values. Both steps had been proven in the preliminary study (see in section 5.3). However, the details in the assignment of the judgment values will be further explained in section 5.4.1. Section 5.4.2 explains the weight calculation on the relationship between criteria to cover in steps 5, 6 and 7. Figure 5.14 has shown the the ANP-FA method construction. The next sub-sections will discuss in detail the ANP-FA method to the weight allocation.

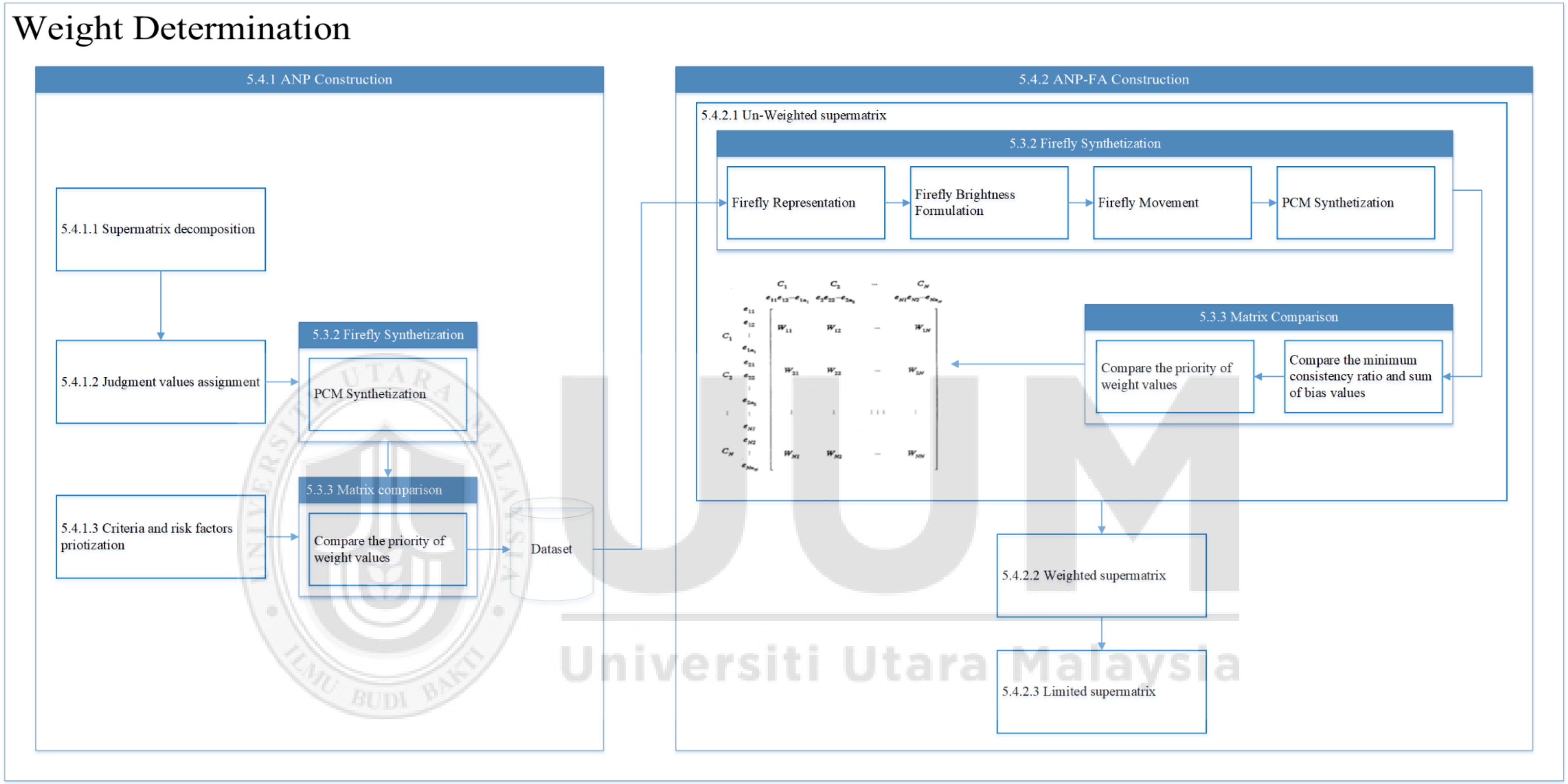

Figure 5.14

The proposed ANP-FA method

5.4.1 Analytic Network Process Construction

ANP was appropriately adopted in real-world decision-making problems (Gölcük & Baykasoğlu, 2016) to consider the relationship between criteria. This study constructed the relationship of criteria from statistical analysis (see in Figure 4.5); it was called ANP structure. In order to allocate the weight, the ANP structure was transformed into the supermatrix similar to Figure 2.4. Then the judgment values assignment was assigned to calculate the weight values filling in the supermatrix. A detailed explanation is discussed subsequently.

5.4.1.1 Supermatrix decomposition

Based on the ANP structure, supermatrix could be constructed as shown in Table 5.12. The supermatrix comprised three sustainability dimensions as clusters including evaluation criteria and risk factors relevance.

Table 5.12

Supermatrix for sustainable ITO

Dimensions	criteria	economic		social		technology	
		C_1	C_2	…	…	C_{n-1}	C_n
Economic	C_1	ω_{C11}	ω_{C12}	…	…	…	ω_{C1n}
	C_2	ω_{C12}	ω_{C22}	…	…	…	ω_{C2n}
Social	…	…	…	…	…	…	…
	…	…	…	…	…	…	…
Technology	C_{n-1}	$\omega_{C(n-1)1}$	…	…	…	…	$\omega_{C(n-1)n}$
	C_n	ω_{Cn1}	…	…	…	…	ω_{Cnn}

Each relationship between criteria in each row that was relevant in a criteria column both inner and outer of sustainability was decomposed into the PCM. It relied on the relationship in Pearson Correlation Coefficient (PCC) analysis by significant value < 0.01 (see Appendix C). The outcomes of the analysis built 21 PCMs which comprised different PCM dimensions. Table 5.13 shows the number of PCM occurring supermatrix decomposition.

Table 5.13

Number of PCMs from supermatrix

PCM dimensions	number of PCMs
2	6
3	2
4	3
5	5
6	2
7	3
Total	21

For example, this study selected a PCM that had five (5) dimensions to present the automatic assignment of the judgment values. The PCM comprised four evaluation criteria and one risk factor that influenced an evaluation criterion in technology sustainability. Those criteria comprised with configuration(C_{12}), information and system security(C_{14}), maintenance and business innovation(C_{16}) and asset(C_{17}) and security of data accessibility(R_6) that influenced disaster recovery criterion(C_{13}).

5.4.1.2 Judgment value assignment

Based on the supermatrix decomposition, each PCM required to the assignment of the judgement value. This study developed the algorithm as shown in Figure 5.15. The algorithm assigned the judgement value in PCM automatically. In addition, the alogorithm adopted the Saaty’s scale (nine scale) to represent the human preference as studies in Saaty (1980).

```
Step 1. Defined the Saaty's scale [1, 2, 3, …, 9]
Step 2. Defined the dimension (n) of PCM
Step 3. Defined the number of possible pairwise matrix (NPM):
            NPM = 9^(n(n−1)/2)

Step 4. Generated the pairwise comparison matrix
        For x in range(0, NPM)
           For i in range(0, n)
              For j in range(0, n)
                   if i < j:
                     4.1 assign the judgment value at i and j (aij)
                   else if i > j:
                     4.2 assign the reciprocal judgment value at i and j
                         (1/aij)
                   else:
                     4.3 assign '1' when i equal j
              End For:
           End For:
        End For:
```

Figure 5.15

Pseudocode of the assignment of judgment values

The algorithm built the PCMs which might / might not adopt the weight values in the supermatrix. Therefore, the PCMs generation had to be investigated by using PCM synthetization (section 5.3.2.4) to ensure that CR does not exceed 0.1. The outcomes in this step were the PCM acceptance as referring to the weight values adoption in the decision-making problem (see Figure 5.16). However, these weight values must be also investigated to capture human knowledge. The investigation process will be explained in next section.

Pairwise Comparison Matrix 1

1	2	1	2	7	0.308
1/2	1	2	3	4	0.269
1	1/2	1	3	8	0.265
1/2	1/3	1/3	1	4	0.118
1/7	1/4	1/8	1/4	1	0.041

Pairwise Comparison Matrix 2

1	2	1	1	7	0.285
1/2	1	1	5	5	0.281
1	1	1	2	5	0.243
1	1/5	1/2	1	4	0.149
1/7	1/5	1/5	1/4	1	0.422

….

Pairwise Comparison Matrix n

1	2	1	2	5	0.314
1/2	1	3	2	6	0.308
1	1/3	1	1	3	0.177
1/2	1/2	1	1	2	0.142
1/5	1/6	1/3	1/2	1	0.059

Figure 5.16

The PCMs acceptance

5.4.1.3 Captured human knowledge

The criteria prioritization captured human knowledge. This was referred from a study by Ahmad et al. (2014). Hence, this study determined the priority of criteria through the mean ($\bar{x}$) value. Table 5.14 shows the criteria priotization of a sample PCM to be a guideline to allocate the weight values.

Table 5.14

The priority of evaluation criteria and risk factors

Criteria		Mean	priority
$\boldsymbol{C_{13}}$	disaster recovery		
$\boldsymbol{C_{14}}$	information and system security	8.20	1
$\boldsymbol{R_{6}}$	security of data accessibility	8.06	2
$\boldsymbol{C_{12}}$	configuration	7.71	3
$\boldsymbol{C_{16}}$	maintenance and business innovation	7.31	4
$\boldsymbol{C_{17}}$	asset	7.14	5

In order to ensure that the outcomes from section 5.4.1.2 captured human knowledge, the study adopted the comparative approach to investigate the similarity of priority of weight values. The investigation was performed with the algorithm in section 5.3.3.2. Figure 5.17 shows the PCMs acceptance, which CR did not exceed 0.1 and captured human knowledge. These PCMs became a dataset for FA to find out the optimizing weight values.

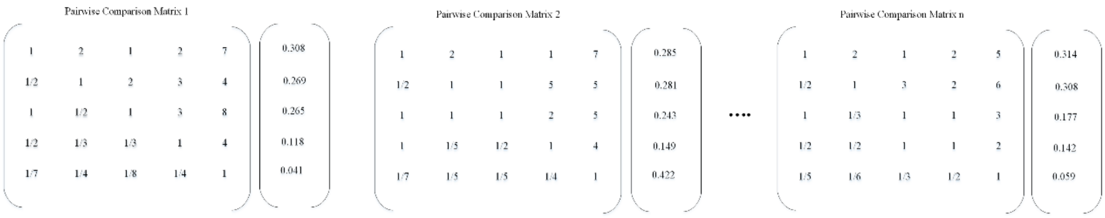

Figure 5.17

PCMs Dataset

5.4.2 Firefly Algorithm in Analytic Network Process Construction

Based on the synthesis of the optimal weight on the relationship between criteria and risk factors, there were three steps showing Un-Weighted, Weighted and Limited supermatrix. Particularly, the Un-Weighted supermatrix needed to integrate the FA searching the optimizing weight value. Therefore, the construction of ANP-FA is elaborated further subsequently.

5.4.2.1 Un-Weighted supermatrix construction

This step adopted firefly synthetization (see in section 5.3.2) to find out the optimizing weight values to fill in the un-weighted supermatrix. The study randomly selected the PCMs from the dataset to be feasibility space for FA. This randomness only selected thirty-five PCMs because it represented the different 35 decision-makers' knowledge; instead of fireflies. Table 5.15 shows 35 fireflies that represent the PCMs including the own brightness.

Table 5.15

Feasibility space

Firefly	PCM initialization					brightness	CR
FF1	1.000	2.000	1.000	1.000	7.000	10.432	0.096
	0.500	1.000	1.000	5.000	5.000		
	1.000	1.000	1.000	2.000	5.000		
	1.000	0.200	0.500	1.000	4.000		

Firefly	PCM initialization					brightness	CR
	0.142	0.200	0.200	0.250	1.000		
FF2	1.000	2.000	1.000	2.000	7.000	15.212	0.066
	0.500	1.000	2.000	3.000	4.000		
	1.000	0.500	1.000	3.000	8.000		
	0.500	0.333	0.333	1.000	4.000		
	0.142	0.250	0.125	0.250	1.000		
				…			
FF16	1.000	2.000	1.000	2.000	7.000	13.205	0.076
	0.500	1.000	2.000	4.000	7.000		
	1.000	0.500	1.000	5.000	5.000		
	0.500	0.250	0.200	1.000	1.000		
	0.143	0.143	0.200	1.000	1.000		
FF17	1.000	2.000	1.000	2.000	7.000	32.018	0.031
	0.500	1.000	1.000	2.000	8.000		
	1.000	1.000	1.000	2.000	4.000		
	0.500	0.500	0.500	1.000	5.000		
	0.143	0.125	0.250	0.200	1.000		
				…			
FF35	1.000	2.000	1.000	2.000	5.000	18.007	0.056
	0.500	1.000	3.000	2.000	6.000		
	1.000	0.333	1.000	1.000	3.000		
	0.500	0.500	1.000	1.000	2.000		
	0.200	0.167	0.333	0.500	1.000		

The feasibility space was performed with the firefly movement and PCM synthetization to search the optimizing PCMs. Finally, there were only two fireflies being selected, they were FF12 and FF16 as shown in Table 5.16. This was because the CR < 0.1 along with judgment values between 0 and 9 by following the Saaty rule as stated in the study of Saaty (2013)

Table 5.16

Fireflies selected

Firefly	PCM optimization					weight	CR	SB
FF12	1.000	2.042	5.089	2.927	5.553	0.460	0.030	2.072
	0.490	1.000	2.123	2.479	1.018	0.207		
	0.196	0.471	1.000	1.018	0.960	0.101		
	0.342	0.403	0.982	1.000	0.950	0.110		
	0.180	0.982	1.041	1.053	1.000	0.123		
FF16	1.000	2.066	2.306	3.780	5.597	0.417	0.003	0.705
	0.484	1.000	1.008	2.418	3.085	0.215		
	0.434	0.992	1.000	2.292	2.442	0.198		
	0.265	0.414	0.436	1.000	1.295	0.095		
	0.179	0.324	0.409	0.772	1.000	0.074		

However, the optimizing PCM should have only one and sustain human knowledge; the study needed to investigate the outcomes in Table 5.16 with the matrix comparison (see in section 5.3.3). The investigation process selected PCM that had minimum CR and SB values when comparing to the PCM in feasibility space. In addition, the priority of weight was also similar to the PCM in feasibility space. Therefore, the study selected FF16 as the optimizing weight value (see in Table 5.17) to fill in the un-weighted supermatrix.

Table 5.17

Optimizing PCM

Firefly	PCM optimization					weight	priority	CR	SB
FF16	1.000	2.066	2.306	3.780	5.597	0.417	1	0.003	0.705
	0.484	1.000	1.008	2.418	3.085	0.215	2		
	0.434	0.992	1.000	2.292	2.442	0.198	3		
	0.265	0.414	0.436	1.000	1.295	0.095	4		
	0.179	0.324	0.409	0.772	1.000	0.074	5		

Therefore, this process was repeated in 21 PCMs to find out the optimizing weight values. Consequently, the un-weighted supermatrix comprised of the optimizing weight values (see in Appendix D). If criteria had no relationships from PCC analysis; it was filled with the zero value in the un-weighted supermatrix (Saaty, 1999). However, these weight values were not also represented in the dependence relationship between criteria. Hence, the un-weighted supermatrix was normalized to become the Weighted Supermatrix. More details will be discussed in the next section.

5.4.2.2 Weighted supermatrix construction

Weighted supermatrix transformed from the un-weighted supermatrix was called Stochastic matrix in accordance with a study in Saaty (2004). He stated that the summary of the weight values in each column of weighted supermatrix must be equal one. Therefore, each weight value in weighted supermatrix were computed from Equation 5.3.

$$Nor(\omega_{ij}) = \frac{\omega_{ij}}{\sum_{i=1}^{j} \omega_{ij}} \tag{5.3}$$

Where:

i = row index

j = column index

ω_{ij} = weight value that represent in row (i) and column (j)

$Nor(\omega_{ij})$ = normalized weight value that represent in row (i) and column (j)

Considering the normalized weight values of criteria that related to the disaster recovery(C_{13}). The normalization value of C_{12} computed with Equation 5.3.

$$Nor(C_{12}) = \frac{0.198}{1+0.198+0.417+0.095+0.074+0.215}$$

$$= 0.099$$

This computation has been applied in all weight values of un-weighted supermatrix. The outcomes can be seen in Appendix E. These weight values represented the independent relationship between criteria, which was addressed in a study by Jayakrishna and Vinodh (2015). For example, the quality as well as information and system security criteria had a high relationship with the disaster recovery (C_{13}) when compared to other criteria in the same column. This was because the weight value of both criteria obtained 0.500 and 0.209 respectively. On the contrary, the asset criterion (C_{17}) was a low relationship because the weight value was equal to 0.037. This reflected that two criteria (quality and security in the information and system) had a high priority in technology sustainability, while asset criterion was a low priority in the same sustainability on the assessment of supplier capability. Unfortunately, these weights indicated only an independent relationship. To ensure that the weight values obtained from ANP-FA method indicated the dependence relationship between criteria, the weight values should be computed in the limited supermatrix, which is further explained in section 5.4.2.3.

5.4.2.3 Limited supermatrix construction

The limited supermatrix computed the optimized weight values on the dependent relationship between criteria. This study developed the algorithm to support the limited supermatrix computation. The algorithm is presented in Figure 5.18.

```
Step 1. Weighted supermatrix is computed in section 5.4.2.2
Step 2. Defined the PCM dimension (n)
Step 3. Initial 'K' number is 2

Step 4. While (True):
            4.1 The weighted supermatix is power with 'K' number
            4.2 The verified value in each row become  the unique value
            For 1 in range(0, n)
                  Set objuniqe variable obtain the result of the unique function
                  to investigate the unique value
                  If len(objunique) == 1:
                        Investigation the next row in supermatrix
                        If all row of supermatrix is unique value
                              Set status = True
                              Exits For Loop
             End For
             If status is not True:
                  Increasing 'K' value by 1
              Else:
                  Exits While Loop
        End While:
Step 5. Obtained the optimizing weight on the dependence relationship
        between criteria in three sustainability dimensions
```

Figure 5.18

Pseudocode of limited supermatrix

The algorithm computed the weight values in supermatrix until the values in each row became the stabilized value. The outcomes presented the optimizing weight value on the dependence relationship between criteria in three sustainability dimensions. Table 5.18 reports the outcomes of the algorithm as referring to Appendix F.

Table 5.18

Optimizing weight values representing dependence relationship between criteria

Sustainability	IDs	evaluation criteria and risk factors	optimizing weight values
Economic	C1	Economic	0.03131
	C2	Quality	0.23929
	C3	Service	0.11964
	C4	Cost/price	0.03522
	C5	Finance	0.03914

Sustainability	IDs	evaluation criteria and risk factors	optimizing weight values
	C6	Satisfaction/responsiveness	0.00000
	R1	Cost management and unexpected cost	0.02624
Social	C7	Social	0.00268
	C8	Relationship/communication process	0.04290
	C9	Reliability/usability	0.00000
	R2	Working collaboration	0.04022
Technology	C10	Technology	0.00281
	C11	Technical capability and experts	0.00162
	C12	Configuration	0.03015
	C13	Disaster recovery	0.03167
	C14	Information and system security	0.12638
	C15	Information and system integrated compatibility	0.01148
	C16	Maintenance and business innovation	0.00643
	C17	Facility/assets	0.02319
	C18	Experience	0.03384
	C19	Research and development	0.00052
	R3	Quality of IT products and services	0.06940
	R4	Knowledge of business process and new technology	0.00341
	R5	Technology complexity	0.00006
	R6	Security of data accessibility	0.07652
	R7	Changing business and technology requirement	0.00588

There were three criteria with high dependence relationship on three sustainability dimensions as quality (0.23929), information and system security (0.12638) and service (0.11964) respectively. Obviously, these criteria should be adopted in the assessment of supplier capability to sustain the ITO because they highly influenced three sustainability dimensions. On contrary, two criteria (satisfaction/responsiveness and reliability/usability) and one risk factor (technology complexity) had no influence on the sustainable ITO because the weight values were equal to zero. These weight values could indicate the dependence relationship between criteria; it was addressed in the study of Jayakrishna and Vinodh (2015). Consequently, ANP-FA method construction achieved the second objective by determining optimizing weight values on the relationship between criteria without human involvement.

5.5 Discussion

This chapter proposed an ESS model for supplier selection of sustainable ITO. The aim of the model was to facilitate ITO decision making process so that the project could be sustainable. On top of that, the model also eliminated the dependency on human in determining the importance weight of the evaluation criteria.

Generally, the evaluation criteria and risk factors adopted in the supplier selection problems of ITO relied on decision-makers' suggestions and ITO characteristics. However, they neglected the sustainable ITO. For this reason, the study had mapped the identified evaluation criteria and risk factors on three sustainability dimensions. There were nineteen (19) evaluation criteria and seven (7) risk factors that had a relationship in three (3) sustainability dimensions. However, the relationship was appropriate in Thai organization environment only.

Furthermore, a novel decision-making method had been designed by integrating FA into ANP method to eliminated human involvement. This method had become the transparency process in terms of the weight determination. The obtained weights represented the relationship among criteria and risk factors in three sustainability dimensions. In addition, human prejudices were reduced during the weight determination. Hence, it could be noted that ANP-FA was appropriate to be adopted in real-world decision problem solving.

5.6 Summary

In a conclusion, this chapter discusses the development of the supplier selection model for sustainable ITO, which is the ESS model. The proposed model addressed the research problems, by including the constructed evaluation criteria and risk factors on sustainable ITO. These were adopted in the supplier selection problem in today's business environment for sustainable ITO. Furthermore, ANP was improved by integrating the FA based on the concept of the hybrid method. ANP-FA was a novel hybrid method for determining the optimized weights on dependence relationships without humans' involvement. The model was constructed based on the outcomes from the theoretical, exploratory and preliminary studies. There were four (4) components in the proposed model. By having this model, the evaluation criteria and risk factors on sustainable ITO were commonly used in wider supplier selection problem for current organization needs. Additionally, the ANP-FA has become a transparency method. The method eliminated human involvement throughout the criteria synthesis. The next chapter elaborates the evaluation of the ESS model.

CHAPTER SIX

ENHANCED SUPPLIER SELECTION MODEL EVALUATION

6.1 Introduction

The evaluation process of the proposed model has been carried out with an experimental approach along with the verification and validation stages. The experimental approach was to conduct a novel hybrid decision making model that eliminated human involvement. Verification of the proposed was performed by experts from the academic field and decision-makers from an organization. Furthermore, the validation was carried through a case study of the organizations in Thailand.

This chapter was started with the discussion on Analytic Network Process (ANP) improvement achieved through experimental approach. The model verification through expert review is explained in Section 6.3, and it was continued with validation through case study in Section 6.4. Section 6.5 provides the validation results and discussion, while 6.6 ends the chapter with the summary.

6.2 Improved Analytic Network Process Method by Experimental Approach

This study designed the experimental framework based on the concept of the hybrid method and comparative approach (see Figure 3.3). The hybrid method intended to compensate shortcoming of ANP such as reported in Gölcük and Baykasoğlu (2016); Kilic et al. (2015); Uygun et al. (2015), while comparative approach investigated the weight priority. The proposed hybrid model eliminated human involvement from ANP by deploying Firefly algorithm (FA) to determine the weight for the decision making criteria. The deployment of FA also reduced human prejudices in decision problems as denoted by the consistency ratio (CR) and a sum of bias (SB). The CR value from hybrid method was equal to 0.004 less than the dataset approximate 0.01, while SB value (0.740) was less than twofold of the SB value in the dataset. Detailed explanation on the evaluation is presented in Chapter Five.

6.3 Verification by Expert Reviews

Expert reviews have been accepted as a significant way to investigate the steps of designing the proposed model (Azman et al., 2018). Therefore, this study adopted the expert review for the verification process. Verification was intended to ensure that the proposed model lead to sustainable IT outsourcing (ITO), and steps of designing the model were correct. There were two main issues to be verified; evaluation criteria and risk factors on three sustainability dimensions (refer to economic, social and technology) and the hybrid decision making model, known as ANP-FA. Experts' identification for the verification included the ones with knowledge and experience in ANP and/or AHP and Swarm Intelligence (SI) as well as sustainability in IT, which focused on software engineering, and software quality was identified. These experts were chosen based on the characteristics suggested by Chang et al. (2012); Mohd Zukhi et al. (2020), which was discussed in Chapter Three.

6.3.1 Experts for Analytic Network Process and Firefly Algorithm Verification

Five experts of ANP/AHP and SI were identified and contacted through phone. Three of them were willing to verify the method, which was considered sufficient as stated in the study by Mohd Zukhi et al. (2020). Consequently, appointments were made and online meetings were held. The following activities were conducted during the review sessions:

1. Researcher presented the overview of the study and the designed steps of designing the ANP-FA to the experts.

2. The experts reviewed the steps of designing ANP-FA and they were given the opportunity to ask questions for further clarification.
3. The experts gave feedback by filling in the feedback form.
4. The researcher then updated the algorithm as suggested by the experts.

6.3.2 Experts for Sustainable IT Outsourcing

Five knowledgable experts from the software engineering and software quality domain identified the potential experts. However, only three of them were willing to verify the three deployed sustainability dimensions along with its corresponding criteria and risk factors. Invitation to become experts for the study were also made though phone call. The related documents were then sent to the experts who agreed to verify and to commit the study. Feedback were provided by them through either e-mail or online meeting. A total of three experts sent their feedback, and this had been sufficient for the purpose of expert review as addressed in study by Mohd Zukhi et al. (2020). The following were activities involved during the expert review process:

1. Researcher presented the overview of the study through online meeting or phone call.
2. The experts then reviewed the sustainability dimensions and its corresponding criteria and risk factors indicated the sustainable ITO.
3. The experts gave their comments by filling in the feedback form.
4. The researcher then updated on the clear explanation in Chapter Two of the sustainability and its corresponding criteria and risk factors following the experts' comments.

Besides the knowledge experts, this study also incorporated the domain experts from the organization since they were the potential users of the model and could give feedback based on their practices in real-world projects. Domain experts verified the outcome of the ANP-FA method along with three sustainability dimensions and its corresponding criteria and risk factors included in the propose model through case study. Table 6.1 summarizes the knowledge experts' background. The organization profile and activities are discussed in Section 6.4 since a case study is adopted to validate the ESS model.

Table 6.1

Experts' Background

	ID	qualification	expertise	years of experience	institutions
Analytic Network Process	Expert A	Ph.D.	MCDM, Analytic Network Process and Analytic Hierarchy Process	10 years	Naresuan University
	Expert B	Ph.D.	MCDM, Analytic Hierarcha Process,	8 years	Pibulsongkram Rajabhat University
	Expert C	Ph.D.	Swarm Intelligence	8 years	Thai-Nichi Institute of Technology
Software engineering	Expert D	Ph.D.	Software Engineering	10 years	Khon Kaen University
	Expert E	Ph.D.	Software Engineering, Software Quality	12 years	Prince of Songkla University
	Expert F	Ph.D.	Software Engineering	8 years	Rangsit University

6.3.3 Verification of Weight Detemination Method

The ANP-FA method was verified by ensuring the correctness of developing it. Correctness refered to whether the FA integrated into ANP which was performed in this study conformed to the ANP steps. It was started from constructed the relationship between evaluation criteria and risk factors (refer to ANP structure) and identified the priority of evaluation criteria and risk factors. The priority could capture the decision-makers' knowledge (Ahmad et al., 2014) to be the guideline for FA finding out the optimizing weight. Finally, it ended with the optimizing weight values representing to the ANP structure. There were twelve (12) steps in the ANP-FA development, as listed in Appendix G. Table 6.2 shows the result of experts' verification. All of the experts agreed that the developed ANP-FA method was correct.

Table 6.2

Results for the ANP-FA verification

Steps	expert A	expert B	expert C
1. The criteria and risk factors have been arranged the relationship in three sustainability dimensions.	Agree	Agree	Agree
2. The relationship between criteria and risk factors transformed a supermatrix.	Agree	Agree	Agree
3. The supermatrix was decomposed into pairwise comparison matrix (PCM).	Agree	Agree	Agree
4. The judgment values were automatically assigned in PCMs including the CR synthesis does not exceed 0.1.	Agree	Agree	Agree
5. The PCMs generation were verified the human knowledge by comparing priority of weight values as referring the dataset (feasibility space).	Agree	Agree	Agree

Steps	expert A	expert B	expert C
6. FA found out the optimizing weight values from the feasibility space (PCMs).	Agree	Agree	Agree
7. PCM synthetization (i.e. judgment value., weight synthetization, consistent synthetization and bias synthetization) was performed to investigate the optimizing PCMs.	Agree	Agree	Agree
8. The comparison of both CR and SB values indicated an optimal PCM from the feasibility space.	Agree	Agree	Agree
9. The comparison of priority of optimal weight values captured human knowledge from the feasibility space.	Agree	Agree	Agree
10. All optimizing weight values filled in the un-weighted supermatrix following the relationships between criteria and risk factors on three sustainability dimensions.	Agree	Agree	Agree
11. The weighted supermatrix has been constructed to the weight normalization.	Agree	Agree	Agree
12. The limited supermatrix has been constructed to calculate the optimizing weight value on the relationship between criteria and risk factors in three sustainability dimensions.	Agree	Agree	Agree

Overall comments:

Expert A: The researcher had designed on the right track.

Expert B: The researcher had designed on the right track. However, the assignment of criteria prioritization to capture the human knowledge should take into account the similarity of priority, especially qualitative criteria.

Expert C: The researcher had designed the steps of FA integrated into ANP was appropriate. On top of that, the method should be compared with the different other algorithms to measure the performance such as Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO).

6.3.4 Verification of Sustainability Dimensions, Evaluation Criteria and Risk Factors

Three sustainability dimensions and its corresponding criteria and risk factors was verified with the comprehensive, understandability, accurateness and organization. These verification criteria were adapted from previous study of Al-tarawneh (2014). The descriptions of these criteria are listed in Table 6.3. The experts provided their feedbacks by filling in the checklist as provided in Appendix I.

Table 6.3

Descriptions of verification criteria

Criteria	descriptions
Comprehensiveness	The criterion showed that the evaluation criteria and risk factors on three sustainability dimensions indicated the sustainable ITO.
Understandability	The criterion suggested that the evaluation criteria, risk factors incorporate on three sustainability dimensions were decomposed clearly and unambiguously.
Accurateness	The criterion indicated that the evaluation criteria and risk factors on three sustainability dimensions achieved the assessment of the suppliers' capability for sustainable ITO.
Organization	The criterion denoted that the evaluation criteria and risk factors on three sustainability dimensions were organized well.

Noticeably, all of the experts agreed that three sustainability dimensions and their corresponding evaluation criteria and risk factors were understandable, accurate and well-organized. However, they had some comments on social sustainability in terms of the comprehensive. For example, Expert D suggested that the meaning explanation should indicate to the working society of stakeholders who were relevant to ITO activity.

Expert E also found that communication criterion should concern about the control process in the collaboration under ITO activity. In addition, there were some criteria in social sustainability incur the bewilderment to adopt in the supplier selection problem as suggested by Expert F. The expert introduced that the criteria should be modified to occur the obviousness and understanding in the social sustainability. For example, the term 'trustiness' was more appropriate for the social sustainability instead of 'reliability/usability'. Hence, the criteria in social sustainability were modified and updated accordingly as suggested. Table 6.4 recapitulates the comments from the knowledgable experts.

Table 6.4

Summary of experts' comments

Criteria	expert D	expert E	expert F
Comprehensiveness	Clarify and explain the meaning of social sustainability to cover stakeholders in the ITO working space. For example, the participants in the team meeting had different roles to propose the requirements.	The communication criterion should indicate the control process in the collaboration for ITO activity such as requirement agreement.	Some criteria adoption in social sustainability incured bewilderment the supplier selection for sustainable ITO.
Understandability	Agree	Agree	Agree
Accurateness	Agree	Agree	Agree
Organization	Agree	Agree	Agree

The experts' comments involved the criteria on social sustainability, so those criteria were modified and updated. The action taken is summarized in Table 6.5.

Table 6.5

The modifying and updating actions

Descriptions	problems / action taken
The meaning of social was written in a short statement without an example to explain who the working collaboration was.	Social criterion was not explained the stakeholders in working collaboration of ITO activity / updated.
The communication criteria (i.e. business and technical requirements) between organization and supplier was done without agreement.	Communication control was not explained and considered in the communication criteria / updated.
The understanding meaning of criteria among decision-makers was adopted in the supplier selection problem, especially criteria related to trustiness.	Decision-makers might confuse some criterion meaning / modified

6.4 Validation by Case Study

ESS model validated through a case study attended by the domain experts from the real organization. The experts identified the priority of both criteria and risk factors on three sustainability dimensions as a guideline to the weight determination. Then the experts mapped the organization's criteria into the evaluation criteria and risk factors. Additionally, the proposed model adopted those criteria to validate the selected supplier when compared the final organization's decision. The next subsections discussed the case study, which consisted of the organization profile and compared the outcome with the final organization decision.

6.4.1 Organization Profile

The organization was the new state enterprise of Thailand, and it was announced to be the public transportation company under the Thai government since 1992. The organization performed the business for building electric train way and service along with developing real estate around the service area. In 1999, the organization opened two electric trainways into the business area in Bangkok city to comfort the travel of the population. Currently, in order to increase the efficient transportation services in Bangkok and its vicinity, the organization was building the extension electric train ways to support the Thai population's journey in the future. It also became the backbone of public transportation in Bangkok and reduced the number of car into the business area. This was obvious that the core competency of the organization was the public transportation service. However, the organization's operation required an efficient IT system to support the business, especially customer service such as pay travel fees on mobile, travel information and so on. These were non-core competency of organization but could not be ignored. IT system has become a crucial key in performing business in the digital era. Thus, the organization employed the potential supplier for ITO projects. Nevertheless, the supplier selection would be under procurement regulations of Thai government addressing the state enterprises law.

6.4.2 Conducting Case Study

The case study was conducted under a complete ITO project. The final organization decision involved the decision-makers' consensus to select the potential supplier for ITO project. It also depended on the evaluation criteria of the organization chosen. This study obtained the evaluation form from the organization, which comprised of the organization's criteria and its corresponding supplier score (see Appendix N) to validate the proposed model. A comparative approach was deployed to examine whether the selected supplier from the proposed model was equivalent to the one practiced by the organization. A detailed in performing case study is further described subsequently.

6.4.2.1 Computed optimized weight on ANP structure

The proposed ANP-FA method was deployed in the case study to synthesize the optimizing weight values for ANP structure. Even though the model excluded human involvement, but it sustained human knowledge by having criteria priority. Priority of criteria used in this study can be seen in Appendix J while the priority outcomes is shown in Table 6.6.

Table 6.6

The priority of evaluation criteria and risk factors

Sustainability	IDs	evaluation criteria and risk factors	priority
Economic	C1	Economic	18
	C2	Quality	1
	C3	Service	5
	C4	Cost/Price	4
	C5	Finance	6
	C6	Satisfaction/responsiveness	7
	R1	Cost management/unexpected cost	25
Social	C7	Social	22
	C8	Relationship and communication process	19
	C9	Reliability/usability	10
	R2	Working collaboration	11
Technology	C10	Technology	20
	C11	Technical capability and expertise	2
	C12	Configuration	8
	C13	Disaster recovery	12
	C14	Information and system security	9
	C15	Information and system integrated compatibility	13
	C16	Maintenance and innovative business	14
	C17	Assets	15
	C18	Experience	3

Sustainability	IDs	evaluation criteria and risk factors	priority
	C19	Research and development	21
	R3	Quality of IT products and services	17
	R4	Knowledge of business process and new technology	26
	R5	Technology complexity	16
	R6	Security of data accessibility	23
	R7	Changing business and technical requirement	24

The priority of criteria provided in Table 6.6 was used as a guideline for the ANP-FA allocate weight for the criteria. The outcomes of the weight allocation was based on the ANP structure. These optimizing weight values indicated the importance of the criteria in assessing the supplier capability lead to sustainable ITO. The optimized weight values had also been a crucial part of the computation of the supplier score without human prejudices in the decision process. The outcomes are reported in Table 6.7.

Table 6.7

Optimizing weight values on the relationships

Sustainability	IDs	criteria and risk factors	optimized weight values on relationship
Economic	C1	Economic	0.04506
	C2	Quality	0.19591
	C3	Service	0.09796
	C4	Cost/Price	0.05069
	C5	Finance	0.05633
	C6	Satisfaction/responsiveness	0.00000
	R1	Cost management/unexpected cost	0.03729
Social	C7	Social	0.00404
	C8	Relationship and communication process	0.06465

Sustainability	IDs	criteria and risk factors	optimized weight values on relationship
Technology	C9	Reliability/usability	0.00000
	R2	Working collaboration	0.06061
	C10	Technology	0.00386
	C11	Technical capability and expertise	0.00161
	C12	Configuration	0.07320
	C13	Disaster recovery	0.03442
	C14	Information and system security	0.10309
	C15	Information and system integrated compatibility	0.02063
	C16	Maintenance and innovative business	0.01144
	C17	Assets	0.04277
	C18	Experience	0.04402
	C19	Research and development	0.00242
	R3	Quality of IT products and services	0.02505
	R4	Knowledge of business process and new technology	0.00177
	R5	Technology complexity	0.00018
	R6	Security of data accessibility	0.01284
	R7	Changing business and technical requirement	0.01017

Based on Table 6.7, there were three criteria obtaining the highly optimized weight values as quality (0.19591), information and system security (0.10309) and service (0.09796). Obviously, three criteria highly influenced three sustainability dimensions. This result was similar to the survey reflecting to the Thai organizations focusing on three criteria for supplier selection problems of sustainable ITO. Noteworthy, there were two criteria without any influence on three sustainability dimensions namely satisfaction/responsiveness and reliability/usability criteria because both criteria obtained the zero value that was the same as the result in Chapter 5. This is emphasized that the organization did not take into account both criteria in supplier selection for sustainable ITO.

6.4.2.2 Mapping of evaluation criteria and risk factors with organization's data

The second stage was to map the evaluation criteria and risk factors with the organization's criteria. Generally, the organization's criteria for supplier selection problems involved the ITO characteristics and the organization's requirements. The deployed criteria and factors might be different from the ones declared by the organization. Hence, this study invited decision-makers to map the evaluation criteria and risk factors into the organization's criteria and this is provided in Appendix K. The outcome is shown in Table 6.8.

Table 6.8

Mapping between organization's criteria and evaluation criteria and risk factors

Organization's criteria	IDs	evaluation criteria and risk factors (ESS model)
Supplier's previous project portfolio (SPPP)	C2	Quality
	C3	Service
	C5	Finance
Price	C4	Cost/price
Project member's experience and expertise (PMEE)	C11	Technical capability and expertise
	C18	Experience
Project development and implementation procedure (PDIP)	C12	Configuration
	C13	Disaster recovery
	C14	Information and system security

Organization’s criteria	IDs	evaluation criteria and risk factors (ESS model)
	C15	Information and system integrated compatibility
Other proposal that may benefit the project (OPBP)	C16	Maintenance and business innovation
	C19	Research and development

Based on undertaken case study, it is learned that the decision-makers had selected most of the evaluation criteria relating to supplier’s technical capability along with the quality of the history project portfolio. In addition, they mentioned that financial capability was important to support the ITO achievement at a reasonable price. These were reflected on only two sustainability dimensions which were economic and technology. Unfortunately, the decision-makers had neglected the evaluation criteria in social sustainability, in which the criteria assessed the ability of supplier’s collaboration. Collaboration is a crucial part of ITO success that occurs between the organization and supplier as addressed in the study of Fusiripong et al. (2017).

6.4.2.3 Validation of enhanced supplier selection model

The third stage was to validate the ESS model. This study arranged the supplier score in each of the organization’s criteria (see Appendix N) into the evaluation criteria on three sustainability dimensions as shown in Table 6.9. The selected evaluation criteria consisted of two sustainability dimensions were economic and technology.

Table 6.9

Map supplier score to the evaluation criteria on sustainability dimensions

Sustainability	IDs	evaluation criteria and risk factors	supplier score	
			supplier A	supplier B
Economic	C2	Quality	150.00	146.00
	C3	Service		

Sustainability	IDs	evaluation criteria and risk factors	supplier score	
			supplier A	supplier B
	C5	Finance		
	C4	Cost/Price	100.00	96.49
Technology	C11	Technical capability and expertise	105.64	137.14
	C18	Experience		
	C12	Configuration	365.40	471.20
	C13	Disaster recovery		
	C14	Information and system security		
	C15	Information and system integrated compatibility		
	C16	Maintenance and business innovation	0.00	50.00
	C19	Research and development		

Four evaluation criteria represented economic sustainability. Therefore, economic sustainability indicated the organization's criteria in terms of SPPP and price criteria. The rest of criteria involved the technology sustainability. In the case study, ESS model computed he supplier score with the optimizing weight values. Hence, Weighted Sum Method (WSM) was adopted to compute the supplier score as followed in Equation 2.8. For example, supplier A score on economic sustainability could be computed as denoted below:

Supplier A score on economic sustainability = 150 x $(\omega_{C2} + \omega_{C3} + \omega_{C5})$ + 100 x ω_{C4}

= 150 x (0.19591 + 0.09796 + 0.05633) + 100 + 0.05069

= 57.599

Thus, all supplier score on two sustainability dimensions are reported in Table 6.10.

Table 6.10

Final supplier score

Sustainability	supplier score for ESS model	
	supplier A	supplier B
Economic	57.599	56.020
Technology	89.352	115.958
Final score	**146.951**	**171.978**

The ESS model result (see Table 6.10) pointed that Supplier B should be selected because the final score (171.978) was higher than Supplier A (146.951). However, Supplier B had a weakness in the history project portfolio with a reasonable price. This might slightly reflect the economic sustainability. On contrary, Supplier B had stronger technical capability than Supplier A. This was because the score of supplier B accounted approximately for more one-fold than supplier A.

Furthermore, ESS model should be examined the preciseness. The outcome of the model should be compared with the organization's decision. Table 6.11 illustrates the outcome comparison between ESS model and Price Performance (PP) method. Appendix N had shown the outcome from the organization.

Table 6.11

The comparasion of supplier that is selected

Suppliers	PP method (org)	priority	ESS model	priority
Supplier A	73.470	2	146.951	2
Supplier B	**83.920**	**1**	**171.978**	**1**

ESS model obviously selected Supplier B similar to the final organization decision. Consequently, ESS model was valid. This was also supported by a statistical t-test as shown in Appendix M. The t-test analysis indicated that the outcome of both approaches was not significantly different on ρ-value > 0.01. In addition, the model validation did not incur the bias from decision-makers because the proposed ESS model was a different process from the organization proposed.

6.4.3 Discussion on Case Study

This section describes the findings from the ESS model performed in the case study. The decision-makers were chosen from the organization, which had identified the priority of both criteria and risk factors as a guideline to the weight determination. ESS model had adopted the priority to allocate the optimized weight values on the relationships between criteria and risk factors without human involvement. Then, the validation result of each component in the ESS model would be presented.

i. Decision-makers' background

Decision-makers, who were nominated by the organization, were a committee in the supplier selection for ITO. They had different positions to consider the suppliers' ability on the various aspects. They were the IT project manager, IT team leader, and project owner (see Table 6.12). This was obvious that three decision-makers had high ITO knowledge and experience in the supplier selection problems.

Table 6.12

Anonymized overview of the decision-makers

IDs	positions	years' experience
A	IT project manager	> 15
B	IT team leader	10 - 15
C	Project owner	10 - 15

ii. The ANP-FA result

ANP-FA method was the synthesis process to the weight allocation on ANP structure. There were two steps namely the optimized Pairwise Comparison Matrix (PCM) and allocated the weight values on ANP structure. Firstly, ANP structure was decomposed as the PCMs to allocate the weight values. Then, Firefly Algorithm (FA) looked for the optimized weight values; along with sustain the human knowledge on the priority of criteria. The ANP-FA outcomes had become the optimized weight values ANP structure (see Table 6.7). This was obvious that ANP-FA had become a transparent decision-making method because the method eliminated human involvement. Consequently, the weight allocation had the fairness in the decision-making problems.

iii. Verification results for sustainable ITO

Three sustainability dimensions and its corresponding evaluation criteria and risk factors were verified by the knowledge experts. These also performed in the verification by the domain experts to ensure that the evaluation criteria and risk factors on three sustainability dimensions could adopt in the practicality. They determined the evaluation criteria and risk factors into the organization's criteria in case study. Noteworthy the decision-makers selected evaluation criteria only two sustainability dimensions namely economic and technology. The selected criteria can assess the ability of supplier in this case study leading to sustainable ITO as shown in Table 6.9. Unfortunately, the criteria and risk factors on social sustainability were neglected. However, they agreed three sustainability dimensions and its corresponding criteria and risk factors adopting in the model namely comprehensive, understandable, accurate, and well organized.

iv. Comparison results

The result of comparison occurred from the first priority selection in the highest supplier score. The supplier score was computed on two sustainability dimensions as economic and technology. The selected supplier from ESS model was similar to the organization decision. The result of both proposed items was also validated with the t-test analysis to ensure that both result did not different significantly as refer to section

6.3.2.3. These indicated to the ESS model valid, which directly reflected the optimized weight values preciseness in case study. Therefore, ESS model could adopt in the practicality of supplier selection problem in terms of weight allocation without human prejudices.

6.5 Validation Results and Discussion

ESS model had completely performed by domain experts. They were satisfied with it and agreed that the proposed model was practicable in the real-world environment. They also validated the proposed model on predefined set of criteria that lead to sustainable ITO. These criteria included gain, interface and task support satisfaction. Each of these criteria was assessed to set of variables. They would be further discussed in the next sub section.

6.5.1 Gain Satisfaction

Among the variables were assessed for gain satisfaction, they were perceived usefulness, decision support satisfaction, comparison with current method, cost-effectiveness, clarify and task appropriateness. These were described based on the comments from the decision-makers.

Table 6.13

The Results of Evaluation for Gaining Satisfaction Criteria

Variables	results of evaluation / explanation
Perceived usefulness	The decision-makers pointed out that the proposed model was useful for their working environment. The model could eliminate humans' involvement in the weight determination of supplier selection problems. Furthermore, the decision-makers preferred the evaluation criteria and risk factors that were identified to lead the sustainable ITO. As nowadays sustainable ITO perspective has been addressed throughout

Variables	results of evaluation / explanation
	the contract of employing a potential supplier. The decision-makers added that this model was without human involvement in the supplier selection problems.
Decision support satisfaction	The decision-makers were satisfied with the ANP-FA method. This was because the method had eliminated humans from the decision method, whereby it could reduce the unfairness in the decision problems. They also stated that the outcomes had captured human knowledge even without human involvement in the decision process.
Comparison with current method	The decision-makers found out that the proposed ESS model had more fairness than the PP method of the organization. This was because the model had eliminated humans from the decision-making process. This became the main reason why the model would be able to reduce the corruption in the procurement process of the organizations.
Cost-effectiveness	ESS model was deemed very cost-effective, as compared to the PP method used. This was because PP method might choose an inefficient supplier which might occur from the unfairness process of decision-makers because the proposed model eliminated human from the selection problem. This directly affected to the selected supplier based on reasonable cost.
Clarify	ESS model eliminated humans from the weight determination throughout the decision process. Additionally, the decision-makers preferred that ESS model provided the appropriate evaluation criteria and risk factors on three sustainability dimensions. These criteria indicated the sustainable ITO to adopt in the supplier selection problems.
Task Appropriateness	The decision-makers agreed that the proposed model was appropriate to determine the weight values for decision making problems. The weight determination also sustained

Variables	results of evaluation / explanation
	human knowledge throughout the assessment of supplier capability. Furthermore, the model had prepared a suitable criteria and risk factors for supplier selection problems leads to sustainable ITO.

The decision-makers were satisfied the proposed ESS model (see details in Table 6.13) due to the model determined the optimizing weight values without human involvement. This incured the transparent decision making process, which directly eliminated corrupting procurement processes in the organizations. Consequently, the organization was able to save the expenditure from the supplier selection process.

6.5.2 Interface Satisfaction

The interface satisfaction was assessed based on five variables namely perceived ease of use, internally consistent, organization (well organized), appropriate for audience and presentation (readable and usable format). The results of the evaluation were provided based on the participants' thoughts, as depicted in Table 6.14.

Table 6.14

The Results of Evaluation for Interface Satisfaction Criteria

Variables	results of evaluation / explanation
Perceived ease of use	The decision-makers stated that ESS model was perceived as easy to be used, especially ANP method due to the model adopted the criteria priority to the weight allocation instead of human involvement.
Internally consistent	The decision-makers found out that ESS model had internally consistent, mainly because the components were consistent. It was started with capturing decision-makers' knowledge through the criteria priority. Then the priority was a guideline to the weight determination by using ANP-

Variables	results of evaluation / explanation
	FA method. Finally, the supplier score had been computed by weight values without human involvement.
Organization (Well organized)	ESS model found to be well organized and structured to use in the real-world environment. The ESS model structure was clear and understood to the sequence of the criteria synthesis for the decision problem.
Appropriate for audience	The proposed model was found to be appropriate for the organization and decision-makers. The decision-makers stated that the weight determination could be performed faster, easier and transparently because the synthesis of the criteria would be without human involvement. This was why organizations could increase fairness in decision problems. In addition, the decision-makers were satisfied the group of evaluation criteria and risk factors on three sustainability dimensions that lead to sustainable ITO under supplier selection problems.
Presentation (readable and useful format)	The proposed model was found to produce useful results in supplier selection problems. Those evaluation criteria and risk factors were organized into three sustainability dimensions for sustainable ITO along with a transparent decision method. Particularly, a list of criteria and risk factors were easily adopted by decision-makers in the supplier selection problems for sustainable ITO. In addition, the decision method had represented fairness in terms of weight determination of each criterion.

Table 6.14 clearly explains the decision-makers were satisfied with the interface of the ESS model because the model applied only the priority of criteria to the weight determination and reduced the complication of human involvement in the ANP method. There were also a suitable group of criteria and risk factors on the sustainability dimensions for decision-makers adopting in the supplier selection problem. This

became the main reason why ESS model had a suitable interface for decision-makers in practicality.

6.5.3 Task Support Satisfaction

Ability of produce expected result, ability to produce relevant results, ability to produce usable results, completeness, ease of implementation and understandability (easy to understand) were the variables used to assess the task support of the satisfaction criterion.

Table 6.15

The Results of Evaluation for Task Support Satisfaction Criteria

Variables	results of evaluation / explanation
Ability to produce expected results	The proposed model was able to produce the result expected, due to the outcome from the model being similar to the existing decision method (PP method). Decision-makers were also satisfied with the weight determination that could indicate the criteria priority in the assessment of supplier capability. This was different from the PP method that did not consider the weight values in the supplier selection problems.
Ability to produce relevant results	Decision-makers highlighted the group of criteria and risk factors on three sustainability dimensions along with the ANP-FA method that was sufficient to produce the relevant result for sustainable ITO. These criteria and risk factors had clear explanations to be adopted in the supplier selection problem. It also added ANP-FA to the weight determination on the relationships between criteria and risk factors which reflected the consideration of the real-world decision problem.
Ability to produce usable results	Decision-makers were satisfied the outcome from the proposed model both group of criteria and novel decision method. The decision-makers could choose appropriate

Variables	results of evaluation / explanation
	criteria and/or risk factors to use in the supplier selection problem for sustainable ITO. In addition, the weight determination had indicated important criteria to assess the supplier capability under fairness but also sustain human knowledge. This became a crucial part of the decision process, especially supplier selection problems.
Completeness	The proposed model was found to be sufficient to lead sustainable ITO. Decision-makers emphasized that the model identified three groups of sustainable criteria along with risk factors to the supplier assessment. Meanwhile, the decision method had analyzed the relationships between criteria to determine the weight values being used in the supplier selection problems.
Ease of implementation	Decision-makers indicated that the model was easy to implement, as it provided a group of criteria and risk factors that could be adopted easily. Additionally, the weight determination method was without human involvement.
Understandability (easy to understand)	The proposed model was found to be readable and understandable. The decision-makers highlighted that the criteria and risk factors on three sustainability dimensions were organized well along with indicating the sustainable ITO. In addition, ANP-FA was satisfied by decision-makers since the method had transparent to the weight allocation for decision problems and reduced the complexity of humans used the method.

The decision-makers were satisfied that the ESS model appropriately supported tasks in the supplier selection as described in Table 6.15. The model proposed a novel decision method to automate weight determination without human involvement. Therefore, the weight determination method had become a transparent process. In addition to the novel decision method, the model proposed three groups of criteria and risk factors for the sustainable ITO to assess the supplier capability. All of these were easily implemented for decision-makers in the supplier selection problems of ITO.

6.6 Summary

This chapter discusses the evaluation of the proposed ESS model consisting of three stages: experimental, verification and validation. Experimental had improved the ANP method by deploying FA to the weight allocation. Verification had performed to the design step of ANP-FA and organizing the criteria and risk factors on three sustainability dimensions by knowledge experts. Based on the feedback, the ESS model was improved. For the validation stage, a case study was adopted for the model assessment. The case study implemented the ESS model to compare the result with one of the completed projects. The results of the ESS model were similar to the final organization decision. Consequently, ESS model was valid and could be adopted in the practicality of the supplier selection problem. The next chapter concludes the study by highlighting the contribution to achieving the objectives. Furthermore, the limitations and future direction of the study are also provided.

CHAPTER SEVEN

CONCLUSION

7.1 Introduction

This chapter concludes the study reported in this thesis. The discussion starts by recapitulating the study in Section 7.2, this continues with the contributions in Section 7.3. The limitations and future directions of the study are described in Section 7.4.

7.2 Study Recapitulation

The main aim of this study was to enhance the supplier selection model based on optimizes Analytic Network Process (ANP) towards sustainable IT outsourcing (ITO). This aim was achieved through three objectives, which have been defined earlier in Section 1.5. The study was recapitulated base on these objectives as follows.

Objective 1: To construct evaluation criteria and risk factors for supplier selection model towards sustainable ITO.

This objective was achieved through literature review and exploratory study as discussed in Chapter Two and Four respectively. This study has paid attention to the current practices for ITO activities through the supplier selection process in diverse businesses in Thailand. The outcome from the study revealed a list of evaluation criteria and risk factors from the viewpoint of three sustainability dimensions: economic, social, and technology. The list was further detailed by determining the importance of each evaluation criteria and risk factors in supplier selection problems.

The evaluation criteria and risk factors were gathered from the review of literature based on various perspectives such as expert suggestion, theory in supplier's performance measurement, and ITO characteristic. In addition, the study adopted the sustainability concept as the sustainable supplier selection and software sustainability to determine and organize the evaluation criteria for the supplier selection of sustainable ITO. The outcome of the review of the literature identified 30 evaluation criteria mapped against three sustainability dimensions (see Table 2.6). There were 12 risk factors gathered from the review of the literature as shown in Table 2.10. These risks occurred from both suppliers and ITO which affected the hazards of business competition apart from many benefits. This was because of the uncertainty of ITO strategy and management, technological complexity and working incompatibility between an organization and a selected supplier. These negatives affected the sustainable ITO employed by the supplier. Hence, risk factors should be considered in ESS model.

Upon completing the exploratory study in Thailand, it was learned that only 19 evaluation criteria and 7 risk factors (see Table 4.22) were relevant to the sustainable ITO in Thailand. These evaluation criteria and risk factors were found to be interrelated based on the three sustainability dimensions. This supports the sustainability concept studied in Brundtland (1987). Furthermore, the prioritization made on evaluation criteria and risk factors can be considered as a guideline in determining the weight values. Most respondents also highlighted the evaluation criteria and risk factors into two sustainability dimensions were economic and technology, which had a highly affecting the supplier selection of ITO in Thai business.

Objective 2: To design an enhance Analytic Network Process (ANP) with Firefly Algorithm (FA) in order to eliminate human involvement in determining the important weights for evaluation criteria.

In this objective, the study proposed ANP-FA deploying firefly algorithm to address the limitation of ANP relying on domain experts in supplier selection (discussed in Chapter 5). The experimental approach had deployed in the ANP enhancement. In addition, the experimental involved the Pairwise Comparison Matrix (PCM) generation, PCM optimization (optimized weight values) based on the data acquisition from existing the review of the literature. The consistency ratio (CR) that obtained from ANP-FA accounted for 0.003, whilst the original CR value (by ANP method) was 0.031. Moreover, the sum of bias (SB) value from ANP-FA was approximately three (3) times less than ANP. This shows that the integrated FA into ANP was successful in eliminating human involvement (allowing for a decision making that did not rely on domain expert that may be bias and differ from one expert to another expert). The domain expert knowledge and experience have been captured and sustained in the priority of optimized weight values.

The final ANP-FA outcomes were the optimized weight values under the ANP structure without humans' involvement as shown in Table 5.18. All the optimized weight values illustrated the indirect and direct relationships among criteria which influenced three sustainability dimensions as economic, social and technology. Also, these could adopt in the supplier selection problems to lead sustainable ITO.

Objective 3: To evaluate the enhanced supplier selection model.

This objective was achieved by performing the two evaluation stages namely verification and validation. Details of the two stages are presented in Chapter 6. The verification stage was performed by the knowledgable experts to verify the evaluation criteria and ANP-FA development steps for supplier selection in ITO. On the other hand, a case study was adopted to validate the proposed enhanced supplier selection (ESS). In the verification stage, ANP-FA development steps had an accuracy to allocate the optimized weight values on ANP structure without humans' involvement. Meanwhile, the correctness of evaluation criteria and risk factors on three sustainability dimensions were investigated based on four criteria assessments namely comprehensiveness, understandability, accurateness and organization. A result of the verification process revealed that the ESS model performed accordingly. The second stage was model validation. The evaluation criteria and risk factors were mapped into organization criteria, then synthesized the optimized weight values were to compute the final supplier score for ranking the suppliers. The proposed ESS model had selected a similar supplier with the final organization decision. In order to ensure that the outcome of both proposed was significantly not different, this study adopted the t-test analysis to the validation. Both investigations showed that the proposed ESS model was of success.

7.3 Contributions

This study had several implications on the theory and practice, especially in the field of Multi-Criteria Decision-Making (MCDM) in supplier selection model. The main contribution of the study was the proposed ESS model for sustainable ITO that comprised of the identified evaluation criteria and risk factors on three sustainability dimensions and ANP method improvement.

7.3.1 The Revises of Enhanced Supplier Selection Model

The main contribution of this study is the ESS model. It was built based on the outcomes of the theoretical, experimental, and exploratory studies. Existing supplier selection model had considered the evaluation criteria and risk factors simultaneously. Even though the evaluation criteria were also mapped against sustainability dimensions (economic, social and environment), nevertheless, the risk factors did not map against the sustainability dimension on sustainable ITO. There were two prespectives identified the risk factors namely supplier risk and ITO risk. One of the potentials for losses was supplier risk due to failures of the supplier in the future while ITO risks were the possible and impact of the ITO failures. These indicated the risks that might impacted sustainable ITO. In addition, this study had extended the ability of existing supplier selection model to achieve the sustainable ITO. The difference was that the proposed ESS model included factors that technology dimension was apart from the economic and social dimensions. The factors of technology dimension were relevant to the environmental dimension based on Green IT, especially, IT infrastructure (i.e. hardware and network equipment). This is supported in the study of Cevere and Gailums (2017); Marnewick (2017). Furthermore, supplier selection model relied on domain expert to the weight allocation. Such an approach might create issues in terms of inconsistency between experts or even bias among the supplier.

The ESS model had constructed the ANP-FA method to allocate the optimized weight values on ANP structure without human involvement. Currently, the hybrid methods of ANP relied on human judgment, identified in the studies by Kilic et al. (2015); Uygun et al. (2015). This is because of ANP is inherited from the AHP method (Saaty, 2004). Nevertheless, the ANP method could overcome the independent structure in the AHP method. As a result, ANP-FA became the novel hybrid method to allocate the optimized weight values on ANP structure. In addition, the optimized weight values were appropriate to adopt in the real-world decision-making problem. Two main important reasons were that the method could eliminate the human with the FA integration into ANP method, effecting prejudices values reduction significantly. Another one was the optimized weight values represent the interrelationship among criteria.

Theoretically, this study contributed to the field of MCDM, particularly in the supplier selection model by providing ESS model for the sustainable ITO. By adopting the proposed model, decision-makers obtained the evaluation criteria and risk factors to lead sustainable ITO in supplier selection problems. In addition, the proposed model had become a transparency process for weight allocation. This became the main reason that most organizations obtained the benefit from the ESS model because supplier selection had fairness. Consequently, organizations can increase the opportunity in their business by the right supplier with the stability of the IT system in the long-term implementation. On top of this, it impacted to the reduce expenditure, increase the competitive advantage business and customer satisfaction.

7.3.2 The Evaluation Criteria and Risk Factors for Supplier Selection of Sustainable IT Outsourcing

The evaluation criteria and risk factors are crucial components in the ESS model to assess the supplier's capability lead to sustainable ITO. These factors had gathered from the review of the literature, which involved with the ITOfor example, software development, data center operation, help desk, network management, and web hosting, Enterprise Resource Planning (ERP), and testing. This became a reason why these evaluation criteria and risk factors could measure the supplier's capability for various ITO of organizations. In addition, this study had also identified the sustainability dimensions for sustainable ITO. There were three sustainability dimensions as economic, social and technology. The dimensions were considered from two aspects namely sustainable supplier selection and software sustainability. Consequently, the supplier selection model consisted of evaluation criteria and risk factors map against three sustainability dimensions. Particularly, technology sustainability pointed out environmental viewpoint through Green IT. There were two extra contributions to this study as follows.

7.3.2.1 The evaluation criteria on three sustainability dimensions and risk factors

Based on the review of the literature, the evaluation criteria (30 criteria) had mapped against a similar meaning into three sustainability dimensions: economic, social, and technology. There were 14 evaluation criteria relevant to economic sustainability, while five evaluation criteria indicated social sustainability. The rest involved the technology sustainability. Meanwhile, the risk factors (12) were gathered from the review of the literature relevant to the supplier risk and ITO risk. These risk factors indicated an undesirable outcome. Therefore, the outcome was a set of appropriate criteria for sustainable ITO on supplier selection problems.

7.3.2.2 The evaluation criteria and risk factors on three sustainability dimensions in Thailand

There were 30 evaluation criteria on three sustainability dimensions (refer to economic, social and technology); including 12 risk factors as analyzed in the exploratory study (see Chapter Four). The outcome was the 19 evaluation criteria and 7 risk factors on three sustainability dimensions leading to sustainable ITO for supplier selection problems. There were six evaluation criteria and one risk factor relevant to economic sustainability, while social sustainability consisted of three evaluation criteria and one risk factor. Ten evaluation criteria and five risk factors were relevant to technology sustainability. The criteria and risk factors in three sustainability dimensions could indicate the sustainable ITO for organizations in Thailand. In addition, these criteria had an inter-relationship, which was constructed with the Pearson Correlation Coefficient (PCC) analysis as called ANP structure. This structure was appropriate to the supplier selection problems in Thai business for ITO projects.

7.3.3 The Improved ANP Method in Supplier Selection

ANP-FA method was a main component in the ESS model. The method could synthesize the ANP structure to allocate the optimized weight values. The outcomes of ANP-FA method had fairness due to the synthesis process without human involvement. However, the method also sustained human knowledge and experience. Thus, ANP-FA had contributed to the MCDM method improvement as well as built transparency in the supplier selection problems. A detailed explanation of these two extra contributions in this study is subsequently presented.

7.3.3.1 The ANP method improvement

Generally, ANP method relied on domain experts to the weight allocation. This was the main reason why the weight values had faced unfairness. ANP method had improved with FA integration (ANP-FA) to eliminate the human for weight allocation. However, the optimized weight values also sustained human knowledge and experience. Thereby, the optimized weight values could adopt in real-world supplier selection problems. In addition, the optimized weight values could indicate the relationship among criteria. In the other words, ANP-FA could improve Analytic Hierarchy Process (AHP) method implicitly. This was because FA had automatically modified the judgment values in Pairwise Comparison Matrix (PCM), which PCM was also a crucial part of AHP method same ANP method.

7.3.3.2 The supplier selection improvement

Supplier selection became a key to supply chain management (SCM) but the outcome also suffered from human prejudices. ANP-FA had improved the supplier selection process in terms of optimized weight values allocation without humans' involvement. This was the main reason why the selection process had become transparent. On top of this, organizations had a transparent selection process in obtaining the right supplier for ITO project. This positive aspects affected the advantage of business competition and assisted in reducing corruption in the procurement section of the organizations.

7.4 Limitations and Future Directions

The limitations and future efforts that can be performed towards enhancing this study are discussed below:

- The ESS model identified 30 evaluation criteria on three sustainability dimensions: economic, social, and technology. There were also 12 risk factors included. The evaluation criteria were mapped against a similar meaning in each sustainability dimension. The process relied on the domain experts, so it occurred the bewilderment in the mapped against meaning similarity. In the future, an automatic tool mapped against the meaning similarity and dissimilarity can be used. The tools will reduce the bewilderment, and increase the accuracy for determining criteria when business and technology requirements changed.
- ESS model had highlighted the elimination of humans to allocate the weight values for the supplier selection problems. ANP-FA had been proposed to allocate the optimized weight values under the criteria interrelationship without humans' involvement. There were two conditions in the examination namely 1) CR and SB value was close to zero, and 2) similar priority of weight values. Nevertheless, ANP-FA faced a convergence problem of FA when there was a number of criteria more than four criteria in PCM. This was because a large bias value of each judgment value might occur throughout the searching process. This was the main reason why the convergence process was slow. Consequently, ANP-FA needs to improve in the future by only modifying the

large bias values in the searching process. Meanwhile, small bias values (close to zero) should not be changed. This might make the convergence process of FA occurring quickly.

REFERENCES

Abdullah, L., & Adawiyah, C. R. (2014). Simple additive weighting methods of multi criteria decision making and applications: A decade review. *International Journal of Information Processing and Management, 5*(1), 39.

Ageron, B., Gunasekaran, A., & Spalanzani, A. (2012). Sustainable supply management: An empirical study. *International Journal of Production Economics, 140*(1), 168-182. doi:10.1016/j.ijpe.2011.04.007

Ahmad, F., Saman, M. Y. M., Mohamad, F. S., Mohamad, Z., & Awang, W. S. W. (2014). Group decision support system based on enhanced AHP for tender evaluation. *International Journal of Digital Information and Wireless Communications (IJDIWC), 4*(2), 248-257.

Ahmadi, H., Nilashi, M., & Ibrahim, O. (2015). Organizational decision to adopt hospital information system: An empirical investigation in the case of Malaysian public hospitals. *International Journal of Medical Informatics, 84*(3), 166-188. doi:10.1016/j.ijmedinf.2014.12.004

Ahmadizadeh-Tourzani, N., Keramati, A., & Apornak, A. (2018). Supplier selection model using QFD-ANP methodology under fuzzy multi-criteria environment. *24*(1), 59-83.

Akomode, O. J., Lees, B., & Irgens, C. (1998). Constructing customised models and providing information to support IT outsourcing decisions. *Logistics Information Management, 11*(2), 114-127. doi:doi:10.1108/09576059810209973

Al-tarawneh, F. (2014). *A framework for cots software evaluation and selection for COTS mismatches handling and non-functional requirements.* (PhD), Universiti Utara Malaysia, 2014.

Alexandrova, M. (2012). IT outsourcing partnerships: Empirical research on key success factors in Bulgarian organizations. *Management: Journal of Contemporary Management Issues, 17*(2), 31-50.

Alexandrova, M. (2015). Risk Factors in IT Outsourcing Partnerships: Vendors' Perspective. *Global Business Review, 16*(5), 747-759. doi:doi:10.1177/0972150915591427

Alikhani, R., Torabi, S. A., & Altay, N. (2019). Strategic supplier selection under sustainability and risk criteria. *International Journal of Production Economics, 208*, 69-82. doi:doi.org/10.1016/j.ijpe.2018.11.018

Alonso, J. A., & Lamata, M. T. (2006). Consistency in the analytic hierarchy process: a new approach. *International journal of uncertainty, fuzziness and knowledge-based systems, 14*(04), 445-459.

Alpar, F. Z., & Lucian-Viorel, H. (2010). A Supplier Selection Model For Software Development Outsourcing. *Annals of Faculty of Economics, 1*(2), 1190-1195.

Amini, M. M., Hosseinalipour, M., & Monavvarian, A. (2017). Identification of critical success factors and organisational competencies in construction companies using an integrated model (a case study of NASR consortium). *International Journal of Business Excellence, 11*(3), 397-412. doi:10.1504/ijbex.2017.081933

Amri, R., & Saoud, N. B. B. (2014, 27-29 Aug. 2014). *Towards a Generic Sustainable Software Model.* Paper presented at the 2014 Fourth International Conference on Advances in Computing and Communications.

Aris, S. R. S., Arshad, N. H., & Mohamed, A. (2008). *Risk management practices in IT outsourcing projects.* Paper presented at the Information Technology, 2008. ITSim 2008. International Symposium on.

Azimifard, A., Moosavirad, S. H., & Ariafar, S. (2018). Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. *Resources Policy, 57*, 30-44. doi:10.1016/j.resourpol.2018.01.002

Azman, F. N., Zaibon, S. B., & Shiratuddin, N. (2018). *A revised production model of learner-generated comic: validation through expert review.* Paper presented at the MATEC web of conferences.

Banaeian, N., Mobli, H., Fahimnia, B., Nielsen, I. E., & Omid, M. (2018). Green supplier selection using fuzzy group decision making methods: A case study from the agri-food industry. *Computers & Operations Research, 89*, 337-347. doi:10.1016/j.cor.2016.02.015

Barrios, M. A. O., De Felice, F., Negrete, K. P., Romero, B. A., Arenas, A. Y., & Petrillo, A. (2016). An AHP-topsis integrated model for selecting the most appropriate tomography equipment. *International Journal of Information Technology and Decision Making, 15*(4), 861-885. doi:10.1142/S021962201640006X

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S. M., Penzenstadler, B., . . . Venters, C. C. (2016). Requirements: The Key to Sustainability. *IEEE Software, 33*(1), 56-65. doi:10.1109/MS.2015.158

Betz, S., & Caporale, T. (2014, 3-5 Dec. 2014). *Sustainable Software System Engineering.* Paper presented at the 2014 IEEE Fourth International Conference on Big Data and Cloud Computing.

Brundtland, G. H. (1987). *Report of the World Commission on environment and development:" our common future."*: United Nations.

Bu, X., & Xu, J. (2009, 20-22 Sept. 2009). *Developing a Decision Model for It Outsourcing Using Analytic Hierarchy Process.* Paper presented at the 2009 International Conference on Management and Service Science.

Çakır, S. (2017). Selecting the best supplier at a steel-producing company under fuzzy environment. *International Journal of Advanced Manufacturing Technology, 88*(5-8), 1345-1361. doi:10.1007/s00170-016-8861-4

Cao, J., Cao, G., & Wang, W. (2012). A hybrid model using analytic network process and gray relational analysis for bank's IT outsourcing vendor selection. *Kybernetes, 41*(7/8), 994-1013. doi:doi:10.1108/03684921211257847

Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management, 38*(5), 360-387. doi:doi:10.1108/09600030810882816

Cevere, R., & Gailums, A. (2017). Information Technology Sustainability Problems and Possible Solutions. *Baltic Journal of Modern Computing, 5*(1), 1.

Chakraborty, A., & Kar, A. K. (2017). Swarm Intelligence: A Review of Algorithms. In S. Patnaik, X.-S. Yang, & K. Nakamatsu (Eds.), *Nature-Inspired Computing and Optimization: Theory and Applications* (pp. 475-494). Cham: Springer International Publishing.

Chang, S.-I., Yen, D. C., Ng, C. S.-P., & Chang, W.-T. (2012). An analysis of IT/IS outsourcing provider selection for small- and medium-sized enterprises in Taiwan. *Information & Management, 49*(5), 199-209. doi:10.1016/j.im.2012.03.001

Chen, L. Y., & Wang, T.-C. (2009). Optimizing partners' choice in IS/IT outsourcing projects: The strategic decision of fuzzy VIKOR. *International Journal of Production Economics, 120*(1), 233-242. doi:10.1016/j.ijpe.2008.07.022

Chen, Y.-H., Wang, T.-C., & Wu, C.-Y. (2011). Strategic decisions using the fuzzy PROMETHEE for IS outsourcing. *Expert Systems with Applications, 38*(10), 13216-13222. doi:10.1016/j.eswa.2011.04.137

Chopra, S., & Sodhi, M. (2014). Reducing the risk of supply chain disruptions. *MIT Sloan Management Review, 55*(3), 72-80.

Cong, G., & Chen, T. (2015). A Novel Dynamic Algorithm for IT Outsourcing Risk Assessment Based on Transaction Cost Theory. *Discrete Dynamics in Nature and Society, 2015*, 10. doi:10.1155/2015/325890

De Boer, L., Labro, E., & Morlacchi, P. (2001). A review of methods supporting supplier selection. *European journal of purchasing & supply management, 7*(2), 75-89.

Dickson, G. W. (1996). An analysis of vendor selection systems and decisions. *Journal of Purchasing, 2,* 5-17.

Digalwar, A. K., Borade, A., & Metri, B. (2014). A Fuzzy AHP Approach for supplier selection. *Operations and Supply Chain Management, 7*(2), 46-53.

Dupont, L., Bernard, C., Hamdi, F., & Masmoudi, F. (2018). Supplier selection under risk of delivery failure: a decision-support model considering managers' risk sensitivity. *International Journal of Production Research, 56*(3), 1054-1069. doi:10.1080/00207543.2017.1364442

Ebrahimnejad, S., Naeini, M., Gitinavard, H., & Mousavi, S. M. (2017). Selection of IT outsourcing services' activities considering services cost and risks by designing an interval-valued hesitant fuzzy-decision approach. *Journal of Intelligent & Fuzzy Systems, 32*(6), 4081-4093.

Efe, B. (2016). An integrated fuzzy multi criteria group decision making approach for ERP system selection. *Applied Soft Computing, 38*, 106-117. doi:10.1016/j.asoc.2015.09.037

Elkhechafi, M., Benmamoun, Z., Hachimi, H., Amine, A., & Elkettani, Y. (2018). Firefly Algorithm for Supply Chain Optimization. *Lobachevskii Journal of Mathematics, 39*(3), 355-367. doi:10.1134/s1995080218030125

Ergu, D., Kou, G., Peng, Y., & Shi, Y. (2011). A simple method to improve the consistency ratio of the pair-wise comparison matrix in ANP. *European Journal of Operational Research, 213*(1), 246-259. doi:10.1016/j.ejor.2011.03.014

Ertuğrul, İ., & Karakaşoğlu, N. (2008). Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. *The International Journal of Advanced Manufacturing Technology, 39*(7), 783-795. doi:10.1007/s00170-007-1249-8

Estember, R. D., & Jacob, J. P. (2019, 12-15 April 2019). *Building a Decision Model for Outsourcing IT Services in Philippine Perspective.* Paper presented at the 2019 IEEE 6th International Conference on Industrial Engineering and Applications (ICIEA).

Faisal, M. N., & Raza, S. A. (2016). IT outsourcing intent in academic institutions in GCC countries: An empirical investigation and multi-criteria decision model for vendor selection. *Journal of Enterprise Information Management, 29*(3), 432-453. doi:doi:10.1108/JEIM-05-2015-0042

Fallahpour, A., Udoncy Olugu, E., Nurmaya Musa, S., Yew Wong, K., & Noori, S. (2017). A decision support model for sustainable supplier selection in sustainable supply chain management. *Computers & Industrial Engineering, 105*, 391-410. doi:10.1016/j.cie.2017.01.005

Fan, Z.-P., Suo, W.-L., & Feng, B. (2012). Identifying risk factors of IT outsourcing using interdependent information: An extended DEMATEL method. *Expert Systems with Applications, 39*(3), 3832-3840. doi:10.1016/j.eswa.2011.09.092

Fister, I., Fister Jr, I., Yang, X.-S., & Brest, J. (2013). A comprehensive review of firefly algorithms. *Swarm and Evolutionary Computation, 13*, 34-46. doi:10.1016/j.swevo.2013.06.001

Freeman, J., & Chen, T. (2015). Green supplier selection using an AHP-Entropy-TOPSIS framework. *Supply Chain Management: An International Journal, 20*(3), 327-340. doi:doi:10.1108/SCM-04-2014-0142

Fusiripong, P., Baharom, F., & Yusof, Y. (2017). Determining Multi-Criteria Supplier Selection towards Sustainable Development of IT Project Outsourcing. *International Journal of Supply Chain Management, 6*(3), 258-270.

Gai-Ge, W., Amir, H. G., Xin-She, Y., & Amir, H. A. (2014). A novel improved accelerated particle swarm optimization algorithm for global numerical optimization. *Engineering Computations, 31*(7), 1198-1220. doi:doi:10.1108/EC-10-2012-0232

Gao, J., & Shan, R. (2012). *A new method for modification consistency of the judgment matrix based on genetic ant algorithm.* Paper presented at the Multimedia Technology (ICMT), 2011 International Conference on.

Ghadimi, P., & Heavey, C. (2014). Sustainable Supplier Selection in Medical Device Industry: Toward Sustainable Manufacturing. *Procedia CIRP, 15*, 165-170. doi:10.1016/j.procir.2014.06.096

Girsang, A. S., Tsai, C.-W., & Yang, C.-S. (2015). Ant algorithm for modifying an inconsistent pairwise weighting matrix in an analytic hierarchy process. *Neural Computing and Applications, 26*(2), 313-327. doi:10.1007/s00521-014-1630-0

Girubha, J., Vinodh, S., & Kek, V. (2016). Application of interpretative structural modelling integrated multi criteria decision making methods for sustainable supplier selection. *Journal of Modelling in Management, 11*(2), 358-388. doi:doi:10.1108/JM2-02-2014-0012

Gölcük, İ., & Baykasoğlu, A. (2016). An analysis of DEMATEL approaches for criteria interaction handling within ANP. *Expert Systems with Applications, 46*, 346-366. doi:10.1016/j.eswa.2015.10.041

Gold, S., & Awasthi, A. (2015). Sustainable global supplier selection extended towards sustainability risks from (1+n)th tier suppliers using fuzzy AHP based approach. *IFAC-PapersOnLine, 48*(3), 966-971. doi:10.1016/j.ifacol.2015.06.208

Gonzalez, R., Gasco, J., & Llopis, J. (2005). Information systems outsourcing success factors: a review and some results. *Information Management & Computer Security, 13*(5), 399-418. doi:10.1108/09685220510627287

González, R., Gascó, J., & Llopis, J. (2016). Information Systems Outsourcing Reasons and Risks: Review and Evolution. *Journal of Global Information Technology Management, 19*(4), 223-249. doi:10.1080/1097198X.2016.1246932

Gorla, N., & Somers, T. M. (2014). The impact of IT outsourcing on information systems success. *Information & Management, 51*(3), 320-335. doi:10.1016/j.im.2013.12.002

Gottschalk, P., & Solli-Sæther, H. (2005). Critical success factors from IT outsourcing theories: an empirical study. *Industrial Management & Data Systems, 105*(6), 685-702. doi:10.1108/02635570510606941

Hamzah, A. K., Sulaiman, R., & Hussein, W. N. (2013, 27-28 Nov. 2013). *A review on IT outsourcing approach and a proposed IT outsourcing model for Malaysian SMEs in e-Business adoption.* Paper presented at the 2013 International Conference on Research and Innovation in Information Systems (ICRIIS).

Hanafizadeh, P. (2018). An empirical analysis on outsourcing decision: the case of e-banking services. *Journal of Enterprise Information Management, 31*(1), 146-172. doi:10.1108/JEIM-11-2016-0182

Hanafizadeh, P., & Zare Ravasan, A. (2017). An investigation into the factors influencing the outsourcing decision of e-banking services; a multi-perspective framework. *Journal of Global Operations and Strategic Sourcing*. doi:10.1108/JGOSS-05-2016-0016

Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: a literature review. *International Journal of Production Research, 53*(16), 5031-5069. doi:10.1080/00207543.2015.1030467

Hodosi, G., & Rusu, L. (2019). IT Outsourcing: Definition, Importance, Trends and Research. In *Risks, Relationships and Success Factors in IT Outsourcing: A Study in Large Companies* (pp. 1-9). Cham: Springer International Publishing.

Hossain, M. F., Adnan, Z. H., & Hasin, M. (2014). Improvement in weighting assignment process in Analytic Hierarchy Process by introducing suggestion matrix and Likert scale. *International Journal of Supply Chain Management, 3*(4).

Hsu, C.-C., Liou, J. J. H., & Chuang, Y.-C. (2013). Integrating DANP and modified grey relation theory for the selection of an outsourcing provider. *Expert Systems with Applications, 40*(6), 2297-2304. doi:10.1016/j.eswa.2012.10.040

Huang, T. C.-K., Chen, Y.-L., & Chang, T.-H. (2015). A novel summarization technique for the support of resolving multi-criteria decision making problems. *Decision Support Systems, 79*, 109-124. doi:10.1016/j.dss.2015.08.004

Ismail, F. F., & Razali, R. (2014, 23-24 Sept. 2014). *Contributing factors of successful software testing outsourcing.* Paper presented at the 2014 8th. Malaysian Software Engineering Conference (MySEC).

Jain, D. M., & Khurana, R. (2016). A framework to study vendors' contribution in a client vendor relationship in information technology service outsourcing in India. *Benchmarking: An International Journal, 23*(2), 338-358. doi:10.1108/BIJ-04-2014-0029

Jain, V., Sangaiah, A. K., Sakhuja, S., Thoduka, N., & Aggarwal, R. (2016). Supplier selection using fuzzy AHP and TOPSIS: a case study in the Indian automotive industry. *Neural Computing and Applications*. doi:10.1007/s00521-016-2533-z

Javani, B., & Rwelamila, P. M. D. (2016). Risk management in IT projects – a case of the South African public sector. *International Journal of Managing Projects in Business, 9*(2), 389-413. doi:doi:10.1108/IJMPB-07-2015-0055

Jayakrishna, K. V., K.E.K., & Vinodh, S. (2015). ANP based sustainable concept selection. *Journal of Modelling in Management*, *10*(1), 118-136. doi:10.1108/JM2-12-2012-0042

Kahraman, C., Beskese, A., & Kaya, I. (2010). Selection among ERP outsourcing alternatives using a fuzzy multi-criteria decision making methodology. *International Journal of Production Research, 48*(2), 547-566. doi:10.1080/00207540903175095

Kahraman, C., Engin, O., Kabak, Ö., & Kaya, İ. (2009). Information systems outsourcing decisions using a group decision-making approach. *Engineering*

Applications of Artificial Intelligence, 22(6), 832-841. doi:10.1016/j.engappai.2008.10.009

Karami, A., & Guo, Z. (2012, 4-7 Jan. 2012). *A Fuzzy Logic Multi-criteria Decision Framework for Selecting IT Service Providers.* Paper presented at the 2012 45th Hawaii International Conference on System Sciences.

Karthikeyan, S., Asokan, P., Nickolas, S., & Page, T. (2015). A hybrid discrete firefly algorithm for solving multi-objective flexible job shop scheduling problems. *International Journal of Bio-Inspired Computation*, *7*(6), 386-401.

Khairi, M. S., & Baridwan, Z. (2015). An empirical study on organizational acceptance accounting information systems in Sharia banking. *The International Journal of Accounting and Business Society, 23*(1), 97-122.

Khan, H., & Faisal, M. N. (2015). A Grey-based approach for ERP vendor selection in small and medium enterprises in Qatar. *International Journal of Business Information Systems, 19*(4), 465-487. doi:10.1504/IJBIS.2015.070205

Khan, S. U., Niazi, M., & Ahmad, R. (2010). *Critical success factors for offshore software development outsourcing vendors: an empirical study.* Paper presented at the International Conference on Product Focused Software Process Improvement.

Khatwani, G., & Kar, A. K. (2017). Improving the Cosine Consistency Index for the analytic hierarchy process for solving multi-criteria decision making problems. *Applied Computing and Informatics, 13*(2), 118-129. doi:10.1016/j.aci.2016.05.001

Kilic, H. S., Zaim, S., & Delen, D. (2015). Selecting "the best" ERP system for SMEs using a combination of ANP and PROMETHEE methods. *Expert Systems with Applications, 42*(5), 2343-2352. doi:10.1016/j.eswa.2014.10.034

Kobelsky, K. W., & Robinson, M. A. (2010). The impact of outsourcing on information technology spending. *International Journal of Accounting Information Systems, 11*(2), 105-119. doi:10.1016/j.accinf.2009.12.002

Kronawitter, K., Wentzel, C., & Papadaki, M. (2013, 7-10 Jan. 2013). *IT Application Outsourcing in Europe: Long-Term Outcomes, Success Factors and Implications for ITO Maturity*. Paper presented at the 2013 46th Hawaii International Conference on System Sciences.

Kucukaltan, B., Irani, Z., & Aktas, E. (2016). A decision support model for identification and prioritization of key performance indicators in the logistics industry. *Computers in Human Behavior, 65*, 346-358. doi:10.1016/j.chb.2016.08.045

Kuo, T., Hsu, C.-W., & Li, J.-Y. (2015). Developing a Green Supplier Selection Model by Using the DANP with VIKOR. *Sustainability, 7*(2), 1661.

Leimeister, S. (2010). *IT outsourcing governance: Client types and their management strategies*: Springer Science & Business Media.

Li, S., & Zeng, W. (2016). Risk analysis for the supplier selection problem using failure modes and effects analysis (FMEA). *Journal of Intelligent Manufacturing, 27*(6), 1309-1321. doi:10.1007/s10845-014-0953-0

Lima-Junior, F. R., & Carpinetti, L. C. R. (2016). A multicriteria approach based on fuzzy QFD for choosing criteria for supplier selection. *Computers & Industrial Engineering, 101*, 269-285. doi:10.1016/j.cie.2016.09.014

Lima Junior, F. R., Osiro, L., & Carpinetti, L. C. R. (2014). A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection. *Applied Soft Computing Journal, 21*, 194-209. doi:10.1016/j.asoc.2014.03.014

Lin, C.-T., Chen, C.-B., & Ting, Y.-C. (2011). An ERP model for supplier selection in electronics industry. *Expert Systems with Applications, 38*(3), 1760-1765. doi:10.1016/j.eswa.2010.07.102

Lin, C., Kou, G., & Ergu, D. (2014). A statistical approach to measure the consistency level of the pairwise comparison matrix. *Journal of the Operational Research Society*, *65*(9), 1380-1386. doi:10.1057/jors.2013.92

Lin, S.-W. (2016). The critical success factors for a travel application service provider evaluation and selection by travel intermediaries. *Tourism Management, 56*, 126-141. doi:10.1016/j.tourman.2016.03.028

Liu, H., Wang, Y., Tu, L., Ding, G., & Hu, Y. (2019). A modified particle swarm optimization for large-scale numerical optimizations and engineering design problems. *Journal of Intelligent Manufacturing, 30*(6), 2407-2433. doi:10.1007/s10845-018-1403-1

Liu, S., Chan, F. T. S., & Ran, W. (2016). Decision making for the selection of cloud vendor: An improved approach under group decision-making with integrated weights and objective/subjective attributes. *Expert Systems with Applications*, *55*, 37-47. doi:10.1016/j.eswa.2016.01.059

Liu, W., & Quan, L. (2013). *A multi-criteria decision making method based on linguistic preference information for IT outsourcing vendor selection in hospitals.* Paper presented at the International Conference on Information, Business and Education Technology.

Loh, L., & Venkatraman, N. (1992). Determinants of Information Technology Outsourcing: A Cross-Sectional Analysis. *Journal of Management Information Systems, 9*(1), 7-24. doi:10.1080/07421222.1992.11517945

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production, 140, Part 3*, 1686-1698. doi:10.1016/j.jclepro.2016.09.078

Macharis, C., Springael, J., De Brucker, K., & Verbeke, A. (2004). PROMETHEE and AHP: The design of operational synergies in multicriteria analysis.: Strengthening PROMETHEE with ideas of AHP. *European Journal of Operational Research, 153*(2), 307-317. doi:doi.org/10.1016/S0377-2217(03)00153-X

Manivel, P., & Ranganathan, R. (2019). An efficient supplier selection model for hospital pharmacy through fuzzy AHP and fuzzy TOPSIS. *33*(4), 468-493.

Mardani, A., Jusoh, A., MD Nor, K., Khalifah, Z., Zakwan, N., & Valipour, A. (2015). Multiple criteria decision-making techniques and their applications–a review of the literature from 2000 to 2014. *Economic Research-Ekonomska Istraživanja, 28*(1), 516-571.

Marnewick, C. (2017). Information system project's sustainability capabality levels. *International Journal of Project Management, 35*(6), 1151-1166. doi:10.1016/j.ijproman.2017.02.014

Martens, B., & Teuteberg, F. (2009). Why risk management matters in IT outsourcing-A systematic literature review and elements of a research agenda.

Mohd Zukhi, M., Hussain, A., & Husni, H. (2020). Culturicon Design Model for Social Mobile Application. In: International Association of Online Engineering.

Montenegro, C., Nuñez, N., & Larco, A. (2017). IT Outsourcing Improvement: Contractual Model of Governance and Management from Customer Perspective. In Á. Rocha, A. M. Correia, H. Adeli, L. P. Reis, & S. Costanzo

(Eds.), *Recent Advances in Information Systems and Technologies: Volume 1* (pp. 616-627). Cham: Springer International Publishing.

Morais, D. C., Costa, A. P. C. S., & de Almeida, A. T. (2014). Group Decision Model for Outsourcing IT Services. *Procedia Technology, 16*, 562-568. doi:10.1016/j.protcy.2014.10.004

Mukherjee, S., & Mukherjee, K. (2015). Selection decisions of offshore ITO service providers for strategic alliances - An AHP-based approach. *International Journal of Business Information Systems, 20*(2), 238-269. doi:10.1504/IJBIS.2015.071541

Nazari-Shirkouhi, S., Miri-Nargesi, S., & Ansarinejad, A. (2017). A fuzzy decision making methodology based on fuzzy AHP and fuzzy TOPSIS with a case study for information systems outsourcing decisions. *Journal of Intelligent & Fuzzy Systems*(Preprint), 1-23.

Nduwimfura, P., & Zheng, J. (2015a). A Model for Offshore Information Systems Outsourcing Provider Selection in Developing Countries. *International Business Research, 8*(7), 68.

Nduwimfura, P., & Zheng, J. (2015b). A Review of Risk Management for Information Systems Outsourcing. *International Journal of Business, Humanities and Technology, 5*(4), 28 - 33.

Nilashi, M., Ahmadi, H., Ahani, A., Ravangard, R., & Ibrahim, O. b. (2016). Determining the importance of Hospital Information System adoption factors using Fuzzy Analytic Network Process (ANP). *Technological Forecasting and Social Change, 111*, 244-264. doi:10.1016/j.techfore.2016.07.008

Nourmohamadi Shalke, P., Paydar, M. M., & Hajiaghaei-Keshteli, M. (2018). Sustainable supplier selection and order allocation through quantity discounts.

International Journal of Management Science and Engineering Management, 13(1), 20-32. doi:10.1080/17509653.2016.1269246

Özdemir, A., & Tüysüz, F. (2017). An integrated fuzzy DEMATEL and fuzzy ANP based balanced scorecard approach: Application in Turkish higher education institutions. *Journal of Multiple-Valued Logic and Soft Computing, 28*(2-3), 251-287.

Oztaysi, B. (2015). A group decision making approach using interval type-2 fuzzy ahp for enterprise information systems project selection. *Journal of Multiple-Valued Logic and Soft Computing, 24*(5-6), 475-500.

Öztürk, B. A., & Özçelik, F. (2014). Sustainable supplier selection with a fuzzy multi-criteria decision making method based on triple bottom line. *5*(3), 129.

Penzenstadler, B. (2013). *Towards a definition of sustainability in and for software engineering*. Paper presented at the Proceedings of the 28th Annual ACM Symposium on Applied Computing, Coimbra, Portugal.

Penzenstadler, B., Bauer, V., Calero, C., & Franch, X. (2012). Sustainability in software engineering: a systematic literature review. *IET Conference Proceedings*, 32-41. digital-library.theiet.org/content/conferences/10.1049/ic.2012.0004

Persis, D. J., & Robert, T. P. (2016). Reliable mobile ad-hoc network routing using firefly algorithm. *International Journal of Intelligent Systems and Applications, 8*(5), 10-18. doi:10.5815/ijisa.2016.05.02

PrasannaVenkatesan, S., & Goh, M. (2016). Multi-objective supplier selection and order allocation under disruption risk. *Transportation Research Part E: Logistics and Transportation Review, 95,* 124-142. doi:doi.org/10.1016/j.tre.2016.09.005

Qi, C., & Chau, P. Y. K. (2015). Relationship or contract? Exploring the key factor leading to IT outsourcing success in China. *Information Technology & People, 28*(3), 466-499. doi:10.1108/ITP-10-2014-0236

Qiang, R., & Li, D. (2015). An Inhomogeneous Multi-Attribute Decision Making Method and Application to IT/IS Outsourcing Provider Selection. *International Journal of Industrial Engineering, 22*(2).

Rabbani, M., Foroozesh, N., Mousavi, S. M., & Farrokhi-Asl, H. (2017). Sustainable supplier selection by a new decision model based on interval-valued fuzzy sets and possibilistic statistical reference point systems under uncertainty. *International Journal of Systems Science: Operations & Logistics*, 1-17. doi:10.1080/23302674.2017.1376232

Raisian, K., Yahaya, J., & Deraman, A. (2017). Sustainable software development life cycle process model based on capability maturity model integration: A study in Malaysia. *Journal of Theoretical & Applied Information Technology, 95*(21).

Ramanathan, L., & Krishnan, S. (2015). An empirical investigation into the adoption of open source software in Information Technology outsourcing organizations. *Journal of Systems and Information Technology, 17*(2), 167-192. doi:10.1108/JSIT-10-2014-0070

Rao, C., Goh, M., & Zheng, J. (2017). Decision Mechanism for Supplier Selection Under Sustainability. *International Journal of Information Technology & Decision Making, 16*(01), 87-115. doi:10.1142/s0219622016500450

Rao, C., Xiao, X., Goh, M., Zheng, J., & Wen, J. (2017). Compound mechanism design of supplier selection based on multi-attribute auction and risk management of supply chain. *Computers & Industrial Engineering, 105*, 63-75. doi:10.1016/j.cie.2016.12.042

Repschlaeger, J., Proehl, T., & Zarnekow, R. (2014). Cloud service management decision support: An application of AHP for provider selection of a cloud-based IT service management system. *Intelligent Decision Technologies, 8*(2), 95-110. doi:10.3233/IDT-130181

Rezaeisaray, M., Ebrahimnejad, S., & Khalili-Damghani, K. (2016). A novel hybrid MCDM approach for outsourcing supplier selection: A case study in pipe and fittings manufacturing. *Journal of Modelling in Management, 11*(2), 536-559. doi:doi:10.1108/JM2-06-2014-0045

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology, 15*(3), 234-281. doi:10.1016/0022-2496(77)90033-5

Saaty, T. L. (1980). Analytic Heirarchy Process. *Wiley StatsRef: Statistics Reference Online*.

Saaty, T. L. (1999). *Fundamentals of the analytic network process*.

Saaty, T. L. (2004). Fundamentals of the analytic network process — Dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering, 13*(2), 129-157. doi:10.1007/s11518-006-0158-y

Saaty, T. L. (2013). Analytic hierarchy process. In *Encyclopedia of operations research and management science* (pp. 52-64): Springer.

Salam, M., & Khan, S. U. (2016, 26-28 Aug. 2016). *Developing green and sustainable software: Success factors for vendors.* Paper presented at the 2016 7th IEEE International Conference on Software Engineering and Service Science (ICSESS).

Samantra, C., Datta, S., & Mahapatra, S. S. (2014). Risk assessment in IT outsourcing using fuzzy decision-making approach: An Indian perspective. *Expert Systems with Applications, 41*(8), 4010-4022. doi:10.1016/j.eswa.2013.12.024

Secundo, G., Magarielli, D., Esposito, E., & Passiante, G. (2017). Supporting decision-making in service supplier selection using a hybrid fuzzy extended AHP approach: A case study. *Business Process Management Journal, 23*(1), 196-222. doi:doi:10.1108/BPMJ-01-2016-0013

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*: John Wiley & Sons.

Senvar, O., Tuzkaya, G., & Kahraman, C. (2014) Multi criteria supplier selection using fuzzy PROMETHEE method. In*: Vol. 313. Studies in Fuzziness and Soft Computing* (pp. 21-34).

Sharma, V. K., Chandna, P., & Bhardwaj, A. (2017). Green supply chain management related performance indicators in agro industry: A review. *Journal of Cleaner Production, 141*, 1194-1208. doi:doi.org/10.1016/j.jclepro.2016.09.103

Shayeghi, H., & Alilou, M. (2015). Application of Multi Objective HFAPSO algorithm for Simultaneous Placement of DG, Capacitor and Protective Device in Radial Distribution Network. *Journal of Operation and Automation in Power Engineering, 3*(2), 131-146.

Shomalnasab, F., Sadeghzadeh, M., & Esmaeilpour, M. (2014). An optimal similarity measure for collaborative filtering using firefly algorithm. *Journal of Advances in Computer Research, 5*(3), 101-111.

Silva, L. C. e., Gusmão, A. P. H. d., Silva, M. M., Poleto, T., & Costa, A. P. C. S. (2015, 9-12 Oct. 2015). *Analysis of IT Outsourcing Services Failures Based on an*

Existing Risk Model. Paper presented at the 2015 IEEE International Conference on Systems, Man, and Cybernetics.

Smuts, H., Kotzé, P., van der Merwe, A., & Loock, M. (2015, 14-15 Oct. 2015). *Threats and Opportunities for Information Systems Outsourcing.* Paper presented at the 2015 International Conference on Enterprise Systems (ES).

Smuts, H., Merwe, A. v. d., Kotz, P., & Loock, M. (2010). *Critical success factors for information systems outsourcing management: a software development lifecycle view*. Paper presented at the Proceedings of the 2010 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists, Bela Bela, South Africa.

Sobinska, M., & Willcocks, L. (2016). IT outsourcing management in Poland – trends and performance. *Strategic Outsourcing: An International Journal, 9*(1), 60-96. doi:10.1108/SO-10-2015-0024

Sofia, O., Luis, F. A. J., Ambrosio, T., José, Rivera P., & Ali, I. (2017). Sustainability requirements for connected health applications. *Journal of Software: Evolution and Process, 0*(0), e1922. doi:doi:10.1002/smr.1922

Song, W., Ming, X., & Liu, H.-C. (2017). Identifying critical risk factors of sustainable supply chain management: A rough strength-relation analysis method. *Journal of Cleaner Production, 143*, 100-115. doi:doi.org/10.1016/j.jclepro.2016.12.145

Srivastav, A., & Agrawal, S. (2017). Multi-Objective Optimization of Slow Moving Inventory System Using Cuckoo Search. *Intelligent Automation & Soft Computing*, 1-7. doi:10.1080/10798587.2017.1293891

Sukru Cetinkaya, A., Ergul, M., & Uysal, M. (2014). Quality of relationship on information technology outsourcing for organizational success in hospitality industry. *Journal of Hospitality and Tourism Technology, 5*(3), 229-244. doi:10.1108/JHTT-07-2014-0027

Tangadulrat, P. (2010). Analytical hierarchy process application in software outsource selection : a case study of IT service provider company. *Master Independent Study*.

Thakur, V., & Anbanandam, R. (2015). Supplier selection using grey theory: a case study from Indian banking industry. *Journal of Enterprise Information Management, 28*(6), 769-787. doi:doi:10.1108/JEIM-07-2014-0075

Tjader, Y., May, J. H., Shang, J., Vargas, L. G., & Gao, N. (2014). Firm-level outsourcing decision making: A balanced scorecard-based analytic network process model. *International Journal of Production Economics, 147, Part C,* 614-623. doi:10.1016/j.ijpe.2013.04.017

Tooranloo, H. S., Ayatollah, A. S., & Karami, M. (2018). IT outsourcing through group decision-making based on the principles of interval-valued intuitionistic fuzzy theory. *11*(1), 96-112.

Triantaphyllou, E. (2000). Multi-criteria decision making methods: a comparative study. *Netherland: Kluwer Academic Publication*.

Uthayakumar, J., Metawa, N., Shankar, K., & Lakshmanaprabu, S. K. (2020). Financial crisis prediction model using ant colony optimization. *International Journal of Information Management, 50,* 538-556. doi:10.1016/j.ijinfomgt.2018.12.001

Uygun, Ö., Kaçamak, H., & Kahraman, Ü. A. (2015). An integrated DEMATEL and Fuzzy ANP techniques for evaluation and selection of outsourcing provider for a telecommunication company. *Computers and Industrial Engineering, 86,* 137-146. doi:10.1016/j.cie.2014.09.014

Varajão, J., Cruz-Cunha, M. M., & da Glória Fraga, M. (2017). IT/IS Outsourcing in Large Companies – Motivations and Risks. *Procedia Computer Science, 121*, 1047-1061. doi:10.1016/j.procs.2017.11.135

Venters, C. C., Capilla, R., Betz, S., Penzenstadler, B., Crick, T., Crouch, S., . . . Carrillo, C. (2018). Software sustainability: Research and practice from a software architecture viewpoint. *Journal of Systems and Software, 138*, 174-188. doi:doi.org/10.1016/j.jss.2017.12.026

Vinodh, S., Patil, A., Sai Balagi, T. S., & Sundara Natarajan, P. (2014). AHP-PROMETHEE integrated approach for agile concept selection. *International Journal of Services and Operations Management, 18*(4), 449-467. doi:10.1504/IJSOM.2014.063245

Wang, G. (2018). *A comparative study of cuckoo algorithm and ant colony algorithm in optimal path problems.* Paper presented at the MATEC web of conferences.

Wang, J.-J., Lin, Z.-K., & Huang, H. (2008). A Decision Model for Information Systems Outsourcing: Using a Multicriteria Method. *Journal of Service Science and Management, Vol.01No.01*, 9. doi:10.4236/jssm.2008.11001

Wang, J.-J., Lin, Z.-K., & Zhang, G.-Q. (2008). *A Decision Model for IS Outsourcing Based on AHP And ELECTREIII.* Paper presented at the Wireless Communications, Networking and Mobile Computing, 2008. WiCOM'08. 4th International Conference on.

Wang, J.-J., & Yang, D.-L. (2007). Using a hybrid multi-criteria decision aid method for information systems outsourcing. *Computers & Operations Research, 34*(12), 3691-3700. doi:10.1016/j.cor.2006.01.017

Watjatrakul, B. (2014). Vendor selection strategy for IT outsourcing: the weighted-criteria evaluation technique. *Journal of Enterprise Information Management, 27*(2), 122-138. doi:10.1108/JEIM-04-2012-0015

Yadav, V., & Sharma, M. K. (2015). Multi-criteria decision making for supplier selection using fuzzy AHP approach. *Benchmarking: An International Journal, 22*(6), 1158-1174. doi:doi:10.1108/BIJ-04-2014-0036

Yadav, V., & Sharma, M. K. (2016). Multi-criteria supplier selection model using the analytic hierarchy process approach. *Journal of Modelling in Management, 11*(1), 326-354. doi:doi:10.1108/JM2-06-2014-0052

Yang, C., & Huang, J.-B. (2000). A decision model for IS outsourcing. *International Journal of Information Management, 20*(3), 225-239. doi:10.1016/S0268-4012(00)00007-4

Yang, I. T., Wang, W.-C., & Yang, T.-I. (2012). Automatic repair of inconsistent pairwise weighting matrices in analytic hierarchy process. *Automation in Construction, 22*(Supplement C), 290-297. doi:10.1016/j.autcon.2011.09.004

Yang, L., & Peng, J. (2012). Comprehensive evaluation for selecting is/it outsourcing vendors based on ahp. *Journal of Information & Computational Science, 9*(9), 2515-2525.

Yang, X.-S. (2008). Firefly algorithm. *Nature-inspired metaheuristic algorithms, 20*, 79-90.

Yang, X.-S. (2010). *Nature-inspired metaheuristic algorithms*: Luniver press.

Yimin, Z., Keqing, G., & Zeshu, W. (2016). *Study on evaluation model of cross-border e-commerce talent based on AHP-PSO.* Paper presented at the Information Management (ICIM), 2016 2nd International Conference on.

Yoon, J., Talluri, S., Yildiz, H., & Ho, W. (2018). Models for supplier selection and risk mitigation: a holistic approach. *International Journal of Production Research, 56*(10), 3636-3661. doi:10.1080/00207543.2017.1403056

Yuce, B., & Mastrocinque, E. (2015). A hybrid approach using the Bees Algorithm and Fuzzy-AHP for supplier selection. *Handbook of Research on Advanced Computational Techniques for Simulation-Based Engineering, 171*.

Zavadskas, E. K., Govindan, K., Antucheviciene, J., & Turskis, Z. (2016). Hybrid multiple criteria decision-making methods: a review of applications for sustainability issues. *Economic Research-Ekonomska Istraživanja, 29*(1), 857-887. doi:10.1080/1331677X.2016.1237302

Zhang, X., & Dai, W. (2016). An empirical study of China's financial risk early warning based on PSO-AHP method. *International Journal of Smart Home, 10*(1), 71-80.

Zhang, X., Deng, Y., Chan, F. T., Adamatzky, A., & Mahadevan, S. (2016). Supplier selection based on evidence theory and analytic network process. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 230*(3), 562-573. doi:doi:10.1177/0954405414551105

Zhong, Y., Jian, L., & Zijun, W. (2009). An integrated optimization algorithm of GA and ACA-based approaches for modeling virtual enterprise partner selection. *ACM SIGMIS Database: the DATABASE for Advances in Information Systems, 40*(2), 37-56.

Zhu, B., Xu, Z., Zhang, R., & Hong, M. (2015). Generalized analytic network process. *European Journal of Operational Research, 244*(1), 277-288. doi:10.1016/j.ejor.2015.01.011

Appendix A

The Objectives and Sources for Instrument Development

Sections	objectives	questions	contents	references
I: DEMOGRAPHIC INFORMATION	To assess the qualification of respondents	1	Position in organization	Ageron et al. (2012); Ahmadi, Nilashi, and Ibrahim (2015)
		2	Years of experience	Ramanathan and Krishnan (2015)
	To study the organizational background	3	organization's business	Faisal and Raza (2016); Lin (2016); Thakur and Anbanandam (2015)
II: SUPPIER SELECTION PRACTICES	To investigate the committee used in supplier selection of IT outsourcing	4	Organization's department	Faisal and Raza (2016); Thakur and Anbanandam (2015); Yadav and Sharma (2016)

Sections	objectives	questions	contents	references
	To investigate the decision structure used in supplier selection of IT outsourcing	5	Decision structure	-
	To investigate the decision method used in supplier selection of IT outsourcing	6	Decision-making method	-
III: PRIORITY OF CRITERIA AND RISK FACTORS ON SUSTAINABLE IT OUTSOURCING FOR SUPPLIER SELECTION PROBLEM	To investigate the sustainability perspectives used in supplier selection of IT outsourcing	7	Sustainability perspectives	Literature review in Table 2.4
	To investigate the frequency used of evaluation criteria in supplier selection of IT outsourcing	8	Evaluation criteria practices	Literature review in Table 2.6

Sections	objectives	questions	contents	references
	To investigate the evaluation criteria that associated with sustainability perspectives	9	Evaluation criterion have associated on sustainability perspectives	Literature review in Table 2.4 and Table 2.6
	To investigate the frequency used of risk factors in supplier selection of IT outsourcing	10	Risk factors practices	Literature review in Table 2.10
	To investigate the risk factors that associated with sustainability perspectives	11	Risk factors have associated on sustainability perspectives	Literature review in Table 2.4 and Table 2.10
	To investigate the evaluation criteria that influenced on three sustainability perspectives	12	Evaluation criteria have influenced on economic, social, and technology sustainability.	Literature review in Table 2.4 and Table 2.6

Sections	objectives	questions	contents	references
	To investigate the risk factors that influenced on three sustainability perspectives	13	Risk factors have influenced on economic, social, and technology sustainability	Literature review in Table 2.4 and Table 2.10
IV: IMPORTANCE LEVEL OF THE CRITERIA AND RISK FACTORS	To investigate the important level of evaluation criteria	14	Evaluation criteria practice	Literature review in Table 2.6
	To investigate the important level of risk factors	15	Risk factors practices	Literature review in Table 2.10

Appendix B

The Instrument

Pusat Pengajian Pengkomputeran
School of Computing
Universiti Utara Malaysia

COLLEGE OF ARTS AND SCIENCES

A SURVEY ON THE CURRENT PRACTICE OF SUPPLIER SELECTION PROCESS TOWARDS SUSTAINABILITY IN IT PROJECT OUTSOURCING

Dear respondents,

We are conducting a survey on the current practices of supplier selection process towards sustainability of IT project outsourcing. The objectives of this survey are:

1. To study the current practices of supplier selection process for IT project outsourcing among Thailand practitioners.
2. To investigate the practitioners' opinion on the evaluation criteria and risk factors regarding sustainability perspectives that need to be considered for supplier selection process.
3. To determine the importance level of the supplier selection criteria and risk factors.

This survey consists of 4 sections:

Section I: Demographic information

Section II: Supplier selection practices in IT outsourcing

Section III: Priority of the evaluation criteria and risk factors regarding sustainability adopting in supplier selection of IT outsourcing

Section IV: The importance levels of the evaluation criteria and risk factors for supplier selection of IT outsourcing.

We would appreciate if you could answer the questions carefully and correctly. It will take around 30 minutes to complete the questionnaire. **<u>All answer will be treated as strictly confidential and will be used for purpose of the study only.</u>** If you have any questions regarding this research, please contact me via email or phone. Thank you for your cooperation and the time taken in answering this questionnaire.

Mr. Prashaya Fusiripong

+66-947-978-142 / prashaya.f@rsu.ac.th

Respondent's name ………………………………………………………………………………	
Company's name ………………………………………………………………………………	
Phone number ……………………………………………	Fax number ……………………………………………
Email ……………………………………………	Date ……………………………………………
Company's website ………………………………………………………………………………	

Section I: Demographic Information

Respondent's Background

1. Your current position in your company.
   - [ ] Planning and strategy manager
   - [ ] Finance manager
   - [ ] Purchasing manager
   - [ ] Information technology director
   - [ ] IT project manager
   - [ ] IT team leader
   - [ ] Other (Please specify) …………………………………....

2. Year of experience participating in the supplier selection of IT outsourcing.
   - [ ] Under 2 years
   - [ ] 2 - 5 years
   - [ ] 5 - 8 years
   - [ ] 8 - 12 years
   - [ ] 12 - 20 years
   - [ ] Over 20 years

Organization's Background

3. Type of organization.
   - [ ] Construction
   - [ ] Healthy / Food & Beverage
   - [ ] Electronic and Information Technology
   - [ ] Travelling / Hotel & Restaurant
   - [ ] Manufacturing
   - [ ] Logistics
   - [ ] Advertising & Creative Media
   - [ ] Cosmetics / Jewelry
   - [ ] Other (Please specify)..

Section II: Supplier Selection Practices in IT Project Outsourcing

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4. Which the organization's department should be significant a part of the purchasing committee for supplier selection in IT outsourcing? **(You can tick more than one item)**
   - [ ] Financial department
   - [ ] Information Technology department
   - [ ] IT project stakeholder
   - [ ] Purchasing department
   - [ ] Planning and strategic department

5. Which of the following decision structure is necessary to be adopted on the supplier selection process in IT outsourcing?

[ ] Independent factors structure

[ ] Dependent factors structure

[ ] Only cost-benefit / financial

6. Which of the proper method should be adopted on the supplier selection process for the IT outsourcing?

[ ] Grey Theory Method

[ ] Analytic Hierarchy Process (AHP) Method

[ ] Analytic Network Process (ANP) Method

[ ] Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

[ ] Perference Ranking Organization MEHTod for Enrichment Evaluations (PROMETHEE)

[ ] Other (Please Specify)…………………………………………………….

Section III: Priority of the evaluation criteria and risk factors regarding sustainability adopting in supplier selection of IT outsourcing.

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7. Please indicate the following sustainability that is important for supplier selection of IT outsourcing **(You can tick more than one item)**.

[ ] Economic

The strategic, management and operation in IT outsourcing are strong to reduce the undesirable expenditure for improving the quality of IT products and services under the supplier performance to customer satisfaction

[ ] Environment

The using IT infrastructure (hardware) is without a negative impact on the environment

[ ] Social

The working collaboration of stakeholders (organization and supplier) to the operation and management under the different culture and/or language along with the organization's staff welfare

[ ] Technology

The high experts' capability is to develop, operate and maintain in the longevity of IT system efficiency along with improving the IT system, but without negatively impact the natural from IT infrastructure

8. Please indicate your opinion on the use of the following evaluation criteria in the supplier selection of IT outsourcing **(You can tick more than one item)**.

Evalaution criteria

[ ] Economic
Reduce expenditure and increase finance capability for the reinvestment

[ ] Quality
Ability in providing the higher technology to the organization toward the performed business in future

[ ] Service
Be able to support the relevant information and technology as well as to consult the IT system

[ ] Performance / Performance history
Achievement of the supplier performed in IT project in the past

[ ] Management
Manageable and understanding for organization's staff to support the supplier

[ ] Strategy
Supporting mechanism for outsourcing activity

[ ] Cost / Price
Consider the reasonable price when employ the supplier for IT outsourcing; including the investment value

[ ] Finance
Cash flow of supplier; included the external economy impacted

[ ] Delivery
Solution delivery on time (as followed contact)

[ ] Satisfaction / Responsiveness
Ability of the supplier's responsibility to solve the problems of IT system to reduce impacting the customers' satisfaction

[ ] Flexibility
Elastic in the performed when the business and technology change

[ ] Contact management
Appropriate the time period for employing the supplier

[ ] Market leadership
Leader of the specific IT solution is in the market such as SAP

[ ] Market sharing
Leader revenue of the specific IT solution is in the market such as SAP

[ ] Social
The effectiveness of working collaboration between organization and supplier as well as the quality of life of employee

[ ] Culture and language
Organization's culture and communication language

Evalaution criteria

[ ] Relationship and communication process
Understandable the working collaboration in operation and management level

[ ] Reliability and usability
Trustiness of suppliers' capability

[ ] Resource
Human behaviors

[ ] Technology
The capability of supplier both technical knowledge and business process for information technology; including the use of IT infrastructure without a negative impact on the nature

[ ] Technical capability and experts
IT specialist capability in terms of technical (IT system)

[ ] Configuration
Ability to config between the existing and the new system by not impacting the current implementation

[ ] Disaster Recovery
Ability to support the unexpected occurrence to recover the system

[ ] Information and system security
Ability to secure planning and restore rapidly

[ ] Information and system integrated compatibility
Ability to manage and operate the existing system with the new system

[ ] Maintenance and innovation of business
Ability to maintained the IT system supported business innovation

[ ] Assets
Ability to prepare the state-of-art IT infrastructure and tools in supporting requirements

[ ] Experience
More experience in IT project management

[ ] Knowledge of the industry
Understandable business process and requirement

[ ] Research and development
Ability to investe and learn innovative solution

9. Please indicate your opinion on the relevance of the following the evaluation criteria for sustainability in the supplier selection of IT project outsourcing **(You can tick more than one item)**.

Evaluation criteria	**Economic**	**Environment**	**Social**	**Technology**
Economic				
Quality				
Service				

Evaluation criteria	Economic	Environment	Social	Technology
Performance / Performance history				
Management				
Strategy				
Cost / Price				
Finance				
Delivery				
Satisfaction / Responsiveness				
Flexibility				
Contact management				
Market leadership				
Market sharing				
Social				
Culture and language				
Relationship and communication process				
Reliability and usability				
Resource				
Technology				
Technical capability and experts				
Configuration				
Disaster recovery				
Information and system security				
Information and system integrated compatibility				
Maintenance and innovation of business				
Assets				
Experience				
Knowledge of the industry				
Research and Development				

10. Please indicate your opinion on the use of the following risk factors in the supplier selection of IT project outsourcing **(You can tick more than one item)**.

Risk factors

[ ] IT outsourcing policy
Uncertainty of the organization's policy for IT outsourcing activity

Risk factors

[ ] IT outsourcing management
Ineffective management plan and non-support from the management level

[ ] Cost management and unexpected cost
An hidden cost and unexpected budget occurrence such as over the contract, exchange rate changed, inflation, and so on

[ ] IT staff and turnover activity
Inability of supplier's staff that included turnover rate

[ ] Organization's culture and language
Miscommunication and non-understanding in different culture and language

[ ] Quality of IT products and services
A low qualification from an agreement in the contract

[ ] Knowledge of business process and new technology
Deficiency of the transferring requirement inefficiency and learning new technology

[ ] Technology complexity
Changed the legacy system to support the current business competition

[ ] Security of data accessibility
Neglected the security policy for private data accessibility

[ ] Changing business and technical requirement
Unreasonable and unclear in the organization's requirement for performing IT project

[ ] Working collaboration
Lack of working collaboration such as no sharing important information, no trust the capability each other

[ ] Supplier's image
Negatively contribution such as leave the project, non-delivery project on-time

11. Please indicate your opinion on the relevance of the following the risk factors for sustainability in the supplier selection of IT project outsourcing **(You can tick more than one item)**.

Risk Factors	Economic	Environment	Social	Technology
IT outsourcing policy				
IT outsourcing management				
Cost management and unexpected cost				
IT staff and turnover activity				
Organization's culture and language				

Risk Factors	**Economic**	**Environment**	**Social**	**Technology**
Quality of IT products and services				
Knowledge of business process and new technology				
Technology complexity				
Security of data accessibility				
Changing business and technical requirement				
Working collaboration				
Supplier's image				

12. Please indicate your opinion on the influencing of the following evaluation criteria for each sustainability in supplier selection of IT project outsourcing **(You can tick more than one item)**.

Evaluation criteria used in the supplier selection of IT project outsourcing	**Strongly disagree**				**Strongly agree**
	1	**2**	**3**	**4**	**5**
1. Importance of ***Economic*** in supplier selection of IT project outsourcing.					
1.1 ***Quality*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.2 ***Service*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.3 ***Performance/Performance history*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.4 ***Management*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.5 ***Strategy*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.6 ***Cost/Price*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					

Evaluation criteria used in the supplier selection of IT project outsourcing	Strongly disagree				Strongly agree
	1	2	3	4	5
1.7 ***Finance*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.8 ***Delivery*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.9 ***Satisfaction/Responsiveness*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.10 ***Flexibility*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.11 ***Contact management*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.12 ***Market leadership*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.13 ***Market sharing*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
2. Importance of ***Social*** in supplier selection of IT project outsourcing.					
2.1 ***Culture and language*** has influenced on ***social*** in supplier selection of IT project outsourcing.					
2.2 ***Relationship and communication process*** has influenced on ***social*** in supplier selection of IT project outsourcing.					
2.3 ***Reliability and usability*** has influenced on ***social*** in supplier selection of IT project outsourcing.					
2.4 ***Resource*** has influenced on ***social*** in supplier selection of IT project outsourcing.					
3. Importance of ***Technology*** in supplier selection of IT project outsourcing.					

Evaluation criteria used in the supplier selection of IT project outsourcing	Strongly disagree				Strongly agree
	1	2	3	4	5
3.1 ***Technical capability and experts*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.2 ***Configuration*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.3 ***Disaster recovery*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.4 ***Information and system security*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.5 ***Information and system integrated compatibility*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.6 ***Maintenance and innovation of business*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.7 ***Asset*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.8 ***Experience*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.9 ***Knowledge of the industry*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.10 ***Research and development*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					

13. Please indicate your opinion on the influencing of the following risk factors for each sustainability in supplier selection of IT project outsourcing **(You can tick more than one item)**.

Risk factors used in the supplier selection of IT project outsourcing	**Strongly disagree**				**Strongly agree**
	1	**2**	**3**	**4**	**5**
1. Importance of ***Economic*** in supplier selection of IT project outsourcing					
1.1 ***IT outsourcing policy*** has influenced on ***economic*** in supplier selection of IT project outsourcing.					
1.2 ***IT outsourcing management*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.3 ***Cost management/unexpected cost*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.4 ***IT staff and turnover activity*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.5 ***Organization's culture and language*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.6 ***Quality of IT products and services*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.7 ***Knowledge of business process and new technology*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.8 ***Technology complexity*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.9 ***Security of data accessibility*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.10 ***Changing business and technical requirement*** has influenced on ***economic*** in supplier selection of IT project outsourcing					

Risk factors used in the supplier selection of IT project outsourcing	**Strongly disagree**				**Strongly agree**
	1	**2**	**3**	**4**	**5**
1.11 ***Working collaboration*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
1.12 ***Supplier's image*** has influenced on ***economic*** in supplier selection of IT project outsourcing					
2. Importance of ***Social*** in supplier selection of IT project outsourcing					
2.1 ***IT outsourcing policy*** has influenced on ***social*** in supplier selection of IT project outsourcing.					
2.2 ***IT outsourcing management*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.3 ***Cost management/unexpected cost*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.4 ***IT staff and turnover activity*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.5 ***Organization's culture and language*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.6 ***Quality of IT products and services*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.7 ***Knowledge of business process and new technology*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.8 ***Technology complexity*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.9 ***Security of data accessibility*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.10 ***Changing business and technical requirement*** has influenced on ***social*** in					

Risk factors used in the supplier selection of IT project outsourcing	Strongly disagree				Strongly agree
	1	**2**	**3**	**4**	**5**
supplier selection of IT project outsourcing					
2.11 ***Working collaboration*** has influenced on ***social*** in supplier selection of IT project outsourcing					
2.12 ***Supplier's image*** has influenced on ***social*** in supplier selection of IT project outsourcing					
3. Importance of ***Technology*** in supplier selection of IT project outsourcing					
3.1 ***IT outsourcing policy*** has influenced on ***technology*** in supplier selection of IT project outsourcing.					
3.2 ***IT outsourcing management*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.3 ***Cost management/unexpected cost*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.4 ***IT staff and turnover activity*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.5 ***Organization's culture and language*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.6 ***Quality of IT products and services*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.7 ***Knowledge of business process and new technology*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.8 ***Technology complexity*** has influenced on ***technology*** in supplier selection of IT project outsourcing					

Risk factors used in the supplier selection of IT project outsourcing	**Strongly disagree**				**Strongly agree**
	1	**2**	**3**	**4**	**5**
3.9 ***Security of data accessibility*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.10 ***Changing business and technical requirement*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.11 ***Working collaboration*** has influenced on ***technology*** in supplier selection of IT project outsourcing					
3.12 ***Supplier's image*** has influenced on ***technology*** in supplier selection of IT project outsourcing					

Section IV: The Importance Level of Evaluation Criteria and Risk Factors for Supplier Selection of IT Project Outsourcing.

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14. Please indicate your opinion on the importance level of each criterion for supplier selection of IT project outsourcing **(You can tick more than one item)**.

Evaluation criteria used in the supplier selection of IT project outsourcing	**Less importance**								**Extremely importance**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Economic									
Quality									
Service									
Performance / Performance history									
Management									
Strategy									
Cost / Price									
Finance									
Delivery									

Evaluation criteria used in the supplier selection of IT project outsourcing	**Less importance**								**Extremely importance**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Satisfaction / Responsiveness									
Flexibility									
Contact management									
Market leadership									
Market sharing									
Social									
Culture and language									
Relationship and communication process									
Reliability and usability									
Resource									
Technology									
Technical capability and experts									
Configuration									
Disaster recovery									
Information and system security									
Information and system integrated compatibility									
Maintenance and innovation of business									
Assets									
Experience									
Knowledge of the industry									
Research and Development									

15. Please indicate your opinion on the importance level of each risk factor for supplier selection of IT project outsourcing **(You can tick more than one item)**.

Risk factors used in the supplier selection of IT project outsourcing	**Less importance**								**Extremely importance**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
IT outsourcing policy									
IT outsourcing management									
Cost management and unexpected cost									
IT staff and turnover activity									

Risk factors used in the supplier selection of IT project outsourcing	**Less importance**								**Extremely importance**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Organization's culture and language									
Quality of IT products and services									
Knowledge of business process and new technology									
Technology complexity									
Security of data accessibility									
Changing business and technical requirement									
Working collaboration									
Supplier's image									

Appendix C

Pearson Correlation Coefficient Analysis

Index		Economic							Social			Technology											Risk factors							
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	R1	R2	R3	R4	R5	R6	R7	R8
C1	R	1	0.188	0.004	0.096	.362*	.714**	0.048	0.057	-0.195	0.184	0.081	-0.146	0.229	0.280	0.231	0.301	.406*	.466**	0.174	0.274	0.074	.596**	-0.053	0.112	0.088	-0.095	0.125	0.136	-0.029
	Sig		0.280	0.983	0.583	0.033	0.000	0.784	0.744	0.262	0.289	0.643	0.403	0.187	0.104	0.182	0.079	0.016	0.005	0.317	0.111	0.673	0.000	0.763	0.523	0.616	0.589	0.473	0.437	0.869
C2	R	0.188	1	.539**	0.159	0.216	0.149	0.187	-0.278	-0.026	0.242	.403*	0.223	.623**	.556**	.647**	.411*	.340*	.440**	0.313	0.064	0.084	0.221	0.063	.527**	0.220	.368*	.433**	.438**	0.207
	Sig	0.280		0.001	0.363	0.212	0.393	0.283	0.106	0.882	0.162	0.016	0.198	0.000	0.001	0.000	0.014	0.045	0.008	0.067	0.715	0.630	0.201	0.721	0.001	0.205	0.029	0.009	0.009	0.234
C3	R	0.004	**.539****	1	.403*	0.123	0.058	0.213	-0.273	0.000	0.135	0.234	0.190	.506**	0.264	.431**	.383*	.336*	.440**	0.241	0.109	0.050	0.123	0.037	.580**	0.110	0.208	0.146	.351*	0.034
	Sig	0.983	**0.001**		0.016	0.481	0.740	0.220	0.113	1.000	0.439	0.177	0.275	0.002	0.125	0.010	0.023	0.048	0.008	0.163	0.534	0.776	0.481	0.833	0.000	0.530	0.231	0.401	0.039	0.847
C4	R	0.096	0.159	.403*	1	-0.021	-0.036	0.171	-0.078	0.186	0.315	.337*	.366*	0.246	0.089	0.176	0.256	0.074	.353*	0.253	0.132	0.006	.335*	0.143	.371*	0.221	0.272	0.065	0.265	0.157
	Sig	0.583	0.363	0.016		0.903	0.837	0.327	0.655	0.283	0.066	0.048	0.031	0.155	0.613	0.312	0.137	0.672	0.037	0.142	0.449	0.972	0.049	0.414	0.028	0.202	0.115	0.709	0.124	0.369
C5	R	.362*	0.216	0.123	-0.021	1	.502**	-0.112	-0.005	-0.085	0.140	0.152	0.052	0.309	0.137	0.203	0.194	0.208	0.324	0.114	0.252	0.065	.399*	-0.098	0.274	-0.055	0.251	0.132	0.219	0.027
	Sig	0.033	0.212	0.481	0.903		0.002	0.521	0.976	0.627	0.422	0.385	0.766	0.071	0.433	0.243	0.265	0.230	0.058	0.516	0.143	0.709	0.018	0.574	0.111	0.752	0.146	0.448	0.205	0.876
C6	R	**.714****	0.149	0.058	-0.036	**.502****	1	0.050	0.076	-0.239	0.109	-0.027	-0.107	0.296	0.100	0.136	0.111	0.076	0.220	-0.063	0.315	-0.236	0.231	-0.027	-0.041	-0.186	-0.036	-0.079	0.061	-0.159
	Sig	**0.000**	0.393	0.740	0.837	**0.002**		0.775	0.663	0.167	0.534	0.879	0.542	0.085	0.568	0.437	0.527	0.666	0.204	0.718	0.065	0.172	0.182	0.878	0.816	0.286	0.839	0.651	0.729	0.362
C7	R	0.048	0.187	0.213	0.171	-0.112	0.050	1	0.136	.381*	.515**	0.040	0.226	0.227	0.150	0.294	.350*	.339*	0.156	.526**	0.043	0.244	0.156	0.151	0.155	-0.028	-0.030	0.094	.343*	0.287
	Sig	0.784	0.283	0.220	0.327	0.521	0.775		0.437	0.024	0.002	0.820	0.192	0.190	0.391	0.086	0.039	0.046	0.372	0.001	0.805	0.158	0.372	0.387	0.373	0.873	0.866	0.591	0.044	0.094
C8	R	0.057	-0.278	-0.273	-0.078	-0.005	0.076	0.136	1	.489**	0.219	-0.099	-0.071	-0.150	0.014	-0.220	-0.021	0.166	-0.087	0.043	0.305	0.235	0.008	-0.073	-0.223	-0.081	0.082	-0.173	-0.138	0.027
	Sig	0.744	0.106	0.113	0.655	0.976	0.663	0.437		0.003	0.206	0.570	0.686	0.390	0.937	0.203	0.905	0.341	0.620	0.807	0.074	0.173	0.962	0.677	0.198	0.643	0.641	0.322	0.431	0.877
C9	R	-0.195	-0.026	0.000	0.186	-0.085	-0.239	.381*	**.489****	1	0.289	0.144	.345*	-0.125	-0.030	0.074	.353*	0.206	-0.129	.431**	0.187	.367*	0.068	.390*	0.013	-0.032	0.311	-0.150	0.284	.549**
	Sig	0.262	0.882	1.000	0.283	0.627	0.167	0.024	**0.003**		0.093	0.409	0.042	0.475	0.864	0.673	0.037	0.236	0.458	0.010	0.283	0.030	0.700	0.021	0.940	0.855	0.069	0.389	0.098	0.001
C10	R	0.184	0.242	0.135	0.315	0.140	0.109	**.515****	0.219	0.289	1	0.123	0.023	0.327	0.097	0.146	.383*	.378*	0.184	.542**	0.176	0.193	.390*	0.052	.500**	0.307	0.054	0.318	.340*	.366*
	Sig	0.289	0.162	0.439	0.066	0.422	0.534	**0.002**	0.206	0.093		0.480	0.894	0.055	0.579	0.402	0.023	0.025	0.289	0.001	0.312	0.267	0.021	0.765	0.002	0.073	0.756	0.063	0.046	0.031
C11	R	0.081	.403*	0.234	.337*	0.152	-0.027	0.040	-0.099	0.144	0.123	1	.814**	.479**	0.314	0.331	.449**	0.275	0.331	0.325	0.068	.392*	0.049	0.327	.356*	0.307	.449**	0.211	.669**	.539**
	Sig	0.643	0.016	0.177	0.048	0.385	0.879	0.820	0.570	0.409	0.480		0.000	0.004	0.066	0.052	0.007	0.110	0.052	0.056	0.697	0.020	0.779	0.056	0.036	0.073	0.007	0.225	0.000	0.001
C12	R	-0.146	0.223	0.190	.366*	0.052	-0.107	0.226	-0.071	.345*	0.023	**.814****	1	0.225	0.094	0.202	.347*	0.128	0.036	.415*	-0.022	0.299	0.007	.389*	0.163	0.197	.346*	0.012	.614**	.534**
	Sig	0.403	0.198	0.275	0.031	0.766	0.542	0.192	0.686	0.042	0.894	**0.000**		0.193	0.589	0.245	0.041	0.465	0.837	0.013	0.901	0.081	0.966	0.021	0.348	0.258	0.042	0.944	0.000	0.001
C13	R	0.229	**.623****	**.506****	0.246	0.309	0.296	0.227	-0.150	-0.125	0.327	**.479****	0.225	1	.594**	.675**	.513**	0.247	.579**	0.103	0.179	0.024	-0.047	-0.057	.407*	0.108	0.259	.372*	.446**	0.123

Index		Economic							Social			Technology											Risk factors							
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	R1	R2	R3	R4	R5	R6	R7	R8
	Sig	0.187	0.000	0.002	0.155	0.071	0.085	0.190	0.390	0.475	0.055	0.004	0.193		0.000	0.000	0.002	0.153	0.000	0.555	0.305	0.892	0.791	0.744	0.015	0.536	0.133	0.028	0.007	0.482
C14	R	0.280	.556**	0.264	0.089	0.137	0.100	0.150	0.014	-0.030	0.097	0.314	0.094	.594**	1	.771**	.422*	.476**	.563**	0.065	0.082	0.104	0.066	-0.169	0.272	0.072	0.262	.551**	0.187	-0.087
	Sig	0.104	0.001	0.125	0.613	0.433	0.568	0.391	0.937	0.864	0.579	0.066	0.589	0.000		0.000	0.012	0.004	0.000	0.709	0.639	0.552	0.708	0.331	0.114	0.683	0.129	0.001	0.282	0.619
C15	R	0.231	.647**	.431**	0.176	0.203	0.136	0.294	-0.220	0.074	0.146	0.331	0.202	.675**	.771**	1	.545**	0.315	.494**	0.161	0.038	-0.057	0.051	-0.084	.380*	0.116	0.259	.607**	.375*	0.086
	Sig	0.182	0.000	0.010	0.312	0.243	0.437	0.086	0.203	0.673	0.402	0.052	0.245	0.000	0.000		0.001	0.066	0.003	0.357	0.828	0.743	0.773	0.630	0.025	0.509	0.133	0.000	0.026	0.624
C16	R	0.301	.411*	.383*	0.256	0.194	0.111	.350*	-0.021	.353*	.383*	.449**	.347*	.513**	.422*	.545**	1	.627**	.410*	.517**	0.056	.447**	.359*	0.167	.410*	0.272	0.306	0.243	.551**	.488**
	Sig	0.079	0.014	0.023	0.137	0.265	0.527	0.039	0.905	0.037	0.023	0.007	0.041	0.002	0.012	0.001		0.000	0.014	0.001	0.750	0.007	0.034	0.337	0.014	0.114	0.074	0.160	0.001	0.003
C17	R	.406*	.340*	.336*	0.074	0.208	0.076	.339*	0.166	0.206	.378*	0.275	0.128	0.247	.476**	0.315	.627**	1	.431**	.619**	0.090	.569**	.482**	-0.057	.429*	0.186	0.066	0.193	0.308	0.134
	Sig	0.016	0.045	0.048	0.672	0.230	0.666	0.046	0.341	0.236	0.025	0.110	0.465	0.153	0.004	0.066	0.000		0.010	0.000	0.607	0.000	0.003	0.746	0.010	0.285	0.705	0.266	0.071	0.444
C18	R	.466**	.440**	.440**	.353*	0.324	0.220	0.156	-0.087	-0.129	0.184	0.331	0.036	.579**	.563**	.494**	.410*	.431**	1	0.233	0.169	0.238	.359*	-0.190	.398*	0.049	0.282	0.298	0.172	-0.096
	Sig	0.005	0.008	0.008	0.037	0.058	0.204	0.372	0.620	0.458	0.289	0.052	0.837	0.000	0.000	0.003	0.014	0.010		0.177	0.331	0.169	0.034	0.275	0.018	0.782	0.101	0.082	0.324	0.582
C19	R	0.174	0.313	0.241	0.253	0.114	-0.063	.526**	0.043	.431**	.542**	0.325	.415*	0.103	0.065	0.161	.517**	.619**	0.233	1	-0.128	.503**	.565**	0.306	.514**	0.329	0.062	0.104	.462**	.555**
	Sig	0.317	0.067	0.163	0.142	0.516	0.718	0.001	0.807	0.009	0.001	0.056	0.013	0.555	0.709	0.357	0.001	0.000	0.177		0.465	0.002	0.000	0.074	0.002	0.054	0.722	0.552	0.005	0.001
C20	R	0.274	0.064	0.109	0.132	0.252	0.315	0.043	0.305	0.187	0.176	0.068	-0.022	0.179	0.082	0.038	0.056	0.090	0.169	-0.128	1	0.214	0.108	-0.010	0.064	-0.063	0.288	0.107	0.284	0.077
	Sig	0.111	0.715	0.534	0.449	0.143	0.065	0.805	0.074	0.283	0.312	0.697	0.901	0.305	0.639	0.828	0.750	0.607	0.331	0.465		0.217	0.536	0.954	0.716	0.718	0.094	0.542	0.098	0.658
C21	R	0.074	0.084	0.050	0.006	0.065	-0.236	0.244	0.235	.367*	0.193	.392*	0.299	0.024	0.104	-0.057	.447**	.569**	0.238	.503**	0.214	1	.335*	0.274	0.178	0.017	0.265	-0.118	.414*	.508**
	Sig	0.673	0.630	0.776	0.972	0.709	0.172	0.158	0.173	0.030	0.267	0.020	0.081	0.892	0.552	0.743	0.007	0.000	0.169	0.002	0.217		0.049	0.112	0.306	0.922	0.124	0.501	0.013	0.002
R1	R	.596**	0.221	0.123	.335*	.399*	0.231	0.156	0.008	0.068	.390*	0.049	0.007	-0.047	0.066	0.051	.359*	.482**	.359*	.565**	0.108	.335*	1	0.021	.404*	0.228	0.095	0.122	0.249	0.257
	Sig	0.000	0.201	0.481	0.049	0.018	0.182	0.372	0.962	0.700	0.021	0.779	0.966	0.791	0.708	0.773	0.034	0.003	0.034	0.000	0.536	0.049		0.904	0.016	0.187	0.586	0.483	0.149	0.135
R2	R	-0.053	0.063	0.037	0.143	-0.098	-0.027	0.151	-0.073	.390*	0.052	0.327	.389*	-0.057	-0.169	-0.084	0.167	-0.057	-0.190	0.306	-0.010	0.274	0.021	1	0.169	0.108	0.295	-0.145	.423*	.642**
	Sig	0.763	0.721	0.833	0.414	0.574	0.878	0.387	0.677	0.021	0.765	0.056	0.021	0.744	0.331	0.630	0.337	0.746	0.275	0.074	0.954	0.112	0.904		0.333	0.535	0.086	0.406	0.011	0.000
R3	R	0.112	.527**	.580**	.371*	0.274	-0.041	0.155	-0.223	0.013	.500**	.356*	0.163	.407*	0.272	.380*	.410*	.429**	.398*	.514**	0.064	0.178	.404*	0.169	1	.487**	0.333	.466**	.438**	0.318
	Sig	0.523	0.001	0.000	0.028	0.111	0.816	0.373	0.198	0.940	0.002	0.036	0.348	0.015	0.114	0.025	0.014	0.009	0.018	0.002	0.716	0.306	0.016	0.333		0.003	0.051	0.005	0.008	0.062
R4	R	0.088	0.220	0.110	0.221	-0.055	-0.186	-0.028	-0.081	-0.032	0.307	0.307	0.197	0.108	0.072	0.116	0.272	0.186	0.049	0.329	-0.063	0.017	0.228	0.108	.487**	1	0.038	.644**	.437**	.339*
	Sig	0.616	0.205	0.530	0.202	0.752	0.286	0.873	0.643	0.855	0.073	0.073	0.258	0.536	0.683	0.509	0.114	0.285	0.782	0.054	0.718	0.922	0.187	0.535	0.003		0.828	0.000	0.009	0.046
R5	R	-0.095	.368*	0.208	0.272	0.251	-0.036	-0.030	0.082	0.311	0.054	.449**	.346*	0.259	0.262	0.259	0.306	0.066	0.282	0.062	0.288	0.265	0.095	0.295	0.333	0.038	1	0.113	.360*	.409*
	Sig	0.589	0.029	0.231	0.115	0.146	0.839	0.866	0.641	0.069	0.756	0.007	0.042	0.133	0.129	0.133	0.074	0.705	0.101	0.722	0.094	0.124	0.586	0.086	0.051	0.828		0.518	0.033	0.015
R6	R	0.125	.433**	0.146	0.065	0.132	-0.079	0.094	-0.173	-0.150	0.318	0.211	0.012	.372*	.551**	.607**	0.243	0.193	0.298	0.104	0.107	-0.118	0.122	-0.145	.466**	.644**	0.113	1	.360*	0.061
	Sig	0.473	0.009	0.401	0.709	0.448	0.651	0.591	0.322	0.389	0.063	0.225	0.944	0.028	0.001	0.000	0.160	0.266	0.082	0.552	0.542	0.501	0.483	0.406	0.005	0.000	0.518		0.034	0.726

Index		Economic							Social			Technology											Risk factors							
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	R1	R2	R3	R4	R5	R6	R7	R8
R7	R	0.136	.438**	.351*	0.265	0.219	0.061	.343*	-0.138	0.284	.340*	.669**	.614**	.446**	0.187	.375*	.551**	0.308	0.172	.462**	0.284	.414*	0.249	.423*	.438**	.437**	.360*	.360*	1	.689**
	Sig	0.437	**0.009**	0.039	0.124	0.205	0.729	0.044	0.431	0.098	0.046	**0.000**	**0.000**	**0.007**	0.282	0.026	**0.001**	0.071	0.324	**0.005**	0.098	0.013	0.149	0.011	**0.008**	**0.009**	0.033	0.034		0.000
R8	R	-0.029	0.207	0.034	0.157	0.027	-0.159	0.287	0.027	.549**	.366*	.539**	.534**	0.123	-0.087	0.086	.488**	0.134	-0.096	.555**	0.077	.508**	0.257	.642**	0.318	.339*	.409*	0.061	.689**	1
	Sig	0.869	0.234	0.847	0.369	0.876	0.362	0.094	0.877	**0.001**	0.031	**0.001**	**0.001**	0.482	0.619	0.624	**0.003**	0.444	0.582	**0.001**	0.658	**0.002**	0.135	**0.000**	0.062	0.046	0.015	0.726	**0.000**	

Noted: Correlation coefficient is significant at ρ value less than 0.01

Noted that:

C1. Economic
C2. Quality
C3. Service
C4. Performance
C5. Cost / Price
C6. Finance
C7. Satisfaction / Responsiveness
C8. Social
C9. Relationship / Communication
C10. Reliability / Usability
C11. Technology
C12. Technical capability and experts
C13. Configuration
C14. Disaster recovery
C15. Information and system security
C16. Information and system integrated compatibility
C17. Maintenance and business innovation
C18. Facility / asset
C19. Experience
C20. Knowledge of the industry
C21. Research and development
R1. Cost management and unexpected cost
R2. IT staff and turnover manner
R3. Quality of IT products and services
R4. Knowledge of business process and new technology
R5. Technology complexity
R6. Security of data accessibility
R7. Changing business and technical requirement
R8. Working collaboration

Appendix D

Un-Weighted Supermatrix in Proposed Model

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
C1	.000	.000	.000	.000	.100	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.100	.000	.000	.000	.000	.000	.000	.000
C2	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1	1	1	.000	.000	.900	.000	.000	1	.000	.000	1	1
C3	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C4	.000	.000	.000	.000	.900	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C5	.250	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C6	.000	.000	.000	.000	.000	.000	.000	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R1	.750	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1	.000	1	.000	.000	.000	.000	.000	.000
C7	.000	.000	.000	.000	.000	.000	.000	.000	.125	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C8	.000	.000	.000	.000	.000	.000	.000	1	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C9	.000	.000	.000	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R2	.000	.000	.000	.000	.000	.000	.000	.000	.875	.000	.000	1	1	.000	.000	.000	1	.000	.000	1	1	.000	.000	.000	.000	1
C10	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.857	.097	.000	.000	.090	.000	.000	.000	.000	.000	.000	1	.000	.037
C11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.595	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.397
C12	.000	.074	.119	.000	.000	.000	.000	.000	.000	.000	.000	.185	.000	.000	.198	.135	.133	.000	.113	.000	.000	.000	.000	.000	.000	.068
C13	.000	.087	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.189	.000	.190	.000	.148	.157	.000	.000	.000	.000	.000	.108	.000
C14	.000	.396	.542	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.532	.417	.000	.475	.000	.690	.000	.000	.000	.000	.000	.555	.000
C15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.144	.000	.124	.000	.102	.000	.110	.000	.220	.234	.000	.000	.000	.000	.050
C16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.095	.000	.058	.000	.041	.114	.078	.081	.000	.000	.000	.000
C17	.000	.018	.035	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.022	.074	.026	.000	.029	.000	.000	.000	.000	.000	.000	.000	.000
C18	.000	.000	.000	.000	.000	.000	.000	.000	1	.143	.000	.000	.000	.000	.000	.000	.195	.187	.000	.000	.688	.296	.000	.000	.000	.119
C19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.018	.023	.000	.030	.000	.000	.000	.000	.000	.000
R3	.000	.241	.303	.000	.000	.000	.000	.000	.000	.857	.000	.000	.000	.000	.000	.000	.000	.503	.000	.583	.000	.000	.632	.000	.301	.308
R4	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.057	.000	.000	.036	.020
R5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.044	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R6	.000	.158	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.215	.548	.000	.000	.000	.000	.000	.534	.316	.000	.000	.000

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
R7	.000	.026	.000	.000	.000	.000	.000	.000	.000	.000	.000	.032	.143	.035	.000	.000	.031	.000	.000	.052	.000	.032	.052	.000	.000	.000

Note that:

C1. Economic
C2. Quality
C3. Service
C4. Cost / Price
C5. Finance
C6. Satisfaction / Responsiveness
C7. Social
C8. Relationship / Communication
C9. Reliability / Usability
C10. Technology
C11. Technical capability and experts
C12. Configuration
C13. Disaster recovery
C14. Information and system security
C15. Information and system integrated compatibility
C16. Maintenance and business innovation
C17. Facility / asset
C18. Experience
C19. Research and development
R1. Cost management and unexpected cost
R2. Working collaboration
R3. Quality of IT products and services
R4. Knowledge of business process and new technology
R5. Technology complexity
R6. Security of data accessibility
R7. Changing business and technical requirement

Appendix E

Weighted Supermatrix in Proposed Model

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
C1	.000	.000	.000	.000	.100	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.050	.000	.000	.000	.000	.000	.000	.000
C2	.000	.000	.500	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.500	.500	.500	.000	.000	.450	.000	.000	.500	.000	.000	.500	.333
C3	.000	.500	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C4	.000	.000	.000	.000	.900	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C5	.250	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C6	.000	.000	.000	.000	.000	.000	.000	.000	.000	.500	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R1	.750	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.500	.000	.333	.000	.000	.000	.000	.000	.000
C7	.000	.000	.000	.000	.000	.000	.000	.000	.063	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C8	.000	.000	.000	.000	.000	.000	.000	1	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
C9	.000	.000	.000	.000	.000	1	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R2	.000	.000	.000	.000	.000	.000	.000	.000	.438	.000	.000	.500	.500	.000	.000	.000	.500	.000	.000	.333	.500	.000	.000	.000	.000	.333
C10	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.429	.049	.000	.000	.045	.000	.000	.000	.000	.000	.000	1	.000	.012
C11	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.298	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.132
C12	.000	.037	.060	.000	.000	.000	.000	.000	.000	.000	.000	.093	.000	.000	.099	.067	.067	.000	.056	.000	.000	.000	.000	.000	.000	.023
C13	.000	.044	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.095	.000	.095	.000	.074	.078	.000	.000	.000	.000	.000	.054	.000
C14	.000	.198	.271	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.266	.209	.000	.237	.000	.345	.000	.000	.000	.000	.000	.277	.000
C15	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.072	.000	.062	.000	.051	.000	.055	.000	.073	.117	.000	.000	.000	.000	.017
C16	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.048	.000	.029	.000	.020	.038	.039	.041	.000	.000	.000	.000
C17	.500	.009	.017	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.011	.037	.013	.000	.015	.000	.000	.000	.000	.000	.000	.000	.000
C18	.000	.000	.000	.000	.000	.000	.000	.000	.500	.071	.000	.000	.000	.000	.000	.000	.098	.093	.000	.000	.344	.148	.000	.000	.000	.040
C19	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.009	.011	.000	.010	.000	.000	.000	.000	.000	.000
R3	.000	.120	.152	.000	.000	.000	.000	.000	.000	.429	.000	.000	.000	.000	.000	.000	.000	.251	.000	.194	.000	.000	.632	.000	.150	.103
R4	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.029	.000	.000	.018	.007
R5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.022	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R6	.000	.079	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.108	.274	.000	.000	.000	.000	.000	.267	.316	.000	.000	.000

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
R7	.000	.013	.000	.000	.000	.000	.000	.000	.000	.000	.000	.016	.071	.018	.000	.000	.015	.000	.000	.017	.000	.016	.052	.000	.000	.000

Note that:

C1. Economic
C2. Quality
C3. Service
C4. Cost / Price
C5. Finance
C6. Satisfaction / Responsiveness
C7. Social
C8. Relationship / Communication
C9. Reliability / Usability
C10. Technology
C11. Technical capability and experts
C12. Configuration
C13. Disaster recovery
C14. Information and system security
C15. Information and system integrated compatibility
C16. Maintenance and business innovation
C17. Facility / asset
C18. Experience
C19. Research and development
R1. Cost management and unexpected cost
R2. Working collaboration
R3. Quality of IT products and services
R4. Knowledge of business process and new technology
R5. Technology complexity
R6. Security of data accessibility
R7. Changing business and technical requirement

Appendix F

Limited Supermatrix in Proposed Model

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
C1	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031	.031
C2	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239	.239
C3	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120	.120
C4	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035	.035
C5	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039	.039
C6	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R1	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026
C7	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
C8	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043	.043
C9	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R2	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
C10	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
C11	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
C12	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030	.030
C13	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032	.032
C14	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126	.126
C15	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011	.011
C16	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
C17	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023	.023
C18	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034	.034
C19	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
R3	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069	.069
R4	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
R5	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
R6	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077	.077

	Economic							Social				Technology														
	C1	C2	C3	C4	C5	C6	R1	C7	C8	C9	R2	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	R3	R4	R5	R6	R7
R7	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006

Note that:

C1. Economic
C2. Quality
C3. Service
C4. Cost / Price
C5. Finance
C6. Satisfaction / Responsiveness
C7. Social
C8. Relationship / Communication
C9. Reliability / Usability
C10. Technology
C11. Technical capability and experts
C12. Configuration
C13. Disaster recovery
C14. Information and system security
C15. Information and system integrated compatibility
C16. Maintenance and business innovation
C17. Facility / asset
C18. Experience
C19. Research and development
R1. Cost management and unexpected cost
R2. Working collaboration
R3. Quality of IT products and services
R4. Knowledge of business process and new technology
R5. Technology complexity
R6. Security of data accessibility
R7. Changing business and technical requirement

Appendix G

ANP-FA Verification Form

Please verify and give comments on the below mentioned steps of ANP-FA development:

Noted: ANP-FA method development aimed to eliminate human involvement from ANP method as supported the transparency process in the decision-making problem.

ANP-FA steps	Comments / Suggestions
1. The criteria and risk factors have been arranged the relationship in three sustainability dimensions.	Agree ☐ Disagree ☐ Comments -- --
2. The relationship between criteria and risk factors transformed a supermatrix.	Agree ☐ Disagree ☐ Comments -- --
3. The supermatrix was decomposed into pairwise comparison matrix (PCM).	Agree ☐ Disagree ☐ Comments -- --
4. The judgment values were automatically assigned in PCMs including the CR synthesis does not exceed 0.1.	Agree ☐ Disagree ☐ Comments -- --
5. The PCMs generation were verified the human knowledge by comparing priority of weight values as referring the dataset (feasibility space).	Agree ☐ Disagree ☐ Comments -- --
6. FA finds out the optimizing weight values from the feasibility space (PCMs).	Agree ☐ Disagree ☐ Comments -- --

ANP-FA steps	Comments / Suggestions
7. PCM synthetization (i.e. judgment value., weight synthetization, consistent synthetization and bias synthetization) was performed to investigate the optimizing PCMs.	Agree ☐ Disagree ☐ Comments -- --
8. The comparison of both CR and SB values indicated an optimal PCM from the feasibility space.	Agree ☐ Disagree ☐ Comments -- --
9. The comparison of priority of optimal weight values captured human knowledge from the feasibility space.	Agree ☐ Disagree ☐ Comments -- --
10. All optimizing weight values fill in the un-weighted supermatrix following the relationships between criteria and risk factors on three sustainability dimensions.	Agree ☐ Disagree ☐ Comments -- --
11. The weighted supermatrix has been constructed to the weight normalization.	Agree ☐ Disagree ☐ Comments -- --
12. The limited supermatrix has been constructed to calculate the optimizing weight value on the relationship between criteria and risk factors in three sustainability dimensions.	Agree ☐ Disagree ☐ Comments -- --

Overall comments/suggestions:

Appendix H

The Evaluation Criteria and Risk Factors on Three Sustainability Dimensions Verification Form

Please indicate the suitability of the practices with the evaluation criteria and risk factors in each sustainability dimension. If they are suitable, tick (√) under YES column, else tick (√) under NO column. Please provide suggestions for improving the practices in the provided column, if any.

Note that: The meaning of three sustainability dimensions is:

Economic sustainability:

The strategic, management and operation in IT outsourcing are strong to reduce the undesirable expenditure for improving the quality of IT products and services under the supplier performance to customer satisfaction.

Social sustainability:

The working collaboration of stakeholders (organization and supplier) to the operation and management under the different culture and/or language along with the organization's staff welfare.

Technology sustainability:

The high experts' capability is to develop, operate and maintain in the longevity of IT system efficiency along with improving the IT system, but without negatively impact the natural from IT infrastructure

Sustainability	IDs	Evaluation Criteria	Verification		
			Yes	No	Suggestion
Economic	C1	**Economic** *Reduce expenditure and increase finance capability for the reinvestment*			
	C2	**Quality** *Ability in providing the higher technology to the organization toward the performed business in future*			
	C3	**Service** *Be able to support the relevant information and technology as well as to consult the IT system*			
	C4	**Cost/Price** *Consider the reasonable price when employ the supplier for IT outsourcing*			
	C5	**Finance** *Cash flow of supplier; included the external economy impacted*			
	C6	**Satisfaction/responsiveness** *Ability of the supplier's responsibility to solve the problems of IT system to reduce impacting the customers' satisfaction*			
	R1	**Cost management and unexpected cost** *An unexpected budget occurrence such as over the contract, exchange rate changed, inflation, and so on*			
Social	C7	**Social** *The effectiveness of working collaboration between organization and supplier as well as the quality of life of employee*			
	C8	**Relationship and communication process** *Understandable the working collaboration in operation and management level*			
	C9	**Reliability/usability** *Trustness in the supplier's capability*			
	R2	**Working collaboration** *Lack of working collaboration such as no sharing important information, no trust the capability each other*			
Technology	C10	**Technology** *The capability of supplier both technical knowledge and business process for information technology; including the use of IT infrastructure without a negative impact on the nature*			
	C11	**Technical capability and expertise** *IT specialist capability to the IT system (both software and IT infrastructure)*			
	C12	**Disaster recovery** *Ability to support the unexpected occurrence to recover the system*			

Sustainability	IDs	Evaluation Criteria	Verification		
			Yes	No	Suggestion
	C13	**Configuration** *Ability to config between the existing and the new system by not impacting the current implementation*			
	C14	**Information and system security** *Ability to secure planning and restore rapidly*			
	C15	**Information and system integrated compatibility** *Ability to manage and operate the existing system with the new system*			
	C16	**Maintenance and innovative business** *Ability to maintained the IT system supported business innovation*			
	C17	**Assets** *Ability to prepare the state-of-art IT infrastructure and tools in supporting requirements*			
	C18	**Experience** *More experience in IT project management*			
	C19	**Research and development** *Ability to investe and learn innovative solution*			
	R3	**Quality of IT products and services** *A low qualification from an agreement in the contract*			
	R4	**Knowledge of business process and new technology** *Deficiency of the transferring requirement inefficiency and learning new technology*			
	R5	**Technology complexity** *Change in the legacy system to support the current business competition*			
	R6	**Security of data accessibility** *Neglect in the security policy for private data accessibility*			
	R7	**Changing business and technical requirement** *Unreasonable and unclear to the organization's requirements for performing IT project*			

Appendix I

The Overall Verification Form

Please indicate whether the sustainable IT outsourcing is:

Comprehensive:

All required evaluation criteria and risk factors on three sustainability dimensions for evaluating the supplier's performance are included

Understandable:

The evaluation criteria and risk factors on three sustainability dimensions are decomposed clearly and unambiguously

Accurate:

The evaluation criteria and risk factors on three sustainability dimensions are adequately decomposed to achieve precise evaluation

Well-organized:

The evaluation criteria and risk factors on three sustainability dimensions are organized well

	Comprehensive	Understandable	Accurate	Well-organized
Economic	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Social	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Technology	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------

Appendix J

Priority of Evaluation Criteria and Risk Factors Validation Form

You can put the priority number between 1 and 26.

IDs	evaluation criteria and risk factors	priority
C1	Economic	
C2	Quality	
C3	Service	
C4	Cost/Price	
C5	Finance	
C6	Satisfaction/responsiveness	
R1	Cost management/unexpected cost	
C7	Social	
C8	Relationship and communication process	
C9	Reliability/usability	
R2	Working collaboration	
C10	Technology	
C11	Technical capability and expertise	
C12	Disaster recovery	
C13	Configuration	
C14	Information and system security	
C15	Information and system integrated compatibility	
C16	Maintenance and innovative business	
C17	Assets	
C18	Experience	
C19	Research and development	
R3	Quality of IT products and services	
R4	Knowledge of business process and new technology	
R5	Technology complexity	
R6	Security of data accessibility	
R7	Changing business and technical requirement	

Appendix K

Mapping Organization's Criteria into Evaluation Criteria and Risk Factors Validation Form

Please put the organization's evaluation criteria and tick (√) to the practical evaluation criteria and risk factors relevance.

Organization's criteria	selected	IDs	evaluation criteria and risk factors
		C1	Economic
		C2	Quality
		C3	Service
		C4	Cost/Price
		C5	Finance
		C6	Satisfaction/responsiveness
		R1	Cost management/unexpected cost
		C7	Social
		C8	Relationship and communication process
		C9	Reliability/usability
		R2	Working collaboration
		C10	Technology
		C11	Technical capability and expertise
		C12	Disaster recovery
		C13	Configuration
		C14	Information and system security
		C15	Information and system integrated compatibility
		C16	Maintenance and innovative business
		C17	Assets
		C18	Experience
		C19	Research and development
		R3	Quality of IT products and services
		R4	Knowledge of business process and new technology
		R5	Technology complexity
		R6	Security of data accessibility
		R7	Changing business and technical requirement

Appendix L
The Validation Form

Please validate and give comments on the below mentioned issued on the ESS model's implementation:

Issues	descriptions	comments / suggestions
Practicality	The proposed model is practical to be implemented in the real-world environment	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Completeness	The proposed model is adequate and sufficient for sustainable IT outsourcing	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Perceived Usefulness	The proposed model is useful for the supplier selection of sustainable IT outsourcing in organization	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Understandability	The proposed model is understandable and readable	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Clarity	The evaluation criteria and risk factors on sustainability dimension and flow of ANP-FA method is defined clearly	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------

Issues	descriptions	comments / suggestions
Ease of use	The proposed model can be implemented easily	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Organization	The proposed model is organized and structured well	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------
Ability to produce usable results	The proposed model produces results that can be used for further improvement of the supplier selection for sustainable IT outsourcing	Agree ☐ Disagree ☐ Comments/Suggestions: ------------------------------------ ------------------------------------ ------------------------------------

Appendix M

T-Test analysis for Model Validation

Organization criteria	Index	Criteria and risk factors	Supplier B	
			Price performance (PP) model	ESS model
Supplier's previous project portfolio	C2	Quality	10.22	51.13
	C3	Service		
	C5	Finance		
Price	C4	Cost/Price	28.95	4.89
Project member's experience and expertise	C11	Technical capability and expertise	9.60	6.26
	C18	Experience		
Project development and implementation procedure	C12	Configuration	32.98	109.01
	C13	Disaster recovery		
	C14	Information and system security		
	C15	Information and system integrated compatibility		
Other proposal that may benefit the project	C16	Maintenance and business innovation	3.50	0.69
	C19	Research and development		

T-Test result

Model	N	Mean	Standard deviation	Sig (2-tailed)
Price performance	5	17.05	13.05	0.445
ESS model	5	34.40	46.49	

Appendix N

Supplier Evaluation Form Organization

The evaluation from: Project ……………….

Day/Month/Year

Organization criteria	Full marks	supplier	
		supplier AAA	supplier BBB
Supplier's previous project portfolio (SPPP)	150	150.00	146.00
Project member's experience and expertise (PMEE)	150	105.64	96.46
Project development and implementation procedure (PDIP)	650	365.40	471.20
Other proposal that may benefit the project (OPBP)	50	0.00	50.00

Noted: Price performance method determined the weight ratio as 70:30

Technical evaluation: Project ……………….

Item	suppliers	total mark (1000 marks)	70% of marks
1	Supplier AAA	621.04	43.47
2	Supplier BBB	804.34	56.30

Price evaluation: Project ……………….

Maximum price: 5,000,000 bath

Item	suppliers	proposed price	total mark (1000 marks)	30% of marks
1	Supplier AAA	4,700,000.00	100.00	30.00
2	Supplier BBB	4,865,000.00	96.49	27.62

Price performance method evaluation: Project ……………….

Item	suppliers	technical (70%)	price (30%)	Total mark (100%)
1	Supplier AAA	43.47	30.00	73.47
2	Supplier BBB	56.30	27.62	83.92

Appendix O

Publications

Fusiripong, P., Baharom, F., & Yusof, Y. (2020). Analytic Hierarchy Process with Firefly Algorithm for Supplier Selection in IT Project Outsourcing. *Journal of Theoretical and Applied Information Technology, 98(8)* 1255-1269.

Fusiripong, P., Baharom, F., & Yusof, Y. (2018). An Analysis of Comparison on Weighted AHP for Improving Supplier Selection in IT Outsourcing. *Proceeding of Knowledge Management International Conference,* 388-392.

Fusiripong, P., Baharom, F., & Yusof, Y. (2017). Determining Multi-Criteria Supplier Selection towards Sustainable Development of IT Project Outsourcing. *International Journal of Supply Chain Management (IJSCM)*, 6(3), 258-270.

Fusiripong, P., Baharom, F., & Yusof, Y. (2017). Identification of Multi-Criteria for Supplier Selection in IT Project Outsourcing. *In AIP Conference Proceedings (Vol. 1891, No. 1, p. 020042).* AIP Publishing.