Best-Value Contract Award Mechanism: A multi-criteria decision making model for construction projects

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This thesis is dedicated to my parents, respected teachers and batch fellows

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ABSTRACT

In construction industry, projects require large amount of money and human effort. But due to project complexity, many projects get delayed and cost overrun puts the progress of project at stake. Traditional low-bid system of contract award has been criticized for its weaknesses in terms of evaluating the bidders' expertise. The main issue is in decision making which is carried out for awarding the contract. It is at the core of project failure in terms of cost and time overruns. The lack of importance to other crucial factors such as safety record, sustainability sensitivity, managerial competence, resource utilizations, etc. has given birth to the idea of Best Value (BV) procurement strategy which takes a holistic view of a bid and analyzes its value proposition in both tangible and intangible terms before awarding the contract. This research attempts to facilitate the client by describing the priority indicators that could help in decision making. The indictors are recognized as key variables that impact the subsequent decisions of contract award. It presents a hierarchical review of relevant literature and integrates the factors that help in decision making using BV approach. This framework comprises of eight dimensions of BV contributing factors – *cost*, *risk*, *performance*, *quality control*, *health and safety*, *project control*, *current workload* and *delay claims*. However decision making in BV cases is quite challenging due to its multi-objective nature. Multi-criteria decision making (MCDM) techniques facilitate in such scenarios. This study uses Analytical Network Process (ANP) for contractor selection. Based on extensive literature review, BV contributing factors are identified and scrutinized by experts. Data is collected from real case studies of highway projects to validate the awarding decisions in the light of BV procurement strategy. The findings indicate that in almost all the cases, the traditional procurement system owing to stringent prequalification measures subliminally took into consideration overall value proposition and only one case study showed anomalies. Conclusions are drawn and practical implications are discussed.

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LIST OF ABBREVIATIONS

Proposed Tender Price	=	PTP
Low project life cycle cost	=	LPCC
Financial capability	=	FC
Additional financial resources for priority projects	=	FRP
Past performance and expertise of the company	=	PPEC
Number of key personnel	=	NKP
Optimized resource utilization	=	ORU
Training and skill level of project team	=	TSP
Quality control measures	=	QCM
Meeting design requirements	=	MDR
User expectations and satisfaction	=	UES
Health and safety performance	=	HSP
Environmental impact	=	EI
Type of project control and monitoring process	=	PCM
Actual schedule achieved for similar works	=	SAW
History of claims and disputes	=	HCM
Number and size of projects in hand	=	NSP
Ability to deal with unanticipated problems	=	ADP

Transfer of risks related to construction, finance and operation	=	TRCO
Project Control	=	PC
Quality Control	=	QC
Health and Safety	=	H & S
Best Value	=	BV
Analytical hierarchy process	=	AHP
Analytical network process	=	ANP
Multi criteria decision making	=	MCDM

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Chapter 1

INTRODUCTION

1.1 General

Construction industry is unique and diverse in which uncertain environments are expected. The cost of labor varies from region to region with the various circumstance including time, weather, and skills. The price and availability of material is also a big concern in construction industry which keeps changing all the time. There are various uncertain conditions along with the risk and time management. The major parties which circle around a project are Client/Owner, Contractor and Consultant architecture/engineer. Owner hires architect/engineer and after successive biddings awards the contract to contractor and designate consultants over his project. The only objective of the owner is to distribute the risk on contractor, architect/engineer and other parties and fulfill his desired work; in return he pays for the whole work. The contract is mostly awarded to the lowest bidder and afterwards the canvassing of bids is done.

1.2 Problem Statement

Environmental degradation, declining economy, crippling taxes are some of the circumstances the construction industry is badly going through (Choudhry and Fang, 2008). Most of the construction projects suffer from cost escalation and fall behind schedule. The main reason for this is insufficient planning before awarding the contract and client's inadequacy to analyze the reasons leading to this mess (Creedy et al., 2010). Most of the clients prefer to award the contract on low price due to prevalent system that ultimately hinders the quality and schedule of the project resulting into cost and time overruns (Sambasivan and Soon, 2007). These issues are seriously reacted to since their effect is so evident. But the overall degeneration is very conveniently ignored as no individual responsibilities are ever put. This demands for holistic decision support systems because partial decision making may lead projects into conflicts in most circumstances which can materialize into disputes in terms of cost and schedule. The dispute resolution is a lengthy, costly and tiring process, and it is always difficult to reach at the best solution (Assaf and Al-Hejji, 2006).

1.3 Objectives:

This study aims at investigating the suitability of BV procurement strategy against the traditional low-bid system and proposing a decision support tool. Since BV proposition is bifurcated into multiple critical success criteria and factors, a single-criteria decision making amounts to compromising the sophistication proffered by this procurement strategy. A solution to this problem is use of multi-criteria decision making (MCDM) techniques which allow taking into consideration the several attributes of selection (Huang et al., 2015). This study uses analytical network process (ANP) which assesses the interdependency between decision criteria and factors (Saaty, 2001). Data is collected on various case studies to demonstrate the applicability of BV contractor selection. Discussion is done to establish the relevance of case studies and the anomalies are explained. The conclusions and recommendations are expected to stimulate discussion in this important area whose deliberated implementation leads to project success.

1.4 Relevance to National Needs:

Pakistan is a developing country which is an awful long way from development almost in every sector. Our construction industry is going through same dilemma. Environmental degradation, declining economy, crippling taxes, that are the circumstances which construction industry is badly going through. Most of our construction projects suffer cost escalation and fall behind schedule, the main reason for this is insufficient planning before awarding the contract and client could not be able to analyze the reason that lead to this mess. Most of the clients prefer to award the contract on low price that ultimately hinders the quality and schedule. By applying MCDM technique, at least we will be able to determine the certain threshold point that causes deviation of cost, quality and schedule. If we would be able to deliver the project on time and catering all the qualities by accurately awarding the contract, a large chunk of the capital, especially in public sector, can be saved.

1.5 Advantages:

Awarding the contract is not an easy job especially when there are a lot of uncertainties involved (Osipova and Eriksson, 2011). In such circumstances our mail focus is to deliver the product as required by keeping the impact in cost and quality in mind. Multi criteria and Best Value approaches help us to analyze the factors that need to be considered before awarding the contract. Since every construction project is unique in a sense that each project differs in site conditions, associated risks, human resource etc., thus there is a need of robust and flexible decision making model. In most circumstances, where projects suffer many disputes in terms of cost and schedule, it is difficult to examine what is the best solution, ultimately disputes arises and we do not have ample time to solve such issues and the parties fabricate tactics that other party suffer the risks. If all such factors are catered before awarding the contract, such issue could be eliminated which would definitely save time and money and keep the relationship between parties pacified. Although it is a bit laborious for client and requires some extra time in evaluating the critical factors which will apparently differ from project to project, this extra effort will bounce back in form of good quality control and quality assurance on site, enhance working relationship between both parties and enable the builder to analyze what is actually required.

1.6 Areas of Application:

This work will include all types of construction projects into its scope ranging from a residential building to a multi-story, industrial buildings, roads, dams and bridges. All is requires to evaluate certain factors that would affect the project before awarding the contract. Moreover, this approach not only applies for public sector projects but also for private sector. Though the need of the client will vary in both, that will allow the needs and expectations of client to meet precisely.

LITERATURE REVIEW

In construction sector, successful project is defined in a unique way. Project performance in terms of time, cost and quality are currently used for measuring its success (Phua and Rowlinson, 2004). These three components of project performance were initially identified by Atkinson (1999), who named it as 'Iron Triangle' as shown in Figure 2.1.

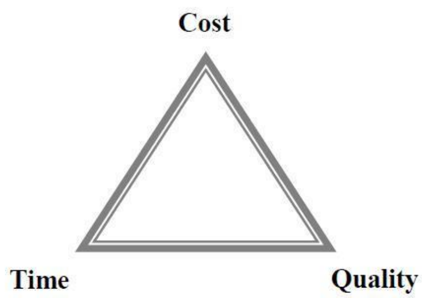


Figure 2.1: Relationship between time, cost and quality

From many decades, the procurement of most of the construction projects has been carried out under traditional low-bid approach. In traditional process of contractor`s selection, most of the projects suffer in terms of time and cost due to the subjective biasness in their selection mechanism. According to the user agency, same level of performance could not be achieved due to subjective bias in contractor`s selection process (Kashiwagi and Byfield, 2002a). The complex and risky decision making in low-bid approach results in misunderstanding, reactive behavior of contractor, lessening quality of work and hostile relationship (Kashiwagi et al., 2010). It is to admonish that owner does not always emphasize on 'lowest-price' selection criteria. In order to indicate the value of money, the cost has to be meddled with the project specific criteria (PSC). Supreme value can be measured from contractor's credentials that is 'selection criteria' during prequalification and final tender evaluation stages (Wong et al., 2000). Most of the research focuses on augmenting the long term performance of projects by evaluating the key factors in selection process (Cheng and Li, 2004). In selection process, the insertion of significant elements that meet the explicit needs of the project, confirms that selected contractor is the best to build the facility. To indicate the quality of contractor`s work, best value measures the past record of his/her performance and as expected, the results show a drift from traditional low-bid approach to Best Value (BV) selection method (Abdelrahman et al., 2008).

Understanding the concept of Best Value is in the best interest of both researchers and practitioners. The client or the representatives of client have to deal with bidding process which is sometimes very arduous and challenging. In academia, researchers mainly focus on the study that could help and guide the organizations in decision making. The traditional low-bid system of contractor selection, other than being extensively diffused, is also very easy since it does not involve a lot of effort in evaluation of its expertise, personnel and performance. Consequently, the project is awarded to that party which offers the lowest price. There is a level of satisfaction with this process on part of various stakeholders like designers, vendors, suppliers, engineers and project managers (Waara and Bröchner, 2006). This process assumes that the contractors will provide good quality and the consent of the owner is that the selected contractor will target the project at lowest price. The reason for the extensive use of the low-bid procurement is its easy documentation (Kashiwagi and Byfield, 2002b).

2.1 Procedures for Competitive Bidding

The thee procedures for competitive bidding are (Khan, 2015)

(a) Single Stage – One Envelope Procedure

Each bid shall comprise of single envelope containing, separately, financial proposal and technical proposal. All bids received shall be opened and evaluated in the manner prescribed in bidding document.

(b) Single Stage – Two Envelope Procedure

The bid shall comprise a single package containing two separate envelopes. Each envelope shall contain separately the financial proposal and the technical proposal. Initially, only the envelope marked "TECHNICAL PROPOSAL" shall be opened. After the evaluation and approval of the technical proposal the procuring agency, shall at a time within the bid validity period, publicly open the financial proposals of the technically accepted bids only. The financial proposal of bids found technically nonresponsive shall be returned unopened to the respective bidders. The bid found to be the lowest evaluated bid shall be accepted

(c) Two Stage – Two Envelope Procedure

First Stage

The bid shall comprise a single package containing two separate envelopes. Each envelope shall contain separately the financial proposal and the technical proposal. Initially, only the envelope marked "TECHNICAL PROPOSAL" shall be opened. The envelope marked as "FINANCIAL PROPOSAL" shall be retained in the custody of the procuring agency without being opened. The technical proposal shall be discussed with the bidders with reference to the procuring agency's technical requirements. Those bidders willing to meet the requirements of the procuring agency shall be allowed to revise their technical proposals following these discussions.

Second Stage

After agreement between the procuring agency and the bidders on the technical requirements, bidders who are willing to conform to the revised technical specifications and whose bids have not already been rejected shall submit a revised technical proposal and supplementary financial proposal, according to the technical requirement. The revised technical proposal along with the original financial proposal and supplementary financial proposal shall be opened at a date, time and venue announced in advance by the procuring agency.

2.2 PIPS BV System:

The PIPS BV system is based on the deductive logic that the expert vendors have low risk and can deliver desired quality at lowest possible cost. It requires preplanning and proactive risk management approach that mitigate the risk before it happens (Kashiwagi et al., 2010).

2.2.1 PIPS Overview:

To improve the procurement, management and delivery of projects and services, the performance Based Studies Research Group (PBSRG) has developed innovative tools. These tools have been amalgamated together as Performance Imformation Procurement System (PIPS). This process has three major phases that are outlined below (Little and Kashiwagi, 2012).

2.2.2 Identification of Potential Best Value:

In this phase vendors are evaluated based on their cost, schedule, ability to identify and mitigate project risks, past perforance information of team and interview of key personnel. Although similar criteria is used in other selection process, the way in which they are collected and analyzed are significantly different.

2.2.3 Clarification:

Contract is awarded immediately after evaluation process is complete. However in PIPS, a period of time is set aside to carefully preplan and clarify the project/services. The clarification occurs between owner and potential best vendor. During this peroid, the vendor primitively reviews the project to assure that they understand the owner's intent, outlines what is included in scope and respond to any questions or interests that owner may have.

2.2.4 Contract Award and Performance Measurement:

After clarification period, the owner has the option to award to potential best value vendor. After successful award, the awarded vendor is required to submit a weekly risk report that tracks all project deviation with regards to time and money. This report will provide an up-to-date analysis of the project on weekly basis and information to key stakeholders.

2.2.5 Significance of PIPS:

The significant features of PIPS are given as:

- Decision making increases risk, so BV method minimizes decision making.
- If no vender differentiates themselves, then BV vendor is the lowest costing vendor.
- By using performance information, expert vendors show their high performance on similar projects.
- Expert will address the needs and concerns of client.
- If BV PIPS overall scores are equal, then owner will go for the lowest price option.
- If BV vendor is more expensive, they must clearly identify why they are more expensive.

2.2.6 Comparison with Traditional Low-Bid System:

The BV PIPS system has the following conceptual differences from traditional systems (Kashiwagi et al., 2014).

- Utilizes expertise to lower cost and add value.
- Identifies expertise as the only factor that can minimize risk of nonperformance.
- Identifies warranties, specifications and standards as inefficient in minimizing risk.
- Identifies that attempting to manage, direct and control non-expert vendors is inefficient and costly.
- Identifies if you ask a vendor to describe a problem, how they know that it is the problem, how they know that they can solve the problem using performance metrics and by recognizing natural laws that differentiates experts from non-experts, the risk of nonperformance is minimized drastically.
- Methodology that a non-expert vendor can identify expert vendor and utilize expertise to lower cost and risk.

2.3 Criteria for Project Success:

There is not a single definition of a project success; many researchers define them in various contexts by considering different indicators that contribute to deliver the project successfully.

Some of those definitions are given as:

- A project as the achievement of a specified objective, which involves a series of activities and tasks that consume resources (Munns and Bjeirmi, 1996).
- Project success is a broad view which varies among persons, stakeholder's expectations and with phases of projects. Every party in a project has different criteria for measuring success (Cooke-Davies, 2002).

- The measures for project success should also include project psychosocial outcomes which refer to the satisfaction of interpersonal relations with project team members (Turner and Müller, 2003).
- The absence of legal claims leads to the success of project. This then calls for including “safety” as a success indicator as well, since it is reasonable to expect that if accidents occur, both contractors and clients may be subject to legal claims, as well as financial loss and contract delay in the construction project (Jugdev and Müller, 2005).

2.4 Best Value:

- It is an efficient and effective approach that minimizes communication and flow of detailed information, creates a “win-win” scenario, the highest possible value at a lowest cost, high vendor profit and minimal project cost and time deviations (Kashiwagi, 2012).
- A procurement process where price and other key factors are considered in the evaluation and selection process to enhance the long-term performance and value of construction. (Scott, 2006).
- It aims at maximizing the outcome of a business transaction. It emphasizes efficiency, value for money, and performance standards. The best value approach requires public sector organizations to establish best practice, develop verifiable standards, and make appropriate contractual arrangements in the procurement of public works and services in order to serve the public in the best possible way (Akintoye et al., 2003).

2.4.1 Concept of BV:

This innovative concept of BV curtailed form the idea that using multiple criteria, the competition among venders increases because one contractor pretend to deliver good quality product than other contractors. Undeniably, the quality grounds are not the same for each contractor. Therefore, it is preferable for the procurement party to have a greater quality project at the price agreed between the parties (Herbsman et al., 1995). User expectation and satisfaction can only be achieved by forming a good relationship between parties involved in the contract. All the quality standards could not be implemented on a project at lowest cost. Therefore, it is thoughtful to use a cost-time tradeoff approach (Shen et al., 1999).

2.4.2 Best Value Contracting / Best Value Source Selection:

Best value contracting, also called BVSS, aims to maximize the outcome of a business transaction through appropriate contractual arrangements. The BVSS allows tradeoffs among price and non-price factors, and thus enables the public client to select a higher priced proposal instead of the lowest priced proposal, provided that the increased benefits merit the additional cost (Zhang, 2006). The relative importance of price and non-price criteria varies in different types of contracts. Price may play a dominant role in an acquisition where there are clear requirements and risks are minimal. However, non-price criteria may dominate in an acquisition where the requirements are not well defined, much development work is needed, and/or there are substantial performance risks (Mickaliger, 2001).

2.4.3 Best Value Contributing Factors:

Based on the previous research regarding contractor selection procedure, a total of 19 factors have been identified. The sources used for searching the literature included “ASCE”, “Science Direct”, “Taylor & Francis Online”, “Cibw117” and “Emerald Insight” etc. Semantic technique and keywords are used in searching process. A total of 62 research publications from different journals of project management, and construction engineering and management published between the years 2000-2015 have been studied. This particular period is selected to focus on the recent trends and examine the attributes that are presently effective in this area of research. The identified factors have been shown in Table 2.1.

Table 2.1: Identified Factors with their references

Sr. No.	Factors	References
1	**Proposed Tender Price**	Greenwood and Wu (2012) Gajjar et al. (2014) Bertolini et al. (2006)
2	**Low project life cycle cost**	Kagioglou et al. (2001) Kashiwagi et al. (2014) Crawford et al. (2006)
3	**Financial capability**	Xia et al. (2014) Al-Harbi (2001) Brady et al. (2005)
4	**Additional financial resources for priority projects**	Kashiwagi and Byfield (2002b) Zhang (2006) Assaf and Al-Hejji (2006)
5	**Transfer of risks related to construction, finance and operation**	Hai and Watanabe (2014) Savicky et al. (2014) Eriksson and Westerberg (2011)
6	**Ability to deal with unanticipated problems**	Gajjar et al. (2014) (Zavadskas et al., 2010) (Taroun, 2014)
7	**Past performance and expertise of the company**	Gransberg and Molenaar (2004) Bassioni et al. (2005)

		Kim and Huynh (2008)
8	**Number of key personnel**	Yeung et al. (2009) Hai and Watanabe (2014) (Assaf and Al-Hejji, 2006)
9	**Optimized resource utilization**	Wong et al. (2000) Wang and Huang (2006) Gajjar et al. (2014)
10	**Training and skill level of project team**	Wong et al. (2000) Cheng and Li (2004) (Dainty et al., 2005)
11	**Quality control measures**	El-Mashaleh et al. (2007) Lin and Shen (2007) Luu et al. (2008)
12	**Meeting design requirements**	Haponava and Al-Jibouri (2011) (Liu et al., 2004) Crawford et al. (2006)
13	**User expectations and satisfaction**	Yasamis et al. (2002) Beatham et al. (2004) Flyvbjerg (2013)
14	**Health and safety performance**	Cheung et al. (2001) Cho et al. (2009) Pan et al. (2012)
15	**Environmental impact**	Luu et al. (2005) El Wardani et al. (2006)

		Abudayyeh et al. (2007)
16	**Type of project control and monitoring process**	Al-Jibouri (2003) Dainty et al. (2003) Vanhoucke (2012)
17	**Actual schedule achieved for similar works**	Abdul-Rahman et al. (2006) (Odeh and Battaineh, 2002) (Frimpong et al., 2003)
18	**History of claims and disputes.**	Olander (2007) Ullah Khan (2014) Zaneldin (2006)
19	**Number and size of projects in hand**	Fong and Choi (2000) Topcu (2004) Watt et al. (2010)

2.5 Grouping of identified factors:

A total of 19 factors have been identified that affect the decision making in selecting the most suitable contractor as shown in Table 1. Upon further studies and investigation of related literature, these factors are grouped into eight main criteria. These criteria are developed by extracting the factors from the previously carried out relevant research and available literature. As a result, the above mentioned factors are referred to as sub-criteria and their grouping has resulted into formulation of main criteria as shown in Table 2.2.

Table 2.2: Grouping of Factors

Sr. No.	Criteria	Identified Factors
1	**Cost**	Proposed tender price Low project life cycle cost Financial capability Additional financial resources for priority projects
2	**Risk**	Transfer of risks related to construction, finance and operation Ability to deal with unanticipated problems
3	**Performance**	Past performance and expertise of company Number of key personnel Optimized resource utilization Training and skill level of project team
4	**Quality control**	Quality control measures Meeting design requirements User expectations and satisfaction
5	**Health and safety**	Health and safety performance Environmental impact
6	**Project control**	Type of project control and monitoring process Actual schedule achieved for similar works.
7	**Delay claims**	History of claims and disputes.
8	**Current Workload**	Number and size of projects in hand

2.5.1 Cost

Cost is one of the most significant criteria for measuring project success. It is defined as the basis at which the general conditions that are mentioned in contract stimulate the project completion within the expected budget (Bubshait and Almohawis, 1994). It cannot be suggested as the cost that is only constituted in tender sum, but it covers cost which is being utilized in various stages of project leading form inception, designing, and execution to maintenance. Overheads and profits of contractors are also summed up in cost. It can be measured as unit cost or lump sum. In acquisition, price plays a vital role where the requirements are well defined and risks are negligible. On contrary, where requirements are not well defined, non-price criteria may dominate (Watt et al., 2010). The Best Value Source Selection (BVSS) energizes creativeness and improvement from contractors who intended to fulfill the requirements of public projects and augments the flexibility in selecting best proposal (Zhang, 2006).

2.5.2 Risk

Project risk is the ambiguous event whose occurrence may positively or negatively impact the project outcomes like cost, quality, schedule and scope (Rose, 2013). In measuring the risk, identified risks are further ranked both qualitatively and quantitatively. In this way the risks are highlighted for further analysis. Project risks and their sources can be classified using various approaches. From the perspective of contractor, project-related risks can be classified that have an impact on project performance in terms of cost (Baloi and Price, 2003). Incentive-based contracts were introduced to overcome the issues that occur in traditional forms of payment. Both client and contractor share the risks and the reward in incentive-based contracts (Floricel and Miller, 2001).

2.5.3 Performance

Past performance of contractor is evaluated prior to its selection. In this process, various attributes such as human resource, machinery and equipment, skill level of project team, optimized resource utilization and number of key personnel are evaluated. In order to improve the overall performance of contractors, they must focus to complete the project in stipulated time, reduce delays and establish good relationships with sub-contractors (Xiao and Proverbs, 2003). Contractor enactment play a dynamic role in success of project since it is the party who has the duty to deliver the project. Augmented contractor performance definitely enhances the user gratification, contractor repute and their effectiveness in the market. Research shows that there is much room for further investigating the contractor performance (Alarcón and Mourgues, 2002) .The contractors who are able to finish by the deadline of project are more viable to bring out future projects (Chan et al., 2002). Therefore, during selection, those contractors who have excellent past performance record should be given preference (Khosrowshahi, 1999).

2.5.4 Quality Control

The assessment of quality is subjective. In construction industry, quality is defined as the totality of features required by the product or services to satisfy a given need; fitness for purpose (Arditi and Gunaydin, 1997). Specification is defined as workmanship guidelines provided to contractors by client at commencement of project execution. Corporate-level quality refers to the quality expected from a construction company in addition to the product and/or service quality. Corporate Quality culture promotes quality conscious work environment and corporate-level quality in a construction company. It establishes and promotes quality and continuous improvement through values, traditions and procedures (Arditi and Lee, 2003). Contractors achieve client satisfaction by establishing strong quality culture and delivering higher quality services and facilities. Owners expect that the contractors must deliver highest quality in every dimension. Therefore, it is of importance to owners to encourage the contractors who follow the quality standards (Cox et al., 2003).

2.5.5 Health and Safety

Health and Safety is defined as the extent to which the general conditions are implemented on the project without major injuries and accidents on site (Bubshait and Almohawis, 1994). Since most of the accidents happen during execution phase, the measurement of safety is primarily focused at this time. In a rapidly built environment, general reminders to implement safety are very important to avoid fatalities. Additionally, warning signs must be displayed to develop a safe and healthy environment at workplace. These warning signs keep the workers attentive to follow safety rules, enable them to communicate the hazards, provide them the necessary instructions about using personal protective equipment (Toole, 2002).

2.5.6 Project Control

The project monitoring and controlling process should be initited from planning phase which involes appropriate breakdown into smaller components, using performance metrics and anayltical tools, earned value management (EVM) and performance forecasting (Nepal et al., 2006). The procedure of evaluating project cost and perfomance has been significantly analyzed (Rose, 2013).In order to quantify the progress based on WBS and cost accounts, several models have been developed. The researchers are still an awful long way from achieving the lowest possible level of scope breakdown to evaluate progress without messing with data handling (Chan et al., 2001).

2.5.7 Delay Claims

In the construction process, delay claims are considered to be an area of uncertainty and severance (Wood and Ellis, 2005). The cost of disruptions is production related and often problematic to justify. Several issues may arise such as how to alleviate the risks relating estimation, resource utilization, poor workmanship, plant breakdown, deprived quality or impaired material (Shi et al., 2001). In case of potentially problematic aspects of delay claims in a construction project, study reveals that various aspects like pre-contract negotiation, clarity in project scope, and agreement between contractor, owner and project team are likely to lessen the conflict among parties and increase the certainty in project success (Aibinu and Odeyinka, 2006).

2.5.8 Current Workload

Current workload refers to the number and size of projects that a company is carrying out at the moment. It gives the information that whether the resources will be available for a particular project depending upon the workload load during construction (Singh and Tiong, 2006). A company having undertaken few projects at one point in time, then they would have ample capacity of resources to incorporate on those projects. In case the company has undertaken many projects then the resources will be distributed, as hence a limited capacity will be available for the projects (Al-Harbi, 2001).

2.6 Yearly appearance of Factors:

In the next step, yearly appearance of these factors has been studied in order to observe the temporal progress in the published literature. An attempt has been made to classify these factors on the basis of year of appearance. For inclusion in the table, a factor has to appear at least once every two year. The yearly appearance has been shown in Table 2.3.

Table 2.3: Yearly appearance of Factors

Sr. No.	**Criteria**	**Identified Factors**	**Yearly Appearance**							
			2000-2001	**2002-2003**	**2004-2005**	**2006-2007**	**2008-2009**	**2010-2011**	**2012-2013**	**2014-2015**
1	**Cost**	Proposed tender price	✓	✓	✓	✓	✓		✓	✓

		Low project life cycle cost	✓	✓		✓	✓	✓		✓
		Financial capability	✓		✓		✓			✓
		Additional financial resources for priority projects		✓		✓				
2	**Risk**	Transfer of risks related to construction, finance and operation.	✓	✓			✓	✓	✓	✓
		Ability to deal with unanticipated problems						✓		✓
3	**Performance**	Past performance and expertise of company	✓	✓	✓	✓	✓	✓	✓	✓
		Number of key personnel	✓		✓	✓	✓			✓
		Training and skill level of project team	✓		✓					
		Optimized resource utilization	✓			✓				✓
4	**Quality Control**	Quality control measures	✓	✓	✓	✓	✓			✓
		Meeting design requirements		✓	✓	✓		✓		✓
		User expectations and satisfaction		✓	✓		✓		✓	✓

5	**Health & Safety**	Health and safety performance	√		√		√		√	√
		Environmental impact	√		√	√	√			√
6	**Project Control**	Type of project control and monitoring process		√					√	
		Actual schedule achieved for similar works.	√	√	√	√	√	√	√	√
7	**Delay Claims**	History of claims and disputes.			√	√				√
8	**Current Workload**	Number and size of projects at hand	√		√	√		√		√

2.7 Appearance and Criticality of Factors:

After sinking through the literature of 62 papers on this subject, the factors show various trends with some being more appearing than others. The appearance of factors and their criticality has been given in Table 2.4.

Table 2.4: Appearance and criticality of Factors

Sr. No.	Criteria	Identified Factors	Appearance	Criticality
1	**Cost**	Proposed tender price	20	32.2 %
		Low project life cycle cost	14	22.5%

		Financial capability	10	16.12%
		Additional financial resources for priority projects	5	8.06%
2	**Risk**	Transfer of risks related to construction, finance and operation	21	33.87%
		Ability to deal with unanticipated problems	3	4.83%
3	**Performance**	Past performance and expertise of company	35	56.45%
		Number of key personnel	12	19.35
		Optimized resource utilization	6	9.67%
		Training and skill level of project team	3	4.83%
4	**Quality Control**	Quality control measures	30	48.38%
		Meeting design requirements	13	20.96%
		User expectations and satisfaction	12	19.35%
5	**Health and Safety**	Health and safety performance	28	45.16%
		Environmental impact	10	16.12%
6	**Project Control**	Type of project control and monitoring process.	7	11.29%
		Actual schedule achieved for similar works.	19	30.64%
7	**Delay Claims**	History of claims and disputes.	8	12.90%

8	**Current Workload**	Number and size of projects at hand	6	9.67%

Considering the above data, the criticality of factors enabled us to determine their relative percentages; some factors like *performance*, *health and safety*, and *quality control* have greater percentages. Although factors like *risk*, *cost* and *project control* are very less deviation comparatively, they are amid in this distribution. It has been shown in the pie chart in Figure 1, that both *delay claims* and *current workload* have lowest percentages.

2.8 Frequency Analysis:

This criticality of criteria helps us to formulate the frequency using a pie chart. The relative frequency of each criterion has been shown in Figure 2.2.

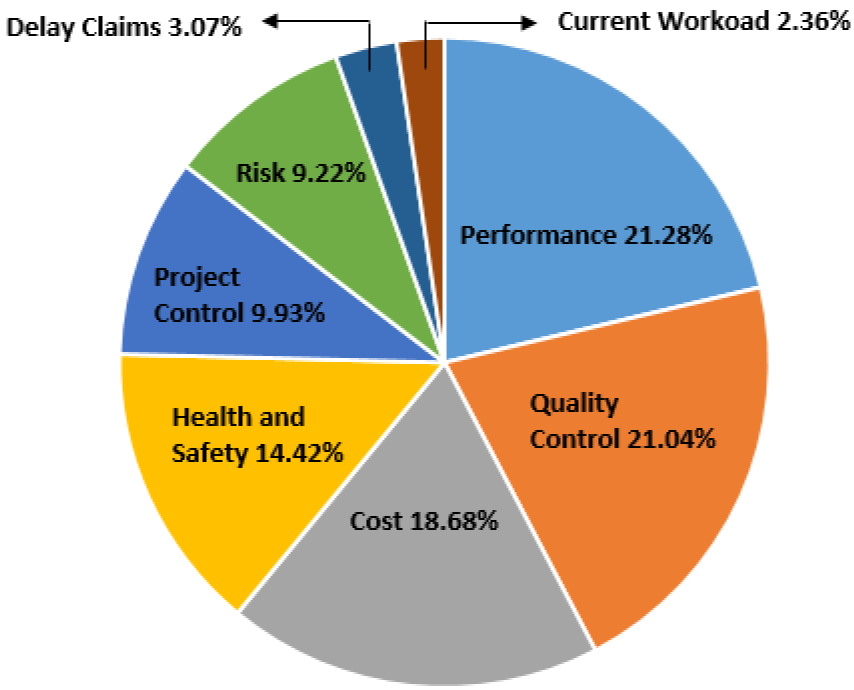


Figure 2.2: Relative Frequency of Criteria

The pie chart presents a clear picture of the components that the researchers have come up with in the 21st century in BV literature. Since execution is the most critical phase of a project and a lot of risks are involved, it has been delegated to the contractor who has the responsibility to complete according to the requirements of the owner. Some attributes are pivotal for contractor selection in which the *performance* is the most imperative. It includes some attributes like *"past performance and expertise of company", "number of key personnel", "optimized resource utilization"* and *"training and skill level of project team"*. The first one has higher criticality and the last has lower. However due to the averaging effect, the criterion of *performance* is considered as critical. As a general rule, individual attributes may have varying criticality but if any of them is reported to have very high frequency, the averaging effect will result into criticality boost into the overall criterion.

2.9 Classification of Criteria on the basis of Journal:

In the next step, the emergence of factors in various journals has been categorized. It is deduced based on detailed observations that some journals have constituted many factors while some have just covered only one. It is evident in Figure 2 that "International Journal of Project Management" has included all the factors. So it may be considered as the most comprehensive journal that researchers can seek guidance from. Some journals like "Construction Management and Economics", "Benchmarking: An International Journal" and "Journal for the Advancement of Performance Information & Value" constituted six criteria. Furthermore "Automation in Construction" and "Building and Environment" included only one factor. This shows that they do not share the same level of comparative focus on the BV literature. The classification on the basis of journals has been shown in Figure 2.3.

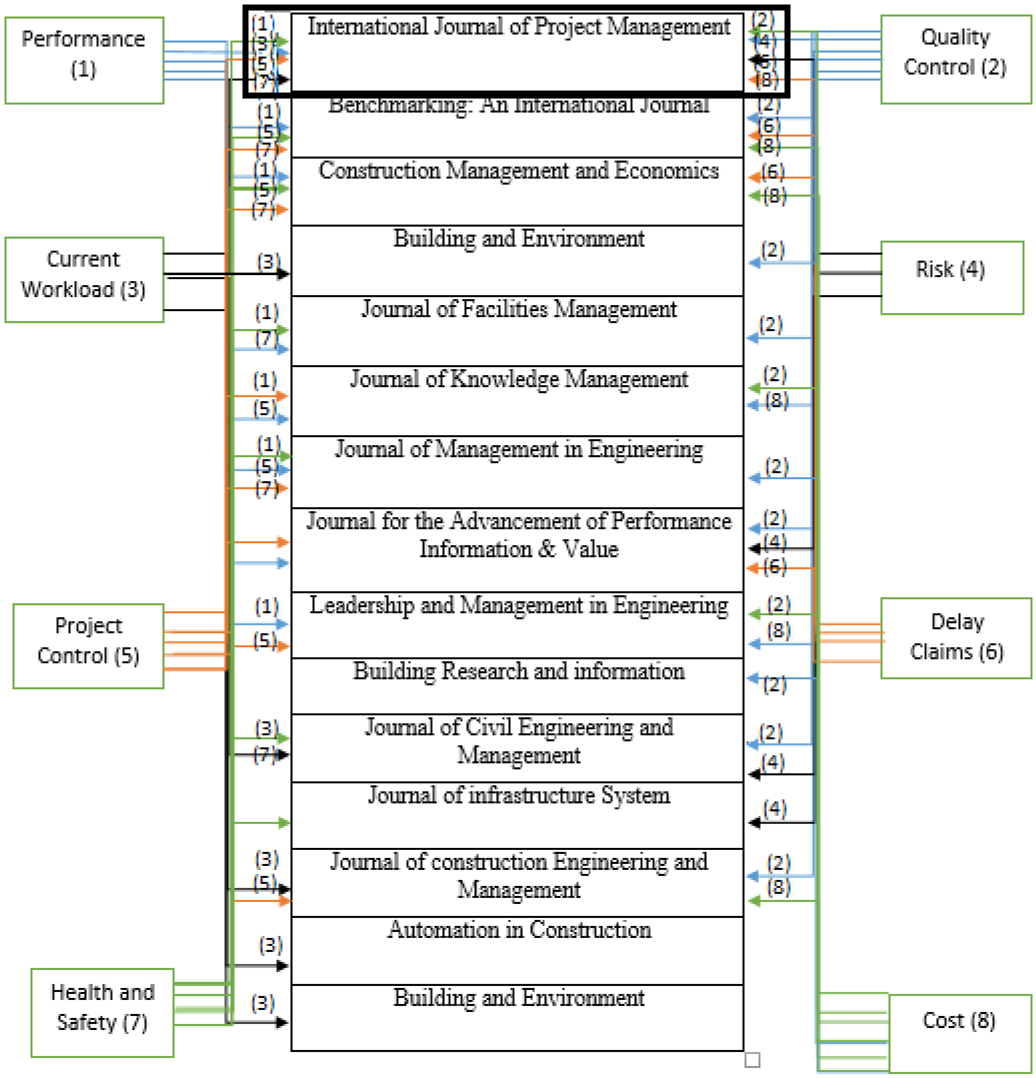


Figure 2.3: Appearance of Factors in various Journals

2.10 Classification of Identified Factors on the basis of sources:

In this step, the sources of articles covering these factors have been identified. Famous libraries of research publications like "ASCE library" and "Science Direct" constituted all the eight factors and most of the papers regarding this field have been downloaded from these sources. "Taylor and Francis Online" is on the second rank. "Emerald Insight" and "Cibw117" included six factors each. Factors along with their respective sources are given in Table 2.5.

Table 2.5: Sources of Factors

Criteria	Sources	Criteria	Sources
Performance	Taylor & Francis Online ASCE Library Emerald Insight Cibw117 Science Direct	**Cost**	Taylor & Francis Online ASCE Library Emerald Insight Cibw117 Science Direct
Quality control	Taylor & Francis Online ASCE Library Emerald Insight Cibw117 Science Direct	**Health and safety**	Taylor & Francis Online Emerald Insight ASCE Library Science Direct
Project control	ASCE Library Emerald Insight Cibw117 Science Direct Taylor & Francis Online	**Delay claims**	Taylor & Francis Online Emerald Insight Cibw117 ASCE Library Science Direct
Risk	ASCE Library Cibw117 Science Direct	**Current Workload**	ASCE Library Taylor & Francis Online Science Direct

2.11 Factors Identification Chart:

There are several factors that influence the success of project enactment which were identified by following an in-depth review of articles as mentioned previously. The contractor and subcontractor perform activities in construction stage. The elements include contractor performance, site supervision, contractor cash flow, overheads, effective cost control system and communication at site. An attempt has been made to formulate a new structure that includes the criteria affecting the project success is developed. It can be used as basis for further complete examination on selection criteria for general construction projects and specific projects like roads, buildings, dams, bridges, etc. Therefore to provide more ease in finding the literature about BV, a more systematic way of project success is established.

In this step, temporal analysis has been carried out on all of the identified factors. The published literature has been limited to 21st century to make it comprehensive and identify the latest trends regarding the topic. Initially some work was carried out on BV in which the researchers had identified some factors that would affect the decision making. Since every research is an ongoing flux, therefore it is not viable to only rely upon the factors that had been initially identified. Efforts have been made to find loopholes that affect the long term decision making process. At initial stage of every research, only few areas have been touched upon. But as the time progressed, the conditions that were previously reigned in particular area didn't necessarily remain the same in upcoming decision making process and hence an inference can be made about the futuristic change in the process. As a result, the maturation of the phenomenon is necessary to be studied.

Considering the literature on BV, the analysis is graphically represented in Figure 3. It shows the crux of this research by indicating the factors which have been identified by the researchers initially. Some factors have been eliminated and new factors have emerged successively, whereas some of them show no change in their appearance over the period of study. The factors number continued to vary with every passing year in such a way that we had a complete picture by the end stage of the study period. Therefore, currently all of the mentioned factors need to be considered in contractor selection using BV approach. This distribution also enables to determine that some factors like *cost*, *quality control*, *project control* and *performance* have appeared continuously which shows that despite evolution of new factors, they demonstrate equal strength over the time. Their continuous emergence in each year shows that the significance of the criteria in decision making process of contractor selection. The historical development of Best Value contributing factors is shown in Figure 2.4.

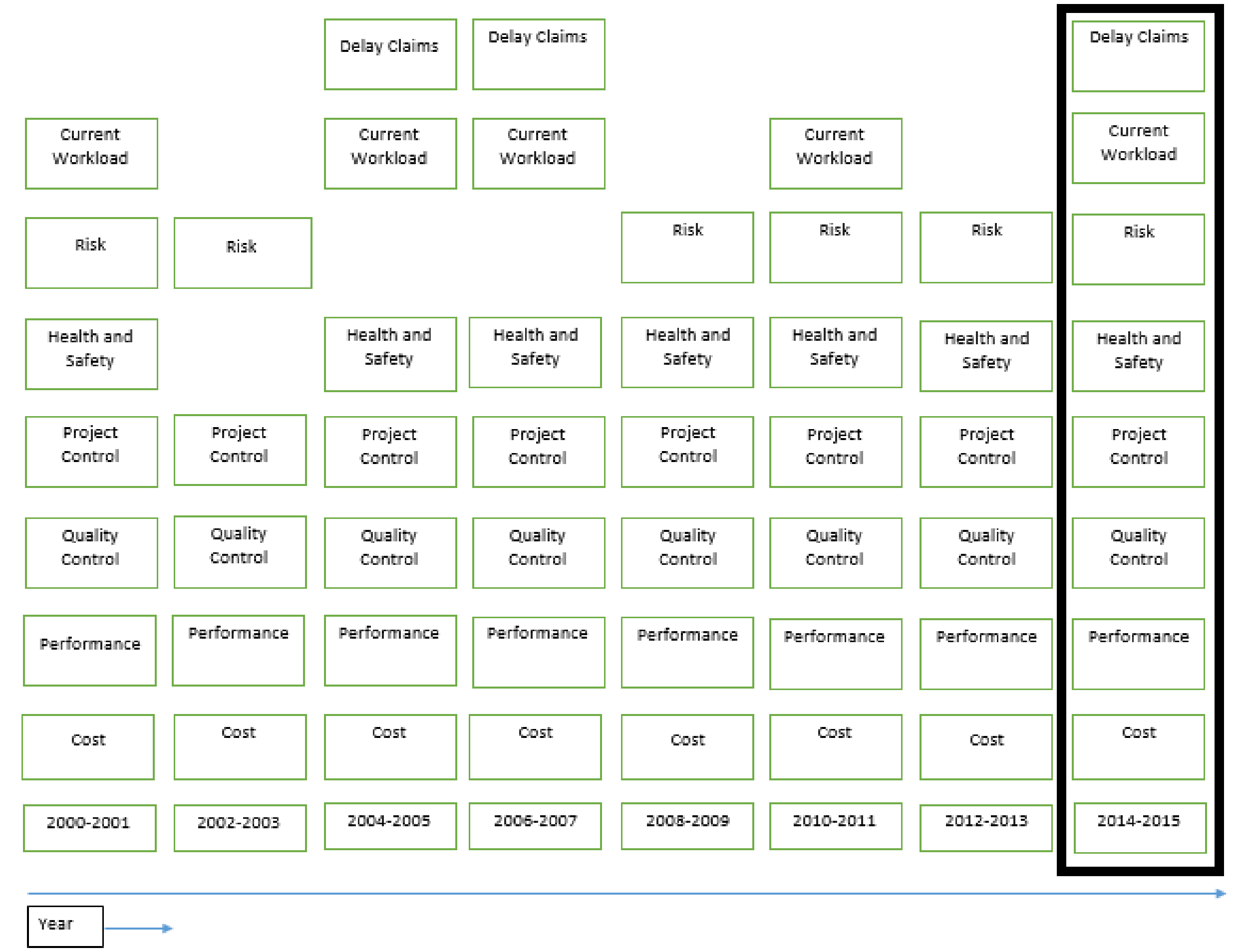


Figure 2.4: Historical development of Best Value contributing Factors

It is to note that publications in 2000-2001 have considered all the factors excluding *delay claims* that arise on construction sites suggesting that most of the criteria have been figured out at the early stages of research in BV procurement process. After that, it can be observed that *current workload* was also not reported in 2002-2003. *Risk* is a key criterion that a contractor should be capable of mitigating but the content analysis shows that it has not been contemplated from 2004-2007. Ample research has been carried out in risk management but risk in decision making has not been considered in the mentioned years. In a similar way, some factors have been ignored in successive years while some have been reported.

RESEARCH METHODOLOGY

3.1 Pilot Survey:

In the next step, a pilot survey is conducted to identify the top factors that affect in contractor selection process. For the said survey, two paths are identified and one of them (shown in green) is selected.

The prime question of the survey is whether or not to carry out a level "0" screening to come up with modified ranking of criteria that affect the most in decision making. This led to two options. In case of ""NO", questionnaire is developed for all the identified factors and a comprehensive survey would have been carried out. In case of "YES", a global survey including both International and Pakistan experts is carried out. The screening panel consisted of authors and field experts having vast experience in Contractor selection process. The procedure is followed has been shown in green color in Figure 3.1.

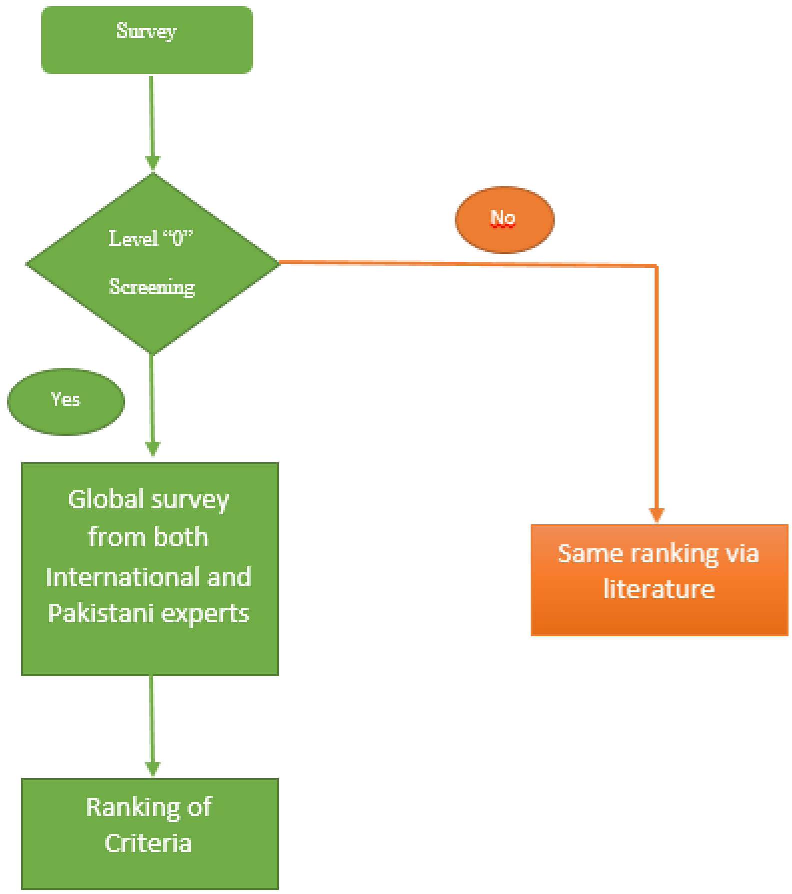


Figure 3.1: Pilot Survey options

3.1.1 Initial Questionnaire:

A questionnaire is developed in accordance to the pilot survey which focuses on simple question that how much a particular factor effect in contractor selection process. This questionnaire has been shown in Appendix 1. The respondents included experts from different countries throughout the world .The distribution of experts is shown in Table 3.1.

Table 3.1: Number of Responses along with their Countries

Sr. No.	Number of responses	Countries
1	Ten	United States of America
2	Five	Pakistan and United Kingdom each.
3	Two	Australia, Malaysia and India each.
4	One	Sweden, New Zealand, Hong Kong, Taiwan, Netherland and Chile each.

Since "Best Value" is a new approach in contractor selection process, therefore most of the countries have just started this method which is still under research process. A lot of research on this method has been done in USA, so most of the responses have been gathered from USA. However, developing countries are following this trend and a lot of research needs to be done in those regions where industry is still following traditional methods in decision making.

3.2 AHP Introduction:

Analytical hierarchy process helps to establish decision models through a process that contains both qualitative and quantitative components. Qualitatively, it helps to decompose a decision problem from the top overall goal to a set of manageable clusters, sub-clusters, and so on down to the final level that usually contains scenarios or alternatives. The clusters or sub-clusters can be forces, attributes, criteria, activities, objectives, etc. Quantitatively, it uses pair-wise comparison to assign weights to the elements at the cluster and sub-cluster levels and finally calculates 'global' weights for assessment taking place at the final level. Each pair-wise comparison measures the relative importance or strength of the elements within a cluster by using a ratio scale. One of the main functions of AHP is to calculate the consistency ratio to ascertain that the matrices are appropriate for analysis (Saaty, 1988). Nevertheless, AHP models assume that there are unidirectional relationships between clusters of different decision levels along the hierarchy and uncorrelated elements within each cluster as well as between clusters. It is not appropriate for models that specify interdependent relationships in AHP. ANP is then developed to enhance the tool's analytical power.

3.2.1 AHP methodology

The main objective of this study is to prioritize the studied factors in decision making process of contractor selection in context of Best Value. Multi-criteria decision-making (MCDM) technique is very beneficial in solving complex problems that cannot be solved directly. The important rule of using MCDM is that the solution should be based on simple criteria that is by considering more than one attribute (Cheng et al., 2005). Because the issues related to contractor selection is becoming more complex, therefore it is challenging to handle all issues pertaining to decision making in a single set of processes. AHP is a mathematical decision-making technique introduced by (Saaty, 2008) to solve complex decision-making problems that are ambiguous and complex (Yang and Huang, 2000). AHP helps in disintegrating the complex problem into a hierarchy of simple factors and sub-factors and with the help of a comparative analysis, it makes their measurement easier (Saaty, 1988). One of the most important features of AHP is that it can be applied to both subjective and objective kinds of problem (Saad, 2001). The main objective behind the development of this technique was to decompose a compound, multi-criteria problem into different levels of hierarchy with the top level of hierarchy as the goal or objective of the problem, middle level as the criteria and sub-criteria and the lowest level as alternative design in a hierarchy structure (Saaty, 1988). Current literature provides an idea about the use of AHP particularly in ranking and priority of different criteria and sub-criteria (Chin and Pun, 2002).

3.2.2 AHP Steps:

The steps of the AHP are as follows.

Step 1:

Define and state the objectives of the complex and ambiguous problem clearly.
Step 2:

The multifaceted problem is decomposed into a hierarchal structure with the help of group decision or survey technique. The hierarchal structure is divided into multiple levels. The top level hierarchy represents the goal of the problem. This goal is sub-divided into various criteria in the next level. The criteria are further divided into sub-criteria levels which highlight the details of the criteria.

Step 3:

To illustrate the importance of one criterion over other, a pairwise comparison can be made through decision matrix. With the help of decision makers and experts, the decision making matrix is constructed on the basis of (Saaty, 1994) nine point scale shown in Table III. In the hierarchal structure, the elements which underlie the common node are compared with the other elements of the same node. For example, if there are “n” elements under the node, then n (n-1)/2 comparisons takes place under that node.

Let there are X_1, X_2, X_3, ….. X_n elements under the node “M” and their numerical weights are w_1, w_2, w_3, …. W_n. The pairwise comparison of these elements in accordance to their relative weights are shown in the form of a matrix, where Z is the comparison matrix (n x n) which represents pairwise comparisons among the elements X_1, X_2, X_3, ….. X_n :

$$
Z = \begin{array}{c} \\ X_1 \\ X_2 \\ \vdots \\ X_n \end{array}
\begin{array}{c} \begin{array}{cccc} X_1 & X_2 & \dots & X_n \end{array} \\
\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_1}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \end{array}
$$

$$
Z = \begin{array}{c} \\ X_1 \\ X_2 \\ \vdots \\ X_n \end{array}
\begin{array}{c} \begin{array}{cccc} X_1 & X_2 & \dots & X_n \end{array} \\
\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}
$$

Where $a_{ij} = w_i/w_j$ (i, j = 1, 2 … n) represents the quantified comparative importance among the pair of elements X_i and X_j. If i =j then $a_{ij} = 1$ and $a_{ij} = 1/a_{ji}$ for $a_{ij}>0$.

Step 4:

After the formation of decision making matrix, the next step is to identify the priority weights of the elements through the maximum eigenvectors and eigenvalues.

According to (Saaty, 1994): λ_{max}

$$
\boldsymbol{\lambda_{max} = \sum_{j=1}^{i} a_{ij} \frac{W_j}{W_i}}
$$

Step 5:

The consistency of the pairwise comparisons is checked in this step. In the pairwise comparison, the inconsistency is measured by consistency index (CI) and the coherence is measured by consistency ratio (CR) and is computed with the help of given formula:

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

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

Where n is the rank of matrix and random index (RI) which is the CI of matrices which are generated randomly. The maximum acceptance limit of CI and RI is 0.1 (Saaty, 1994). If the values are more than 0.1, it will highlight that the pairwise comparison is inconsistent and hence discarded. For different values of ‘n’, the respective values of RI are depicted in the Table (Saaty, 1994):

N	2	3	4	5	6	7	8	9
RI	.00	.58	.90	1.12	1.24	1.32	1.41	1.45

Step 6:

After identifying the priority weights of each elements, that are local weights of elements, the next step is to identify the global weights of all elements with respect to the goal defined in the AHP model.

Step 7:

Finally, after calculating the global weights, all the elements are rearranged in the decreasing order according to the global prioritization.

3.3 ANP Introduction:

ANP developed by Saaty (1996) is a (MCDM) model which allows for the consideration of inter-dependencies among and between different levels of attributes and alternatives. It is a more refined form of Analytical Hierarchy Process (AHP) approach, incorporating feedback and interdependent relationships among decision alternatives to provide a framework for decision making (Power and Sharda, 2007).Since the introduction, it has been applied to a large variety of decision making and forecasting problems. Similar to AHP, the ANP is based on deriving scale measurement to be used for allocating resources according to their ratio-scale priorities (Saaty and Vargas, 2012). AHP models assume a unidirectional hierarchical relationship among decision levels, but ANP does not require this strictly hierarchical structure and allows for more complex inter-relationships among the decision levels (Cheng and Li, 2007). ANP generalizes the pairwise comparison process so that decision models can be built as complex networks of decision objectives, criteria, stakeholders, alternatives, scenarios and other environmental factors that influence one another's priorities (Saaty, 2004). The key concept of the ANP is that influence does not necessarily have to flow only downwards, it can flow between any two factors in the network causing non-linear results of priorities of alternative choices (Saaty, 2005).

3.3.1 Pairwise comparison for each level of criteria and sub-criteria:

This is the first step which is related to the collection of information and data with the help of expert judgments from both industry and academia. For this purpose, an online survey is conducted to prioritize the top factors that could effect in contractor selection. This survey has been shown in Appendix 2.

The experts selected for the evaluation were responsible for the implementation and assessment of contract award practices in their respective organizations. They have enough experience in the construction management and decision making of contractor selection, particularly at the strategic level in their organizations. They hold the positions like Deputy Director, Procurement specialist, team leaders, etc. They have a substantial amount of knowledge and experience in the various procurement practices in the construction industry.

3.3.2 Brief Review on application of ANP:

ANP finds applications in various fields. It has been used by numerous authors for solving different types of problems. Meade and Sarkis (1999) used ANP as the decision making methodology for the evaluation of alternatives (e.g. projects) to help organizations become more agile with a specific objective of improving the manufacturing-business processes. Similarly, Cheng and Li (2004) applied ANP for contractor selection while Agarwal et al. (2006) used ANP-based approach for modelling the metrics of lean, agile and le-agile supply chain. They explored the relationship among lead-time, cost, quality and service level, and the leanness and agility of a case supply chain in fast moving consumer goods business. They concluded with the justification of the framework which analyzed the effect of market winning criteria.

3.3.3 ANP Steps:

ANP approach comprises of four steps (Chung et al., 2005; Saaty, 1996; Yüksel and Dagdeviren, 2007).

Step 1:

The configuration decision problem needs to be structured into its important components. In this case, the relevant criteria and alternatives are structured in the form of a control hierarchy where the higher the component level, the more 'strategic' the decision. A control hierarchy is simply a hierarchy of criteria and sub-criteria where priorities are derived with respect to the overall goal of the system being analyzed. Identification of control criteria, clusters, elements and alternatives: to structure the decision problem and develop the ANP model, the goal, control criteria, clusters, elements and alternatives have to be identified.

Step 2:

Pairwise comparisons and priority vectors: In ANP, like AHP, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. In addition, interdependencies among criteria of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty's scale. The scales of comparison have been shown in following Table 3.2.

Table 3.2: Scales of Comparison

Verbal Scale	Intensity of Importance
Extremely importance	9
Very strong importance	7
Strong Importance	5
Moderate Importance	3
Equal Importance	1

Intermediate importance	2,4,6,8

Step 3:

Step 3 is the formulation of super matrix. A super matrix is a two-dimensional matrix of elements by elements. The priority vectors from the paired comparisons appear in the appropriate column of the super matrix. The tables of super matrix are shown in Appendix 3. The table of unweighted super matrix contains the local priorities derived from the pairwise comparisons throughout the network. All the local priority information can be read directly from the unweighted Super matrix.

The weighted super matrix is obtained by multiplying all the elements in a component of the unweighted super matrix by the corresponding cluster weight.

The limit super matrix is obtained by raising the weighted super matrix to powers by multiplying it times itself.

We are concerned with the limiting priorities of the matrix as it represents all possible interactions in the system.

Step 4:

The final step is the selection of best alternative. The final priorities of factors and criteria are evaluated and based upon their priority weighing, a higher priority alternatives is considered the best among all.

3.3.4 Pairwise Comparison:

Pairwise comparison in used to derive accurate ratio scale priorities, as opposed to using traditional approaches of "assigning weights" which can also be difficult to justify. Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared. Pairwise comparisons are carried out for all the parent/children sets of nodes. The nodes that are to be pairwise compared are always all in the same cluster and are compared with respect to their parent element, the node from which they are connected. This pairwise comparison of each factor with one another is shown in Figure 3.2.

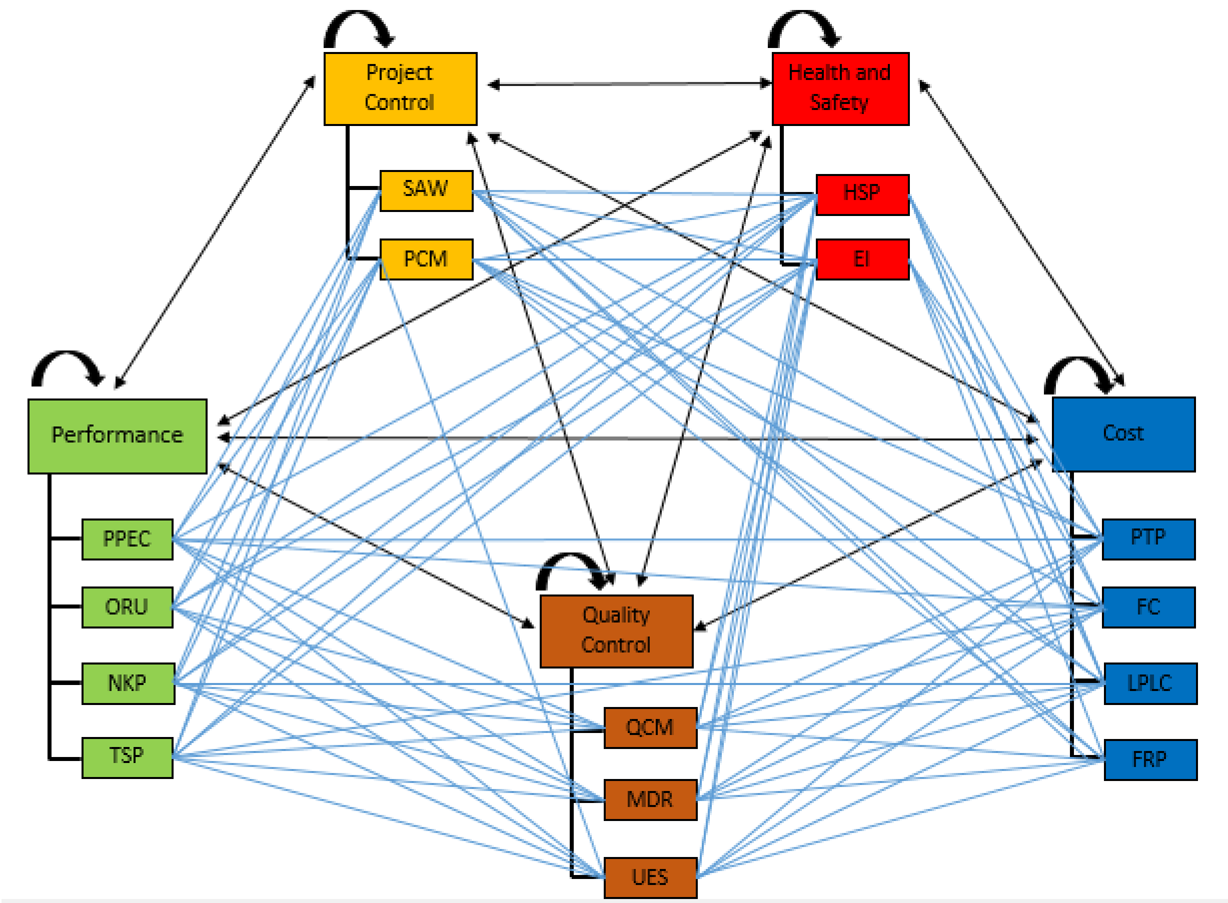


Figure 3.2: The ANP Network Component

3.3.5 Super Decisions:

The Super Decisions software implements the AHP and ANP for decision making with dependence and feedback developed by Dr. Thomas Saaty. The program was written by the ANP team, working for Creative Decision Foundation. Both methods use the same fundamental prioritization process based on deriving priorities by making judgments on pairs of elements, or obtaining priorities by normalizing direct measurements (Adams and Saaty, 2003).In AHP, the decision elements are arranged in a hierarchic decision structure from the goal to the criteria to the alternatives of choice. While in ANP the decision elements are grouped in clusters and the sub-criteria factors are networked to each other and alternatives in the form of standard Markov chain (Saaty, 2004).

RESULTS AND SYNTHESIS

4.1 Pilot Survey Results:

As a result of the pilot survey, the following Table is obtained. The average score in the Table 4.1 refers to the average of the scores assigned by the respondents to the identified factor.

Table 4.1: Questions from questionnaire and average response score

Sr. No.	Questions	Average Score	Relative Frequency
1	The significance of "Past performance and expertise of company" in contractor selection.	4.53125	.067
2	The significance of "meeting design requirements" in contractor selection.	4.125	.061
3	The significance of "Low project life cycle cost" in contractor selection.	3.21875	.047
4	The significance of "environmental impact" in contractor selection.	3.21875	.047
5	The significance of "user expectation and satisfaction" in contractor selection.	3.625	.053
6	The significance of "health and safety performance" in contractor selection.	3.53125	.052

7	The significance of "financial capability of contractor" in contractor selection.	4.125	.061
8	The significance of "optimized resource utilization" in contractor selection.	3	.044
9	The significance of "additional financial resources for priority projects" in contractor selection.	2.78125	.041
10	The significance of "transfer of risk related to construction, finance and operation" in contractor selection.	3.15625	.047
11	The significance of "quality control measures" in contractor selection.	3.8125	.056
12	The significance of "training and skill level of project team" in contractor selection.	3.6875	.054
13	The significance of "actual schedule achieved for similar works" in contractor selection.	3.625	.053
14	The significance of "type of project control and monitoring procedure" in contractor selection.	3.5625	.053
15	The significance of "number of key personnel" in contractor selection.	3.34375	.049
16	The significance of "ability to deal with unanticipated problems" in contractor selection.	3.625	.053
17	The significance of "history of claims and disputes in previous projects" in contractor selection.	3.84375	.057

18	The significance of "proposed tender price" in contractor selection.	3.71875	.055
19	The significance of "Number and size of projects at hand" in contractor selection.	3.28125	.048

4.1.1 Overall Criteria Score:

All the identified factors have been grouped in eight criteria. In this step, the average scores of factors that grouped in each criterion have been summed up. In this way, we get a cumulative score of each criterion. Table 4.2 shows the score and their relative percentages.

Table 4.2: Overall Criteria Score

Sr. No.	Criteria	Factors	Criteria score
1	**Cost**	Low Project life cycle cost	0.047
		Propose tender price	0.055
		Financial capability	0.061
		Additional financial resources for priority projects	0.041
		Overall "Cost" Score	**0.204**
2	**Risk**	Ability to deal with unanticipated problems	0.053
		Transfer of risk related to construction, finance and operation	0.047
		Overall "Risk" Score	**0.100**

3	**Performance**	Training and skill level of project team	0.054
		Number of key personnel	0.049
		Optimized resource utilization	0.044
		Past performance and expertise of company	0.067
		Overall "Performance" Score	**0.215**
4	**Quality Control**	Quality control measures	0.056
		User expectation and satisfaction	0.053
		Meeting design requirements	0.061
		Total "Quality Control" Score	0.171
5	**Health and Safety**	Health and safety performance	0.0521
		Environmental impact	0.0475
		Overall "Health and Safety" Score	**0.0995**
6	**Project Control**	Actual schedule achieve for similar works.	.053
		Type of project control and monitoring process	.053
		Overall "Project Control" Score	**0.106**
7	**Delay Claims**	History of claims and disputes	0.057
		Total "Delay Claims" Score	.057
8	**Current Workload**	Number and size of projects in hand	.048
		Overall "Current Workload" Score	**.048**

4.1.2 Relative Percentages of Criteria via Survey:

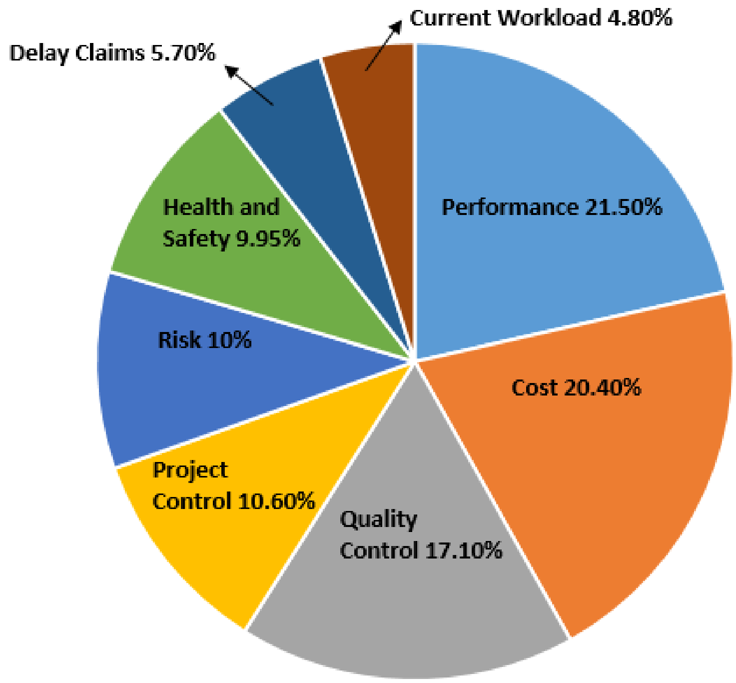


Figure 4.1: Relative Percentage of Criteria via Survey

Consider the Figure 4.1, the hierarchy of factors can be figured out, some factors like performance, cost and quality control would be at the upper level, although factors like risk, health and safety, and project control are near at hand to each other, but they are somewhere in the middle, bottom line has been accommodated by delay claims and current workload.

The relative percentages of factors tells us clear picture about the criteria that have the significant effect in contractor selection process. Since execution is the most critical phase of project and a lot of risks are involved. It has been delegated to the contractor who has the responsibility to complete the project according to the requirement of owner. Some attributes need to be considered in which the past performance is the most imperative among all. As mentioned previously that performance includes some attributes like “past performance and expertise of company” “number of key personnel”, “optimized resource utilization” and “training and skill level of project team”.

These attributes have different percentages to each other but one of them has the highest among all the identified factors, so it has the highest percentage as shown above.

The pie chart helped us in identification of the top criteria from industry that the field experts gave maximum considerations to throughout the world. These criteria can be ranked on the basis of their relative percentages. The ranking has been shown in Table 4.3.

Table 4.3: Ranking of Criteria via Survey

Sr. No	**Criteria**	**Percentages**
1	Performance	21.50%
2	Cost	20.40%
3	Quality Control	17.10%
4	Project Control	10.60%
5	Risk	10.0%
6	Health and Safety	9.95%
7	Delay Claims	5.70%
8	Current Workload	4.80%

4.2 Spearman's Rank correlation test:

Spearman's Rank correlation coefficient is used to identify and test the strength of a relationship between two sets of data. It is often used as a statistical method to aid with either proving or disproving a hypothesis.

The formula used to calculate Spearman's Rank is shown below.

$$r = 1 - \frac{6\sum d^2}{n^3 - n}$$

Where r = spearman's co-efficient

d = difference in ranks

n = number of samples

Table 4.4 demonstrates the spearman test regarding the ranking of criteria.

Table 4.4: Spearman rank correlation for criteria

Criteria	Percentage via Literature	Rank	Percentage via Pilot Survey	Rank	Difference in Ranks	D Sq.
Performance	21.28%	1	21.5%	1	0	0
Cost	18.68%	3	20.4%	2	1	1
Risk	9.22%	6	10.0%	5	1	1
Health and Safety	14.42%	4	9.95%	6	-2	4
Project Control	9.93%	5	10.6%	4	1	1
Quality Control	21.04%	2	17.1%	3	-1	1
Delay Claims	3.07%	7	5.7%	7	0	0
Current Workload	2.36%	8	4.8%	8	0	0
					Sum	8

Sum X 6	48
n^3 –n	504
(Sum X 6) / (n^3 –n)	0.095238
r	0.9047

Using the above equation, the value of ‘r’ comes out to be .9047 up to 4 decimal places or .90 up to 2 decimal places.

Significance of ‘r’ value:

To see if this *r* value is significant, a Spearman’s Rank significance graph must be used. Degree of freedom is calculated in order to do this.

Degree of freedom = n-2

In this example: 8-2 = 6

Using this number and your value ‘r’ you can use the table below to work out the significance level of data (the green lines).

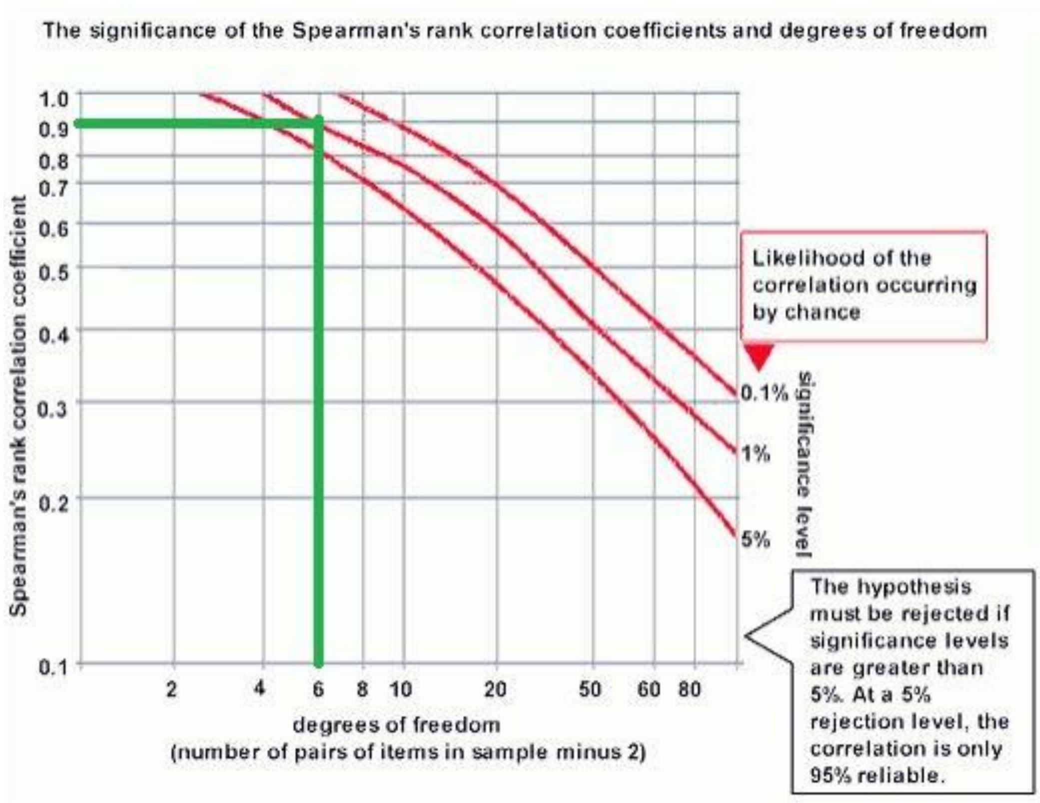


Figure 4.2: Spearman rank Correlation Graph

As it can be seen from Figure 4.2 that the green line meets the red line at 1% significance level, this means that there is around 99% chance that the relationship is significant and not random. The percentages from literature and pilot survey show a slight variation in ranking of criteria. The Spearman test is performed to measure the significance of data. After performing the test, it has been confirmed that both of the ranking of criteria from literature and pilot survey are significant.

4.3 Total Criteria Score:

The ranking from both literature and survey show some similarities and differences at various points. Therefore, spearman correlation test has been performed that has shown that our results are significant. To get a clear picture of criteria, a cumulative score is taken by multiplying the score from literature and survey.

Total Criteria Score (T.C.S) = L.S x S.S (3.1)

Where:

T.F.S = Total factor score,

L.S = Score from Literature

S.S = Score from Survey.

As a result of the combined score the ranking of criteria that significantly affecting the decision making are identified. The ranking of criteria along with their total score has been shown in Table 4.5.

Table 4.5: Total Criteria Score

Sr. No	Criteria	Literature Score	Survey Score	Total Score
1	**Performance**	21.28%	21.50%	4.58%
2	**Cost**	18.68%	20.40%	3.81%
3	**Quality Control**	21.04%	17.10%	3.60%
4	**Health and Safety**	14.42%	9.95%	1.43%
5	**Project Control**	9.93%	10.60%	1.05%
6	**Risk**	9.22%	10.0%	.92%
7	**Delay Claims**	3.07%	5.70%	.17%
8	**Current Workload**	2.36%	4.80%	.11%

4.4 Prioritization of Best Value Contributing Factors (BVCFs) in Contractor Selection

A hierarchy can be developed by creative thinking, recollection and using people's perception (Saaty, 2000). There is no specific level in the hierarchical structure, as the structure and number of levels totally depend upon the nature of the managerial decision (Zahedi, 1986). After setting out the goal of the study, related criteria and sub-criteria identified in earlier stages were structured into a hierarchal form starting at the top with the goal and various criteria and sub-criteria in subsequent levels. (Saaty, 2000) recommended the procedures for the selection of different levels of criteria and development of hierarchical structure. With the help of these guidelines, an AHP framework is constituted to accomplish the goal of study. Figure 4.3 demonstrates a three-level decision hierarchy integrating these criteria and sub-criteria.

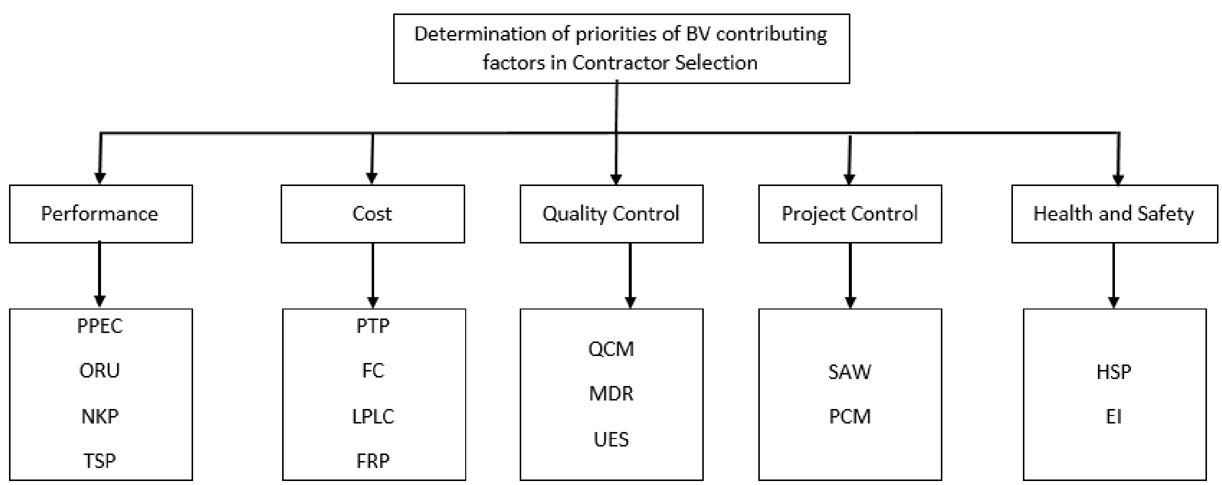


Figure 4.3: An AHP based model for determination of priorities of Best Value contributing factors in contractor selection

4.4.1 Assigning Relative Weights:

In the AHP process, decision factors are compared by assigning a weight to their relative importance. After the establishment of hierarchy, a comparison matrix was developed. This matrix is a priority statement from the individual experts. The experts evaluated the relative importance of all the criteria and sub-criteria. All the experts were asked to compare the criteria and factors very carefully by allotting a relative value on a 9-point scale proposed by Saaty (1988), keeping goal or objective of the model in mind. The comparison is based on the relative importance of 'i_{th}' factor over the 'j_{th}' factor. The outcome of this pairwise comparison was a positive reciprocal matrix, where the diagonal a_{ii} = 1, and another factor has the reciprocal property. For example, if factor 'i' is "*p*-times" important than Factor 'j', then according to the rule of reciprocity, factor 'j' is "1/*p* times" more important than Factor 'i'. The comparison done on the1-9 scale has two features. First, it provides a specific range of comparison, and second, people have enough thoughtfulness to differentiate between two points. The 1-9 scale is used to come out with the relative importance of a pair of factors.

The intensity of importance of each of the values of the scale is shown in Table 4.6 (Saaty, 1994):

Table 4.6: Total Criteria Score

Verbal Scale	Intensity of importance
Extremely importance	9
Very strong importance	7
Strong importance	5
Moderate importance	3
Equal importance	1

Intermediate importance	2,4,6,8

4.4.2 Pairwise comparison of Criteria:

The pairwise comparison of all five criteria of this study with respect to the goal that is determination of priorities of Best Value contributing factors in contractor selection is carried out. It highlights the relative importance of each criteria against the goal of the model. The synthesized matrix is shown in Table 4.7.

Table 4.7: Pairwise comparison of Criteria

Consistency ratio (.03018)	**Performance**	**Cost**	**Health and Safety**	**Project Control**	**Quality Control**
Performance	1	2	5	4	2
Cost	1/2	1	7	4	2
Health and Safety	1/5	1/7	1	1/3	1/4
Project Control	1/4	1/4	3	1	1/2
Quality Control	1/2	1/2	4	2	1

4.4.3 Pairwise comparison of Factors:

As similar to the pairwise comparison of criteria, the pairwise comparison of critical success factors is also done. the pairwise comparison has been made as: the factors *past performance and* *expertise of company, number of key personnel, optimized resource utilization and training and skill level of project team* has been compared with respect to "Performance" criteria; *proposed tender price, low project life cycle cost, financial capability and additional financial resources for priority projects* has been compared with respect to "Cost" criteria; *health and safety performance and environmental impact* has been compared with respect to "Health and Safety" criteria; *type of project control and monitoring process and actual schedule achieved for similar works* has been compared with respect to "Project control" criteria and *quality control measures, meeting design requirements and user expectations and satisfaction* has been compared with respect to "Quality control" criteria. These comparisons have been shown in Table 4.8, 4.9, 4.10, 4.11 and 4.12 respectively.

Table 4.8: Pairwise comparison matrix of "Performance" factors

Consistency ratio (.0303)	**PPEC**	**NKP**	**ORU**	**TSP**
PPEC	1	3	3	5
NKP	1/3	1	2	4
ORU	1/3	1/2	1	2
TSP	1/5	1/4	1/2	1

Table 4.9: Pairwise comparison matrix of "Cost" factors

	PTP	**LPCC**	**FC**	**FRP**

Consistency ratio (.0211)				
PTP	1	3	2	5
LPCC	1/3	1	1/3	2
FC	1/2	3	1	4
FRP	1/5	1/2	1/4	1

Table 4.10: Pairwise comparison matrix of "Health and Safety" factors

Consistency ratio (.00)	HSP	EI
HSP	1	2
EI	1/2	1

Table 4.11: Pairwise comparison matrix of "Project Control" factors

Consistency ratio (.00)	PCM	SAW
PCM	1	1/2
SAW	2	1

Table 4.12: Pairwise comparison matrix of "Quality Control" factors

Consistency ratio (.0088)	QCM	MDR	UES
QCM	1	2	3
MDR	1/2	1	2
UES	1/3	1/2	1

4.4.4 Normalized Matrix:

Normalization is a method of computing numbers that takes into account the overall values. Normalized matrix is formulated in two stages:

First is the summation of each column of the reciprocal matrix.

Then we divide each element of matrix with the sum of its column and obtain a normalized matrix. The sum of each column is 1.

This matrix of criteria, factors of performance, cost, health and safety, quality control and project control are shown in Table 4.13, 4.14, 4.15, 4.16, 4.17 and 4.18 respectively.

Table 4.13: Normalized matrix of Criteria

Consistency ratio (.032)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	2/5	1/2	1/4	1/3	1/3	.380

Cost	1/5	1/4	1/4	1/3	1/3	.302
Health and Safety	4/49	3/82	1/20	1/34	1/23	.047
Project Control	1/9	2/31	1/7	3/34	2/23	.096
Quality Control	1/5	1/8	1/5	1/6	1/6	.174

Table 4.14: Normalized matrix of "Performance" factors

Consistency ratio (.0303)	**PPEC**	**NKP**	**ORU**	**TSP**	**Priority Vector**
PPEC	1/2	5/8	1/2	3/7	.519
NKP	1/6	1/5	1/3	1/3	.254
ORU	1/6	1/9	1/6	1/6	.148
TSP	1/9	1/19	1/13	1/12	.078

Table 4.15: Normalized matrix of "Cost" factors

Consistency ratio (.0211)	**PTP**	**LPCC**	**FC**	**FRP**	**Priority Vector**
PTP	1/2	2/5	5/9	3/7	.470
LPCC	1/6	1/7	4/43	1/6	.137

FC	1/4	2/5	2/7	1/3	.317
FRP	6/61	1/15	3/43	1/12	.078

Table 4.16: Normalized matrix of "Health and Safety" factors

Consistency ratio (.00)	**HSP**	**EI**	**Priority Vector**
HSP	2/3	2/3	.667
EI	1/3	1/5	.333

Table 4.17: Normalized matrix of "Project Control" factors

Consistency ratio (.00)	**PCM**	**SAW**	**Priority Vector**
PCM	1/3	1/3	.333
SAW	2/3	2/3	.667

Table 4.18: Normalized matrix of "Quality Control" factors

Consistency ratio (.008)	**QCM**	**MDR**	**UES**	**Priority Vector**
QCM	5/9	4/7	1/2	.539
MDR	2/7	2/7	1/3	.270
UES	1/5	1/7	1/6	.163

4.4.5 Calculation of Local weights and Global weights:

After the normalization of matrices, the next step is to calculate the local weights of each criteria and sub-criteria. These local weights are the relative value of the element with respect to the particular element which is placed at its immediate above hierarchy level. After calculating the relative value with respect to the immediate above node, now the decision maker's main focus is to identify the relative value of each element with respect to the main goal of the hierarchy. These values are known as global weights. According to (Saaty, 2008), the local weight and the global weight of the goal of the hierarchy is 1. Global priorities for any hierarchical elements are calculated by weighing their local priorities by the global priorities assigned to the elements they originate from (i.e. at the preceding level), called their parents (Davies, 1994).

4.4.6 Ranking the criteria and sub-criteria:

To clearly identify the impact of all critical success factors on the goal or objective of the hierarchy model, it is necessary to rearrange the critical success factors in the decreasing order format because it will be easy for the decision makers to identify which factors are affecting the decision making most significantly. The priority weights of factors are shown in Table 4.19.

Table 4.19: Composite priority weights for criteria and factors

Criteria	Local Weights of Criteria	Factors	Local Weights of Factors	Global Weights
Performance	.380	Past performance and expertise of company	.519	.1972

		Number of key personnel	.254	.0965
		Optimized resource utilization	.148	.0562
		Training and skill level of project team	.078	.0296
Cost	.302	Proposed tender price	.470	.1419
		Low project life cycle cost	.137	.0413
		Financial capability	.317	.0957
		Additional financial resources for priority projects	.078	.0235
Health and Safety	.047	Health and Safety performance	.667	.0313
		Environmental Impact	.333	.0156
Project Control	.096	Type of project control and monitoring process	.333	.0319
		Actual schedule achieved for similar works.	.667	.0640
Quality Control	.174	Quality control measures	.539	.0937

		Meeting design requirements	.270	.0469
		User expectations and satisfaction	.163	.0283

This research provides a method for ranking the critical factors that could significantly effect in decision making for awarding the contract. For this purpose, analytical hierarchy process is used to rank those factors by comparing their significance upon each other. This technique seems to accomplish sophisticated results that are based purely on the assignation of experts of the absolute priorities of each criterion. The priorities of Factors are shown in following chart:

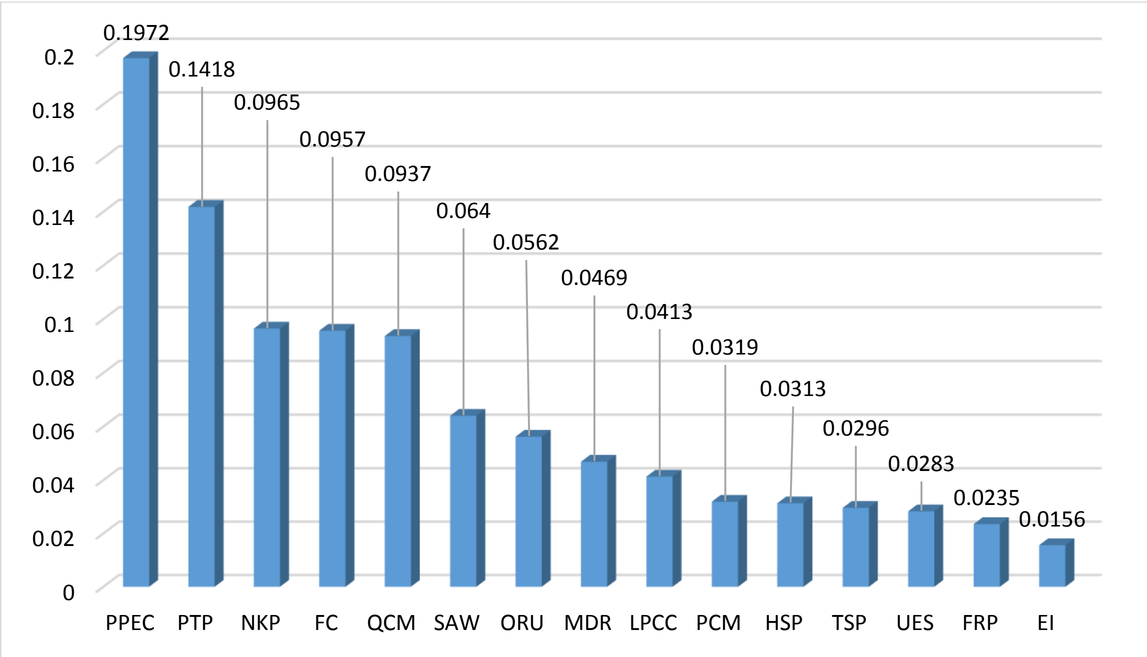


Figure 4.4: Bar Chart of Prioritization of Factors

In AHP, the pairwise comparison of criteria and factors are done as shown in tables above. After performing various steps, the local and global weights of all factors are determined as shown in

Table 4.19. The second column displays the local weights of criteria which shows that performance criteria with overall weight of 38.0 percent stands at the top position and its weightage is approximately nine times more than the weightage of health and safety criteria that is 4.7%. The result reveals that despite cost and quality control, contractors are primarily evaluated on the basis on their past performance in which the resources (labor and non-labor) and number and sizes of projects previously carried out.

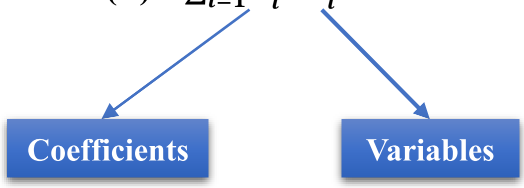
The factor “Past performance and expertise of company” possesses maximum weight (19.72%). It shows that the normally the contract is awarded to lowest bidder, but still contractors are evaluated on the basis of their past performance shown on previous projects. The ranking has been shown in a bar diagram in Figure 4.4. This graphical representation clearly portrays the priority-level of all critical factors in “Best Value procurement” which will assist the clients in making comprehensive decision for awarding the contract.

The factors “Proposed tender price (.1419)”, “number of key personnel (.0965)”, “financial capability (.0957)”, “quality control measures (.0937)” acquire distinctively higher weights than other mentioned factors and are very close to each other. The second most significant factor is the “Proposed tender price”. This factor enables the client to make comparison between the tenders and cost plan and to assess where the value lies within different tenders and allowing values for money. It is used to identify the areas of savings that might be negotiated with tenderers while still in competition. Since procurement in public projects, cost is the most dominant factor that need to be looked upon. Therefore, the price that is being proposed by bidders will set a fine line for the client in decision for awarding the contract.

4.4.7 Equation for MCDM using AHP:

Using AHP, the overall contribution of each factor has been determined which indicates the intensity of importance of each factor in contractor selection. The equation for a MCDM of contractor selection has been developed from the prioritization of factors is shown as:

Contractor score (Ć) $= \sum_{i=1}^{15} \boldsymbol{a_i} \cdot \boldsymbol{X_i}$



In this equation 'a_i' are the coefficients which concentrates the value of factors which are determined in previous section.

'X_i' are the variables and their values ranging from 1,2,3,…..,9. The user will incorporates the values of variables depending upon competency and capability of contractor concerning that particular factor.

4.5 Case Studies of Highway Projects Contractor Selection using Analytical Network Process (ANP)

The final ranking of criteria which comes out as a result of literature study and pilot survey as shown in Table 4.2. The table shows that level of significance of factors which could affect in decision making. ANP has been applied on top five criteria that are Cost, Performance, Quality Control, Project Control and Health and Safety. The ANP structure of these five criteria, their dependency upon each other and inner dependencies are shown in following figure:

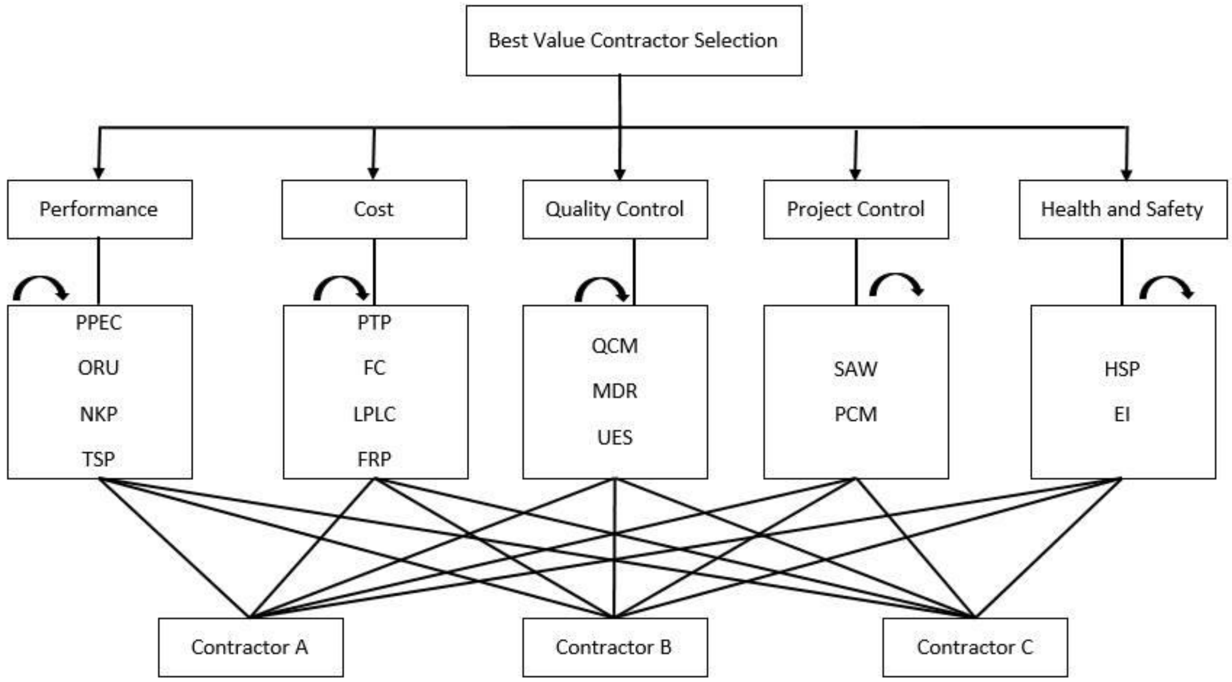


Figure 4.5 ANP Structure

In order to demonstrate the multi-criteria nature of contractor selection, five case studies have been taken to evaluate the contract award process in highway procurement. The factors and their grouping that are mentioned previously are based on the results of literature review which are used in the decision making of most suitable contractor. This study focuses to apply the ANP on the case studies of highway projects that are undertaken by National Highway Authority (NHA), a federal public body authorized to construct and operate highways in Pakistan.

As per the basic requirement of procuring public projects, contract is awarded to the lowest bidder. It is the primary aim of the client that project should be completed within predefined time, cost and quality standards. In order to deliver the project successfully, the BV contributing factors (cost, performance, quality control, project control, and health and safety) play a significant role. All the bidders aim at fulfilling the project objectives by conforming to these factors as shown in Figure 2. The level of significance of these factors varies according to the requirements of client and differing project conditions. ANP has been applied on these factors to evaluate the suitability of different decision making alternatives. The ANP structure of these five criteria, their dependency upon each other and interdependencies are shown in Figure 2. The web of connections is quite intricate in reality due to intergroup and intragroup relationships but has been simplified for better communication and understanding.

In the following sections detailed discussion analysis using ANP pertaining to real projects are presented.

4.5.1 Case Study 1:

The salient features of this project are as shown in Table 4.20.

Table 4.20: Salient Features of Case Study 1

Project Name	Rehabilitation of Hala Moro Road N-5
Client	National Highway Authority (NHA)
Consultant	SMEC Pvt. Ltd.
Contractor	M/S Xuchang – Sachal JV
Project Cost	1.9 Billion PKR
Project Duration	18 Months

Project Type	Dual Carriageway
Length	84 km
Project Completion	May, 2015
Prequalified Contractor A	M/S Xuchang – Sachal JV
Prequalified Contractor B	M/S Xianjiang Beixin Road and Bridge Co
Prequalified Contractor C	M/S Sinohydro – Usmani JV

ANP has been applied in selecting the most suitable contractor for this project. The steps as follows:

i. Pairwise Comparison:

Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared.

a. Cluster Comparison:

To compare clusters take each cluster in turn (as the parent) and pairwise compare all the clusters it connects to for importance with respect to their influence on it. The Table 4.21 shows the cluster comparison of criteria:

Table 4.21: Pairwise comparison of Criteria w.r.t Alternatives

Consistency ratio (.029)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/2	4	2	3	.271
Cost	2	1	5	2	3	.371
Health and Safety	1/4	1/5	1	1/4	1/3	.054
Project Control	1/2	1/2	4	1	2	.186
Quality Control	1/3	1/3	3	1/2	1	.114

In the pairwise comparison matrix, the reliability of subjective input can be measured by consistency ratio. It should be less than 0.1 otherwise the subjective input should be re-evaluated. The value of 0.029 is well within the acceptable range for reliable and consistent data. On comparing performance and quality control, the input value between them shows that former is moderately preferred to the later criterion. Due to intermediate value of 2, cost is equally-to-strongly preferred to health and safety. Priority vector is the normalized Eigen vector of comparison matrix which shows the priorities of criteria after comparing all of them. Cost has the highest priority value of .371 while health and safety has the lowest priority value of 0.054. This indicates the traditional economy-dominant preference where health and safety is not necessarily considered as an opportunity.

b. Comparison w.r.t Criteria:

In the first step of pairwise comparison, the criteria are compared with each other and their respective factors w.r.t parent criteria. The criteria like *Performance, Cost, Project control, Health and Safety and Quality control* are compared with each other and their respective factors w.r.t to their corresponding criteria. Since this comparison is very lengthy, therefore Table 4.22 and 4.23 show the pairwise comparison of criteria and factors only w.r.t cost.

Comparisons w.r.t Cost

Table 4.22: Pairwise comparison matrix of criteria w.r.t Cost

Consistency ratio (.022)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1	4	1	2	.263
Cost	1	1	5	1	3	.304
Health and Safety	1/4	1/5	1	1/3	1/2	.066

Project Control	1	1	3	1	1	.223
Quality Control	1/2	1/3	2	1	1	.143

The inconsistency value of .022 which is less than .10 is acceptable which shows that there is no need to re-evaluate the assigned values. In criteria based comparison, project control is strongly preferred to health and safety, and performance and cost are given equal importance. After valuing all the criteria, cost has the highest priority while health and safety has the least which is relatively similar to cluster comparison and indicates to the same implications.

Table 4.23: Pairwise comparison matrix of Cost factors

Consistency ratio (.003)	PTP	LPCC	FC	FRP	Priority Vector
PTP	1	4	1	2	.370
LPCC	1/4	1	1/3	1/2	.099
FC	1	3	1	2	.345
FRP	1/2	2	1/2	1	.185

Cost factors are compared with inconsistency ratio of .003. *Proposed tender price* which has the highest priority (.370) is equally preferred to *financial capability* (.345) while moderately-to-strongly preferred to *additional financial resources for priority projects* which has the least priority (.185).

c. Comparison w.r.t Factors:

In this step, the factors of each criteria are compared with each other w.r.t to each factor from which they are connected to. But due to the lengthy calculations, it is quite difficult to show every comparison. Therefore, pairwise comparison of *quality control* factors and alternatives only w.r.t *low project life cycle cost* has been shown in following Table 4.24 and 4.25.

Comparisons w.r.t "Low project life cycle cost"

Table 4.24: Pairwise comparison matrix of Quality factors w.r.t Low project life cycle cost

Consistency ratio (.008)	QCM	MDR	UES	Priority Vector
QCM	1	1/3	1/2	.163
MDR	3	1	2	.539
UES	2	1/2	1	.296

The assigned values for comparing quality control factors are valid as per the inconsistency ratio of 0.008. Considering the priorities of factors, *meeting design requirements* is the most significant among all the quality control factors while *user expectation and satisfaction* is the least significant.

Table 4.25: Pairwise comparison matrix of alternatives w.r.t Low project life cycle cost

Consistency ratio (.008)	Contractor A	Contractor B	Contractor C	Priority Vector
Contractor A	1	3	2	.539

Contractor B	1/3	1	1/2	.163
Contractor C	1/2	2	1	.296

On comparing the contractors with respect to the *low project life cycle cost*, the contractor A comes out to be the most significant while contractors C and B are placed at second and third. At this point, the alternatives are only compared with respect to single factor. The overall priorities may differ after relating them with respect to all criteria and factors.

d. Comparison w.r.t Alternatives:

After comparing all of the criteria and factors, the next step is to compare the factors w.r.t alternatives (A, B and C) which shows that how much a factor is preferred to another on the basis of alternatives. Similarly, this comparison is very lengthy. Therefore, only pairwise comparison of *quality control* factors w.r.t *Contractor A* has been shown in following Table 4.26.

Comparison w.r.t "Contractor A"

Table 4.26: Pairwise comparison matrix of Quality factors w.r.t contractor A

Consistency ratio (.017)	QCM	MDR	UES	Priority Vector
QCM	1	1/3	2	.238
MDR	3	1	4	.625
UES	1/2	1/4	1	.136

The inconsistency value of .017 which is less than .10 is acceptable. The comparison with respect to quality control factors indicates that *meeting design requirements* which has the highest priority value (.625) is strongly preferred to *quality control measures* (.238) while *user expectation and satisfaction* (.136) is the least important.

ii. Super matrix:

Super matrices are the result of pairwise comparison. This includes unweighted, weighted and limiting super matrix. These all super matrices are included in Appendix 3.

iii. Final Selection:

After super matrix formation, analytical network process (ANP) yields the priorities of alternatives. The following chart shows the priorities of contractors which demonstrates their hierarchy from least significant to the most critical one that has been considered awarding the contract in above case study.

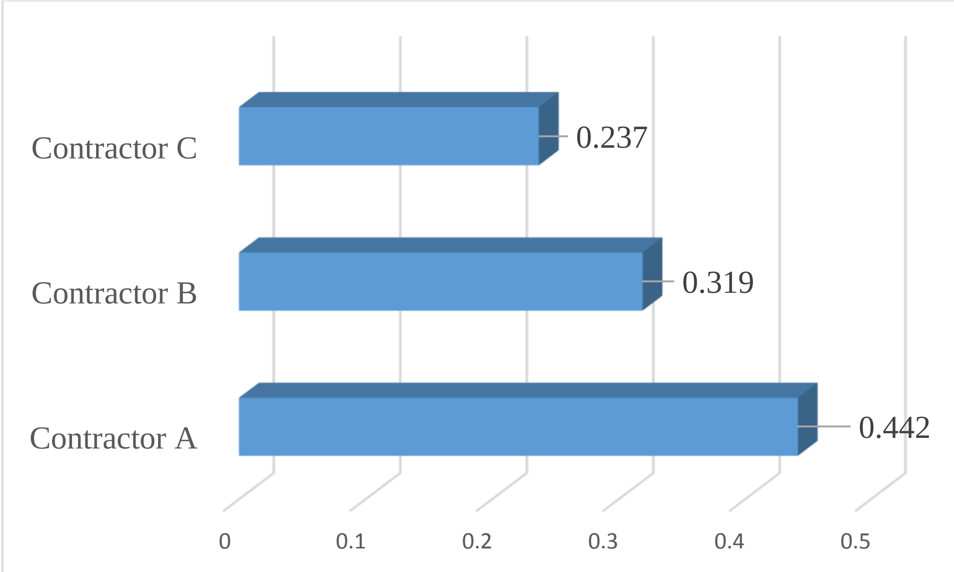


Figure 4.6: Bar Chart of Priorities of Alternatives of Case Study 1

Contractor selection has been a critical issue over the past few years. Contractors not only being evaluated in terms of technical aspects but also the financial capacity is determined for proper utilization of resources. Construction clients, especially public organizations are prone to accept the lowest bid from prequalified contractors. Because of variability and competitiveness issues of construction industry, it is not deniable that tender sum is a major consideration for both client and contractor. After pre-qualification, bids are evaluated in terms of many factors like quality control, performance, expertise, cost etc. Among all, cost is the most dominant criteria on the basis of which contract is awarded.

Contractor A has the highest score (.442) among all and is considered best for the contract award for this project. The same conclusion was reached by the decision makers in reality and the contract was awarded to Contractor A. Though they did not necessarily base their decision on such detailed analysis, BV procurement was employed in their own way in the form of prequalification (technical evaluation) and financial assessment. It was due to the fact that every construction project is exclusive in terms if site conditions, market value, risk and cost. The contractor selection using ANP technique gives the decision makers the mechanism to make additions and deletions in factors and assign priorities regarding individual requirements.

4.5.2 Case Study 2:

The salient features of this project are shown in Table 4.27.

Table 4.27: Salient Features of Case Study 2

Project Name	Construction of Chattar Kalas and Dulai Bridges at S-2
Client	National Highway Authority (NHA)
Consultant	M/S EGC (Pvt.) Ltd.
Contractor	M/S HRL (Pvt.) Ltd.
Project Cost	150 Million PKR
Project Duration	9 Months
Project Type	Dual Carriageway
Length	L1= 50m, L2= 25m
Project Completion	Sept, 2014
Prequalified Contractor A	M/S HRL (Pvt.) Ltd.

Prequalified Contractor B	M/S GRC (Pvt.) Ltd.
Prequalified Contractor C	M/S Mahmood Construction

Similar to the above case study, ANP has been applied in selecting the most suitable contractor for this project. The overall procedure and steps that have been performed are the same as mentioned in previous case study. These steps as follow:

i. **Pairwise Comparison**:

Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared.

a. Cluster Comparison:

To compare clusters take each cluster in turn (as the parent) and pairwise compare all the clusters it connects to for importance with respect to their influence on it. Table 4.28 shows the cluster comparison of criteria.

Table 4.28: Pairwise comparison of Criteria w.r.t Alternatives

Consistency ratio (.088)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/3	5	3	2	.267

Cost	3	1	5	2	2	.378
Health and Safety	1/5	1/5	1	1/4	1/2	.052
Project Control	1/3	1/2	4	1	3	.187
Quality Control	1/2	1/2	2	1/3	1	.111

b. **Comparison w.r.t Criteria:**

In the first step of pairwise comparison, the criteria are compared with each other and their respective factors w.r.t parent criteria. The criteria like *Performance, Cost, Project control, Health and Safety and Quality control* are compared with each other and their respective factors w.r.t to their corresponding criteria. Since this comparison is very lengthy, therefore following Table 4.29 and 4.30 show the pairwise comparison of criteria and factors only w.r.t quality control.

Comparisons w.r.t Quality Control

Table 4.29: Pairwise comparison matrix of criteria w.r.t Quality Control

Consistency ratio (.032)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/4	3	1/3	1/2	.105

Cost	4	1	6	2	2	.391
Health and Safety	1/3	1/6	1	1/4	1/5	.048
Project Control	3	1/2	4	1	1/2	.20
Quality Control	2	1/2	5	2	1	.253

Table 4.30: Pairwise comparison matrix of Quality Control factors

Consistency ratio (.008)	**QCM**	**MDR**	**UES**	**Priority Vector**
QCM	1	2	3	.539
MDR	1/2	1	2	.296
UES	1/3	1/2	1	.163

c. Comparison w.r.t Factors:

In this step, the factors of each criteria are compared with each other w.r.t to each factor from which they are connected to. But due to the lengthy calculations, it is quite difficult to show every comparison. Therefore, pairwise comparison of *performance* factors and alternatives only w.r.t *quality control measures* are shown in Table 4.31and 4.32.

Comparisons w.r.t "Quality Control measures"

Table 4.31: Pairwise comparison matrix of performance factors w.r.t quality control measures

Consistency ratio (.011)	PPEC	NKP	ORU	TSP	Priority Vector
PPEC	1	1/4	1/3	1/6	.068
NKP	4	1	2	1/2	.280
ORU	3	1/2	1	1/3	.167
TSP	6	2	3	1	.485

Table 4.32: Pairwise comparison matrix of alternatives w.r.t quality control measures

Consistency ratio (.08)	Contractor A	Contractor B	Contractor C	Priority Vector
Contractor A	1	1/3	1/2	.163
Contractor B	3	1	2	.539
Contractor C	2	1/2	1	.296

d. Comparison w.r.t Alternatives:

After comparing all of the criteria and factors, the next step is to compare the factors w.r.t alternatives (A, B and C) which shows that how much a factor is preferred to another on the basis of alternatives. Similarly, this comparison is very lengthy. Therefore, only pairwise comparison of *quality control* factors w.r.t *Contractor A* has been shown in Table 4.33.

Comparison w.r.t "Contractor C"

Table 4.33: Pairwise comparison matrix of Quality factors w.r.t contractor C

Consistency ratio (.017)	QCM	MDR	UES	Priority Vector
QCM	1	1/3	2	.238
MDR	3	1	4	.625
UES	1/2	1/4	1	.136

ii. Super matrix:

Super matrices are the result of pairwise comparison. This includes unweighted, weighted and limiting super matrix. These all super matrices are included in Appendix 3.

iii. Final Selection:

After super matrix formation, analytical network process (ANP) yields the priorities of alternatives. The following chart shows the priorities of contractors which demonstrates their hierarchy from least significant to the most critical one that has been considered awarding the contract in above case study.

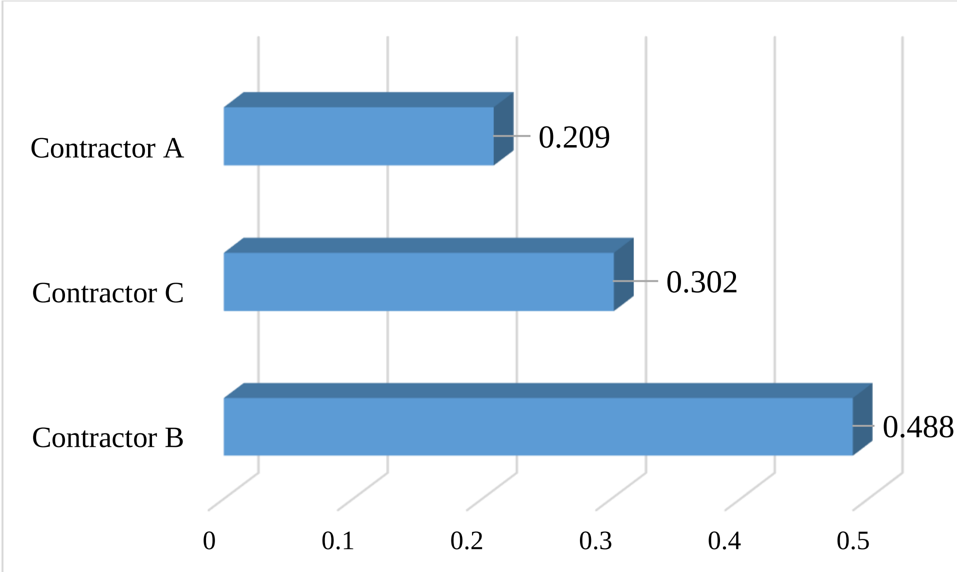


Figure 4.7: Bar Chart of Priorities of Alternatives of Case Study 2

After applying this technique in second case study, different results are found. As shown in Figure 4.8, Contractor B, which was actually the second lowest bidder is ranked top among all prequalified bidders with score 0.488. Contractor C which was originally the third lowest bidder is placed at second position and Contractor A who is the winner of contract by offering lowest cost is dropped to bottom position. In this case, BV approach was not necessarily implemented in its spirit and contract was awarded solely on the basis of bid price. Had the decision makers considered other factors, such as quality control, health and safety, etc., their decision could have led to awarding the contract to Contractor B. But in defense of Contractor A, it can be mentioned that their documentation was so strong that it led the decision makers into believing in their responsiveness and efficiency.

4.5.3 Case Study 3:

The salient features of this project are shown in Table 4.34.

Table 4.34: Salient Features of Case Study 3

Project Name	Rehabilitation of Rohri – Pannuaqil Road
Client	National Highway Authority (NHA)
Consultant	SMEC (Pvt.) Ltd.
Contractor	M/S Zarghoon Enterprises
Project Cost	1.1 Billion PKR
Project Duration	12 Months
Project Type	Dual Carriageway
Length	32 km
Project Completion	April 2015
Prequalified Contractor A	M/S Zarghoon Enterprises
Prequalified Contractor B	M/S SMADB

Prequalified Contractor C	M/S Muhammad Ramzan – Umar Jan & Co. JV

Similar to the above case study, ANP has been applied in selecting the most suitable contractor for this project. The overall procedure and steps that have been performed are the same as mentioned in previous case study. These steps as follows:

i. Pairwise Comparison:

Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared.

a. Cluster Comparison:

To compare clusters take each cluster in turn (as the parent) and pairwise compare all the clusters it connects to for importance with respect to their influence on it. Table 4.35 shows the cluster comparison of criteria:

Table 4.35: Pairwise comparison of Criteria w.r.t Alternatives

Consistency ratio (.022)	**Performance**	**Cost**	**Health and Safety**	**Project Control**	**Quality Control**	**Priority Vector**
Performance	1	1/3	6	2	2	.230
Cost	3	1	6	3	4	.451

Health and Safety	1/6	1/6	1	1/5	1/3	.043
Project Control	1/2	1/3	5	1	2	.167
Quality Control	1/2	1/4	3	1/2	1	.106

b. Comparison w.r.t Criteria:

In the first step of pairwise comparison, the criteria are compared with each other and their respective factors w.r.t parent criteria. The criteria like *Performance, Cost, Project control, Health and Safety and Quality control* are compared with each other and their respective factors w.r.t to their corresponding criteria. Since this comparison is very lengthy, therefore Table 4.36 and 4.37 show the pairwise comparison of criteria and factors only w.r.t cost.

Comparisons w.r.t Health and Safety

Table 4.36: Pairwise comparison matrix of criteria w.r.t Health and Safety

Consistency ratio (.051)	**Performance**	**Cost**	**Health and Safety**	**Project Control**	**Quality Control**	**Priority Vector**
Performance	1	1/2	1/3	3	5	.187
Cost	2	1	2	4	7	.385

Health and Safety	3	1/2	1	2	6	.283
Project Control	1/3	1/4	1/2	1	3	.10
Quality Control	1/5	1/7	1/6	1/3	1	.041

Table 4.37: Pairwise comparison matrix of Health and Safety factors

Consistency ratio (.00)	HSP	EI	Priority Vector
HSP	1	2	.667
EI	1/2	1	.333

c. Comparison w.r.t Factors:

In this step, the factors of each criteria are compared with each other w.r.t to each factor from which they are connected to. But due to the lengthy calculations, it is quite difficult to show every comparison. Therefore, pairwise comparison of *quality control* factors and alternatives only w.r.t *low project life cycle cost* are shown in Table 4.38 and 4.39.

Comparisons w.r.t "Health and Safety performance"

Table 4.38: Pairwise comparison matrix of cost factors w.r.t health and safety performance

Consistency ratio (.019)	PTP	LPCC	FC	FRP	Priority Vector
PTP	1	5	2	3	.472
LPCC	1/5	1	1/4	1/3	.072
FC	1/2	4	1	2	.284
FRP	1/3	3	1/2	1	.170

Table 4.39: Pairwise comparison matrix of alternatives w.r.t health and safety performance

Consistency ratio (.051)	Contractor A	Contractor B	Contractor C	Priority Vector
Contractor A	1	3	3	.593
Contractor B	1/3	1	2	.249
Contractor C	1/3	1/2	1	.157

d. Comparison w.r.t Alternatives:

After comparing all of the criteria and factors, the next step is to compare the factors w.r.t alternatives (A, B and C) which shows that how much a factor is preferred to another on the basis of alternatives. Similarly, this comparison is very lengthy. Therefore, only pairwise comparison of *quality control* factors w.r.t *Contractor A* has been shown in following Table 4.40.

Comparison w.r.t "Contractor B"

Table 4.40: Pairwise comparison matrix of Health and Safety factors w.r.t contractor B

Consistency ratio (.00)	**HSP**	**EI**	**Priority Vector**
HSP	1	1/2	.333
EI	2	1	.667

ii. Super matrix:

Super matrices are the result of pairwise comparison. This includes unweighted, weighted and limiting super matrix. These all super matrices are included in Appendix 3.

iii. Final Selection:

After super matrix formation, analytical network process (ANP) yields the priorities of alternatives. The following chart shows the priorities of contractors which demonstrates their hierarchy from least significant to the most critical one that has been considered awarding the contract in above case study.

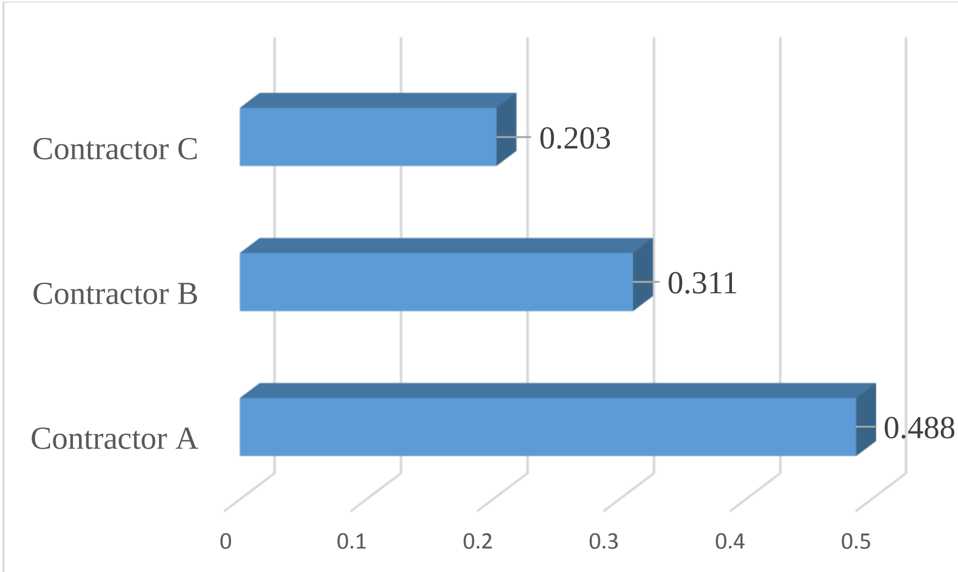


Figure 4.8: Bar Chart of Priorities of Alternatives of Case Study 3

The bar chart in Figure 4.9 explains the results of third case study which shows that Contractor A is the best as per their BV proposition. Also the Contractor A was the lowest bidder among all and qualified not only on the basis of lowest proposed bid price but also in terms of other criteria like performance, health and safety, quality control, and project control. Contractors B and C are placed at the second and third positions showing their lower BV proposition. This illustrates that not only both of them are not proposing optimum cost which is a significant BV contributing factor but also lack in performance and quality as evaluated from their previous record.

4.5.4 Case Study 4:

The salient features of this project are as follows:

Table 4.41: Salient Features of Case Study 4

Project Name	Rehabilitation of Mansehra – Naran – Jalkhad Chillas Road (N-15)
Client	National Highway Authority (NHA)
Consultant	M/S EGC (Pvt.) Ltd.
Contractor	M/S Rustam – Dynamic JV
Project Cost	844 Million PKR
Project Duration	12 Months
Project Type	Dual Carriageway
Length	32 km
Project Completion	May, 2015
Prequalified Contractor A	M/S Rustam – Dynamic JV

Prequalified Contractor B	M/S Behram Construction Co.
Prequalified Contractor C	M/S FWO

Similar to the above case study, ANP has been applied in selecting the most suitable contractor for this project. The overall procedure and steps that have been performed are the same as mentioned in previous case study. These steps as follows:

i. Pairwise Comparison:

Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared.

a. Cluster Comparison:

To compare clusters take each cluster in turn (as the parent) and pairwise compare all the clusters it connects to for importance with respect to their influence on it. Table 4.42 shows the cluster comparison of criteria.

Table 4.42: Pairwise comparison of Criteria w.r.t Alternatives

Consistency ratio (.022)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/3	6	2	2	.230

Cost	3	1	6	3	4	.451
Health and Safety	1/6	1/6	1	1/5	1/3	.043
Project Control	1/2	1/3	5	1	2	.167
Quality Control	1/2	1/4	3	1/2	1	.106

b. Comparison w.r.t Criteria:

In the first step of pairwise comparison, the criteria are compared with each other and their respective factors w.r.t parent criteria. The criteria like *Performance, Cost, Project control, Health and Safety and Quality control* are compared with each other and their respective factors w.r.t to their corresponding criteria. Since this comparison is very lengthy, therefore Table 4.43 and 4.44 show the pairwise comparison of criteria and factors only w.r.t performance.

Comparisons w.r.t Performance

Table 4.43: Pairwise comparison matrix of criteria w.r.t Performance

Consistency ratio (.018)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/2	4	2	2	.250
Cost	2	1	7	2	3	.401

Health and Safety	1/4	1/7	1	1/3	1/2	.058
Project Control	1/2	1/2	3	1	1	.157
Quality Control	1/2	1/3	2	1	1	.132

Table 4.44: Pairwise comparison matrix of Performance factors

Consistency ratio (.0248)	PPEC	NKP	ORU	TSP	Priority Vector
PPEC	1	2	1	6	.364
NKP	1/2	1	1/3	4	.181
ORU	1	3	1	5	.394
TSP	1/6	1/4	1/5	1	.06

c. Comparison w.r.t Factors:

In this step, the factors of each criteria are compared with each other w.r.t to each factor from which they are connected to. But due to the lengthy calculations, it is quite difficult to show every comparison. Therefore, pairwise comparison of *cost* factors and alternatives only w.r.t *past performance and expertise of company* has been shown in Table 4.45 and 4.46.

Comparisons w.r.t "Past performance and expertise of company"

Table 4.45: Pairwise comparison matrix of Cost factors w.r.t Past performance and expertise of company

.022	PTP	LPCC	FC	FRP	Priority Vector
PTP	1	5	2	3	.469
LPCC	1/5	1	1/4	1/2	.078
FC	1/2	4	1	3	.314
FRP	1/3	2	1/3	1	.137

Table 4.46: Pairwise comparison matrix of alternatives w.r.t Past performance and expertise of company

Consistency ratio (.00)	Contractor A	Contractor B	Contractor C	Priority Vector
Contractor A	1	3	3	.6
Contractor B	1/3	1	1	.2
Contractor C	1/3	1	1	.2

d. Comparison w.r.t Alternatives:

After comparing all of the criteria and factors, the next step is to compare the factors w.r.t alternatives (A, B and C) which shows that how much a factor is preferred to another on the basis of alternatives. Similarly, this comparison is very lengthy. Therefore, only pairwise comparison of *quality control* factors w.r.t *Contractor A* has been shown in Table 4.47.

Comparison w.r.t "Contractor B"

Table 4.47: Pairwise comparison matrix of Performance factors w.r.t contractor B

Consistency ratio (.081)	PPEC	NKP	ORU	TSP	Priority Vector
PPEC	1	3	1/2	3	.315
NKP	1/3	1	1/4	1/2	.094
ORU	2	4	1	2	.427
TSP	1/3	2	1/2	1	.162

ii. Super matrix:

Super matrices are the result of pairwise comparison. This includes unweighted, weighted and limiting super matrix. These all super matrices are included in Appendix 3.

iii. Final Selection:

After super matrix formation, analytical network process (ANP) yields the priorities of alternatives. The following chart shows the priorities of contractors which demonstrates their hierarchy from least significant to the most critical one that has been considered awarding the contract in above case study.

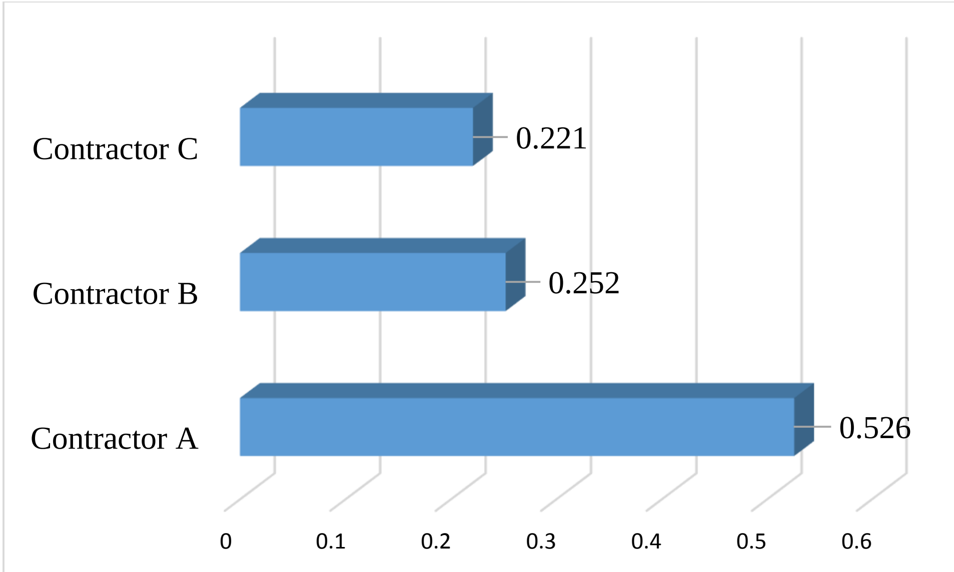


Figure 4.9: Bar Chart of Priorities of Alternatives of Case Study 4

Considering the results of case study 4 as shown in Figure 4.10, the Contractor A which was actually the lowest responsive bidder won the contract for this project. This contractor had the capacity of fulfilling the requirements of client in terms of quality, performance and cost as established during prequalification and detailed tender evaluation. The other alternatives (B and C) are positioned at the second and third places; it shows that both of them do not conform to the requirements as stated in contract documents. In this process the strengths and weaknesses of each contractor in terms of criteria are wide-open, thus paving a way for ANP as valid technique for contractor selection (Bayazit, 2006). Since cost was the decisive criterion to win the contract and both Contractors B and C did not propose the lowest price, they were considered illegible for the award.

4.5.5 Case Study 5:

The salient features of this project has been shown in Table 4.48.

Table 4.48: Salient Features of Case Study 5

Project Name	Rehabilitation of Jacobabad - Dera Allah Yar (N-65)
Client	National Highway Authority (NHA)
Consultant	M/S SMEC (Pvt.) Ltd. with Associates
Contractor	M/S Umar Jan & Co. – Muhammad Ramzan & Co.
Project Cost	566 Million PKR
Project Duration	12 Months
Project Type	Dual Carriageway
Length	15.7 km
Project Completion	March, 2015
Prequalified Contractor A	M/S Umar Jan & Co. – Muhammad Ramzan & Co.
Prequalified Contractor B	M/S FWO

Similar to the above case study, ANP has been applied in selecting the most suitable contractor for this project. The overall procedure and steps that have been performed are the same as mentioned in previous case study. These steps as follows:

i. Pairwise Comparison:

Pairwise comparison is the process of comparing the relative importance, preference, or likelihood of two elements (for example, criteria) with respect to another element (for example, the goal) in the level above to establish priorities for the elements being compared.

a. Cluster Comparison:

To compare clusters take each cluster in turn (as the parent) and pairwise compare all the clusters it connects to for importance with respect to their influence on it. Table 4.49 shows the cluster comparison of criteria.

Table 4.49: Pairwise comparison of Criteria w.r.t Alternatives

Consistency ratio (.022)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/3	6	2	2	.230
Cost	3	1	6	3	4	.451
Health and Safety	1/6	1/6	1	1/5	1/3	.043

Project Control	1/2	1/3	5	1	2	.167
Quality Control	1/2	1/4	3	1/2	1	.106

b. Comparison w.r.t Criteria:

In the first step of pairwise comparison, the criteria are compared with each other and their respective factors w.r.t parent criteria. The criteria like *Performance, Cost, Project control, Health and Safety and Quality control* are compared with each other and their respective factors w.r.t to their corresponding criteria. Since this comparison is very lengthy, therefore Table 4.50 and 4.51 show the pairwise comparison of criteria and factors only w.r.t Project Control.

Comparisons w.r.t Project Control

Table 4.50: Pairwise comparison matrix of criteria w.r.t Project Control

Consistency ratio (.027)	Performance	Cost	Health and Safety	Project Control	Quality Control	Priority Vector
Performance	1	1/4	2	1/2	1/3	.098
Cost	4	1	5	1	2	.334
Health and Safety	1/2	1/5	1	1/6	1/5	.050

Project Control	2	1	6	1	2	.305
Quality Control	3	1/2	5	1/2	1	.211

Table 4.51: Pairwise comparison matrix of Project Control factors

Consistency ratio (.00)	PCM	SAW	Priority Vector
PCM	1	1/2	.333
SAW	2	1	.667

c. Comparison w.r.t Factors:

In this step, the factors of each criteria are compared with each other w.r.t to each factor from which they are connected to. But due to the lengthy calculations, it is quite difficult to show every comparison. Therefore, pairwise comparison of *cost* factors and alternatives only w.r.t *actual schedule achieved for similar works* has been shown in Table 4.52 and 4.53.

Comparisons w.r.t "Actual Schedule achieved for similar works"

Table 4.52: Pairwise comparison matrix of Quality Control factors w.r.t Actual Schedule achieved for similar works

Consistency ratio (.017)	QCM	MDR	UES	Priority Vector

QCM	1	1/4	1/3	.122
MDR	4	1	2	.558
UES	3	1/2	1	.320

Table 4.53: Pairwise comparison matrix of alternatives w.r.t Actual Schedule achieved for similar works

Consistency ratio (.008)	Contractor A	Contractor B	Priority Vector
Contractor A	1	2	.667
Contractor B	1/2	1	.333

d. Comparison w.r.t Alternatives:

After comparing all of the criteria and factors, the next step is to compare the factors w.r.t alternatives (A, B and C) which shows that how much a factor is preferred to another on the basis of alternatives. Similarly, this comparison is very lengthy. Therefore, only pairwise comparison of *Project control* factors w.r.t *Contractor C* has been shown in Table 4.54.

Comparison w.r.t "Contractor A"

Table 4.54: Pairwise comparison matrix of Project Control factors w.r.t contractor A

Consistency ratio (.00)	PCM	SAW	Priority Vector
PCM	1	1/2	.333
SAW	2	1	.667

ii. Super matrix:

Super matrices are the result of pairwise comparison. This includes unweighted, weighted and limiting super matrix. These all super matrices are included in Appendix 3.

iii. Final Selection:

After super matrix formation, analytical network process (ANP) yields the priorities of alternatives. The following chart shows the priorities of contractors which demonstrates their hierarchy from least significant to the most critical one that has been considered awarding the contract in above case study.

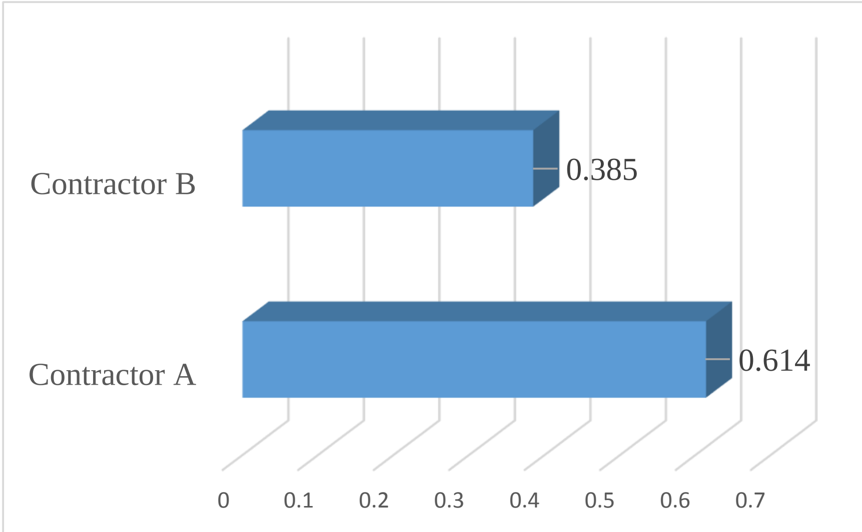
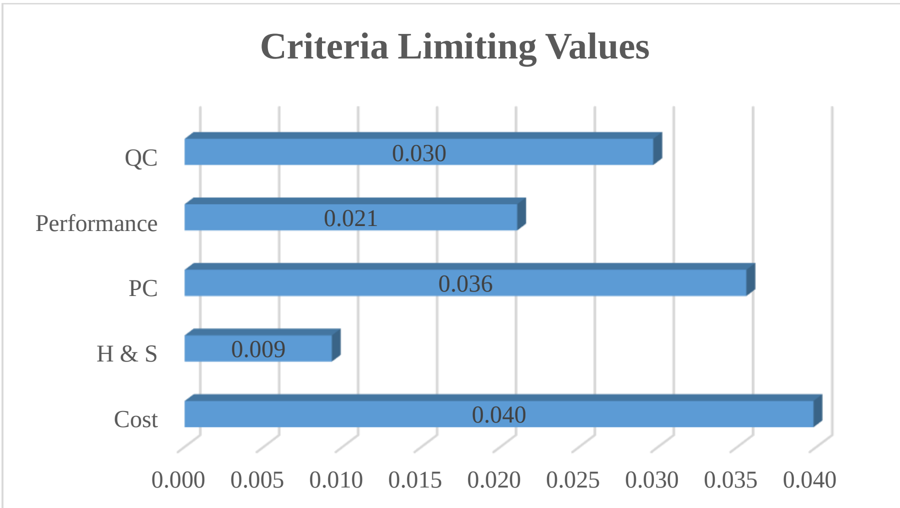


Figure 4.10: Bar Chart of Priorities of Alternatives of Case Study 5

In the last case study, only two contractors were prequalified for the selection process. Figure 4.11 shows that Contractor A is most competent as compared to B with respect to previously established BV criteria and more importantly is also the lowest responsive bidder. There is not much difference of values between the two which shows that Contractor B also has the capacity to deliver the goods for this project. Since it is a multi-criteria decision making process in which one alternative is to be selected among all, in comparison between the two, the overall score of Contractor A is higher than B. Therefore, the results show that contractor A is more efficient in past performance and expertise, capable of completing the project on time and retains the desired quality standards. Hence, they are the best for awarding the contract.

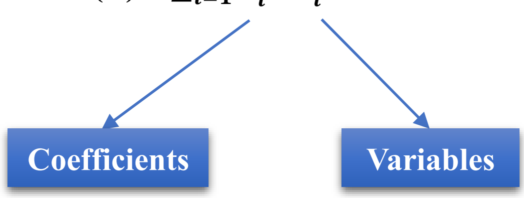
4.5.6 Equation for MCDM using ANP

The overall limiting values of criteria from the five case studies are shown in Figure



Using ANP, the overall limiting values of criteria from five case studies have been figured out. Equation for MCDM using ANP has been developed as shown below:

$$\textbf{Contractor score } (\acute{C}) = \sum_{i=1}^{5} a_i \cdot X_i$$



In this equation 'a_i' are the limiting values of criteria and 'X_i' are the variables which the user will incorporates for each contractor depending upon their capabilities with respect to the mentioned criteria. As a result the contract is awarded to that bidder who occupies the overall highest score.

CONCLUSIONS and RECOMMENDATIONS

5.1 Review of Literature from 2000-2015:

The BV approach of contractor selection emphasizes primarily on past performance and the level of quality that the contractor has delivered on previous projects. Apparently, it can be observed that cost has been the only criterion in this selection especially in traditional low-bid system. Although, in traditional low-bid system the selection process is comparatively easy, it has a lot of issues regarding project delivery, schedule and quality control. Thus it poses serious questions on the project success. Apart from these attributes, research shows that there are some other factors that need to be addressed. This research focuses on the said factors which had been reported in the past few years and their evolution with the passage of time.

The process of contractor selection considering criteria other than low-bid can strengthen the overall success of the project. The current research has presented some of the paramount practices in this area and also highlighted a well-regulated approach to contractor selection. The aim is to augment the schedule and quality of construction projects while nurturing satisfying and constructive working atmosphere among the parties involved. Such an environment can only be achieved by targeting factors that are mentioned above in contractor selection process. In order to strike a balance in successful project outcomes, criteria like quality control, performance, health and safety must be considered on priority.

The results provide a significant contribution to the body of knowledge regarding contractor selection. Particularly, our research underlines the prominence of typical criteria that is used in contractor selection. The appearance of each criterion and their criticality guides us to develop a weighting scheme in evaluation system. In doing so, a win-win situation can be achieved for both the users and tenderers, particularly with respect to risk, performance and quality control.

In recommendation, currently it is observed that all the identified factors are being considered. Some factors like *performance*, *project control*, *quality control*, *cost*, *health and safety* are appeared in most of the publications through various years of study while some factors show a flick in appearance. In this study, one factor that is *current workload* which is placed at bottom position must be contemplated for future studies. If the contractor has undertaken several projects simultaneously then it is cumbersome to monitor and administer all of them equally. As a result, poor quality and performance hinders the project success. Hence during selection, besides performance and quality control, number and size of projects in hand must also be evaluated.

5.2 Determination of priorities of Best Value contributing factors in Contractor Selection:

The main purpose of this study is to propose AHP methodology for the identification and prioritization of critical success factors that effect in decision making of contractor selection process. A total of nineteen factors have been identified form the literature. By using AHP, the relative importance of all these factors and their relative impact in contractor selection have been identified. Results indicate that Performance and Cost factors occupy the top positions in hierarchy of factors that shows that they are the most critical factors to be considered. The other factors have relatively low scores that indicates their minute significance in decision making process.

The main reason to propose AHP methodology that is has been already applied and justified in various real-world complex applications. The methodology and hierarchical structure is simple and can be easily understood at the operational level and it deals with the variables both tangible and intangible in nature. It maintains the transparency in decisions by decomposing the complex issues into simple hierarchical structure. AHP assists the group decision makers to identify the complex relationship among the elements of the concerned problem. Therefore, was adopted for prioritizing the Best Value contributing factors according to the specific objective or goal.

The study presents a complete framework of critical factors along with their global weights to the procurement engineers. Therefore, the decision makers able to identify the necessary resources and required capabilities of contractors through this framework to manage and endure their competitive advantage. It is not possible to deal with all the factors at the same time. So, with the prioritization gives a thorough understanding that on which criteria they have to work upon depending on their own requirements. Therefore, this relative significance of factors can be very helpful for the procurement personnel in accurate decision making while awarding the contract.

The proposed AHP model is simple to use and the computations can be run using available software that is Super Decisions or can be done using spread sheet program. This hierarchy structure allow the user to readily determine the relative contribution and significance of the identified factors in accurate decision making. The proposed model reflects the owner’s needs and preferences because the relative weights of factor are assigned according to his/her own requirements.

5.3 Contractor Selection using Analytic Network Process (ANP):

Contractor selection has been a critical issue since always. Contractor evaluation carried out not only in terms of technical aspects but also financial capacity guarantees proper utilization of resources and paves way for project success. The clients, especially public organizations are prone to accepting the lowest bid from prequalified contractors due to established practices of traditional low-bid system. Because of variability and competitiveness issues of construction industry, it is not deniable that tender sum is a major consideration for both client and contractor. After prequalification, bids are evaluated in terms of many factors like quality control, performance, expertise, cost, etc. Among all, cost has remained the most dominant criterion on the basis of which contract is awarded.

Traditional selection process can lead to inefficiencies and poor project performance due to low importance given to factors such other than cost. BV procurement strategy can help look at the holistic value proposition of a bid and help decision makers award the contract to a bidder on basis of overall suitability. This multi-criteria decision making can benefit from ANP which can help to improve the selection process and obtain the best decision by considering multiple criteria that are mentioned previously. This technique not only reduces the overall amount of time required for the selection process but also extends the functionality of MCDM that involve interdependent relationships.

The holistic approach of BV in terms of construction projects constitutes quality, time and cost, and suggests a balance among these factors for successful project delivery. It is implied that no factor must be so over-estimated that the overall efficiency of project is compromised.

ANP has been applied to the mentioned case studies for precise decision making on multiple attributes of alternative bidders. In the competitive selection process, accurate choice of bidder is complex. Careful consideration upon all the criteria should be done to avoid a biased decision. Therefore, after applying MCDM technique, the results of contractor selection are further refined and validated. Since majority of case studies show that however uninformed a better decision was made by the organization, ANP validates the decision making process of contractor selection which is the ultimate pathway for successful project delivery.

The results from the five case studies reveal that majority of the projects were procured by analyzing the contractors on the basis of their competencies in terms of financial as well as technical capacities. However, this was achieved rather intuitively and unscientifically. Therefore, it is recommended that BV procurement decision making should be benefitted by the use of ANP. The practical implications of this study facilitate the decision makers in identifying and assessing BV contributing factors, and figuring out their interdependent significance with respect to project objectives. It can act as a decision support system in contractor selection in public as well as private procurement. The research methodology proposed in this study is not restricted to highway projects only but also can be applied to other projects like dams, commercial and residential buildings. This will allow insight into comparison of decision criteria in the different segments of construction industry.

In recommendation, the user can model their problems by controlling the number of elements considered in the category of control criteria. In this research, total of fifteen factors grouped in five criteria have been used for decision making up to second hierarchy level. The number of indicators and their categorization could be modified depending upon the strength of decision problem. This is the flexibility of model that number of indicators and hierarchy level could be easily adjusted. The more comprehensive decision could be made by improving the subjective input for comparison. The model that requires higher complexity requires greater input effort by the user.

In this research, highway case studies have been undertaken for MCDM. For further research, the scope of BV and AHP/ANP, is not limited to the highway projects only. It can be broadened to include industrial, buildings and commercial projects as well. The number of indicators and alternatives, and their hierarchy level need to be altered for different divisions of construction projects. The limitation of this model is that it only applies for one stage bidding process. The two stage of bidding process is irrelevant for MCDM using ANP. Since in pairwise comparison, all the attributes of contractors are assessed at one stage and the final selection is done based upon the relative score of each alternative. Therefore, any ANP based decision making process will take place at one stage.

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Appendix 1

Factors affecting the contractor's selection using Best Value approach

This form assesses the factors that significantly affect the contractor`s selection using Best Value approach.
Please assign scores ranging from 0 to 5 to the said factors corresponding to their significance in contractor`s selection process.
Whereas:

0: not significant at all
1: very low significance
2: low significance
3: moderate significance
4: high significance
5: very high significance

Country of Residence: ____________

Sr. No.	Question	Score
1	The significance of "past performance and expertise of company" in contractor selection.	0 1 2 3 4 5
2	The significance of "meeting design requirements" in contractor selection.	0 1 2 3 4 5
3	The significance of "low project lifecycle cost" in contractor selection.	0 1 2 3 4 5
4	The significance of "environmental impact" in contractor selection.	0 1 2 3 4 5
5	The significance of "user expectation and satisfaction" in contractor selection.	0 1 2 3 4 5
6	The significance of "health and safety performance" in contractor selection.	0 1 2 3 4 5
7	The significance of "financial capability" in contractor selection.	0 1 2 3 4 5
8	The significance of "additional financial resources for priority projects" in contractor selection.	0 1 2 3 4 5
9	The significance of "optimized resource utilization" in contractor selection.	0 1 2 3 4 5
10	The significance of "transfer of risk related to construction, finance and operation" in contractor selection.	0 1 2 3 4 5
11	The significance of "quality control measures" in contractor selection.	0 1 2 3 4 5

12	The significance of "actual schedule achieved for similar works" in contractor selection.	0 1 2 3 4 5
13	The significance of "type of project control and monitoring procedures" in contractor selection.	0 1 2 3 4 5
14	The significance of "number of key personnel" in contractor selection.	0 1 2 3 4 5
15	The significance of "ability to deal with unanticipated problems" in contractor selection.	0 1 2 3 4 5
16	The significance of "history of claims and disputes in previous projects" in contractor selection.	0 1 2 3 4 5
17	The significance of "proposed tender price" in contractor selection.	0 1 2 3 4 5
18	The significance of "number and size of projects at hand" in contractor selection.	0 1 2 3 4 5
19	The significance of "training and skill level of project team" in contractor selection.	0 1 2 3 4 5

Appendix 2

Prioritizing Best Value Contributing factors for contractor selection

This survey is intended to collect responses of researchers and professionals for the purpose of prioritizing factors that have a possible contribution in contractor selection process. For this purpose some factors of cost, performance, health and safety, quality control and project control will be presented to you. Please contribute to this survey and help us develop a framework for contract award mechanism. Your response to this survey is highly appreciated.

Name: ______________________________

Organization: ________________________

Designation: _________________________

Qualification: ________________________

Experience in years: ___________________

The scales of comparison have been shown in following table:

Table: Scales of Comparison

Verbal Scale	Intensity of importance
Extremely importance	9
Very strong importance	7
Strong importance	5
Moderate importance	3
Equal importance	1
Intermediate importance	8,6,4,2

1. **Criteria comparison:**
   - How important is "cost" to "health and safety" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

   - How important is "cost" to "performance" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “cost” to “project control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “cost” to “quality control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “health and safety” to “performance” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “health and safety” to “project control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “health and safety” to “quality control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “performance” to “project control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “performance” to “quality control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is “project control” to “quality control” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

2. Comparison w.r.t “Health and Safety”

- How important is “health and safety performance” to “environmental impact” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

3. Comparison w.r.t “Performance”

- How important is “past performance and expertise of company” to “number of key personnel” in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "past performance and expertise of company" to "optimized resource utilization" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "past performance and expertise of company" to "training and skill level of project team" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "number of key personnel" to "optimized resource utilization" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "number of key personnel" to "training and skill level of project team" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "optimized resource utilization" to "training and skill level of project team" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

4. Comparison w.r.t "Quality Control"

- How important is "meeting design requirements" to "quality control measures" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "meeting design requirements" to "user expectation and satisfaction" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "quality control measures" to "user expectation and satisfaction" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

5. Comparison w.r.t. "Project Control"

- How important is "actual schedule achieved for similar works" to "project controlling and monitoring procedures" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

6. Comparison w.r.t. "Cost"

- How important is "additional financial resources for priority projects" to "financial capability" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "additional financial resources for priority projects" to "low project life cycle cost" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "additional financial resources for priority projects" to "proposed tender price" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "financial capability" to "proposed tender price" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

- How important is "low project life cycle cost" to "proposed tender price" in contractor selection.

9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

Appendix 3

Unweighted Super matrix Case Study 1

		Alternatives			Cost Factors				Criteria					H & S Factors		PC factors	
		A	B	C	FRP	FC	LCC	PTP	Cost	H & S	PC	Performance	QC	EI	HSP	PCM	SAW
Alternatives	A	0.000	0.000	0.000	0.134	0.310	0.061	0.495	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.250	0.750
	B	0.000	0.000	0.000	0.123	0.301	0.073	0.504	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.250	0.750
	C	0.000	0.000	0.000	0.145	0.290	0.056	0.510	0.000	0.000	0.000	0.000	0.000	0.750	0.250	0.333	0.667
Cost Factors	FRP	0.625	0.137	0.238	0.346	0.496	0.088	0.070	1.000	0.000	0.000	0.000	0.000	0.250	0.750	0.667	0.333
	FC	0.297	0.540	0.163	0.334	0.451	0.136	0.080	1.000	0.000	0.000	0.000	0.000	0.333	0.667	0.200	0.800
	LCC	0.540	0.163	0.297	0.152	0.324	0.052	0.473	1.000	0.000	0.000	0.000	0.000	0.333	0.667	0.333	0.667
	PTP	0.540	0.297	0.163	0.235	0.193	0.068	0.504	1.000	0.000	0.000	0.000	0.000	0.333	0.667	0.250	0.750
Criteria	Cost	0.000	0.000	0.000	0.185	0.345	0.100	0.370	0.305	0.066	0.222	0.263	0.144	0.000	0.000	0.000	0.000
	H & S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.386	0.285	0.100	0.188	0.041	0.333	0.667	0.000	0.000
	PC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.051	0.305	0.099	0.211	0.000	0.000	0.333	0.667
	Performance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.401	0.059	0.157	0.251	0.132	0.000	0.000	0.000	0.000
	QC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.391	0.049	0.201	0.105	0.254	0.000	0.000	0.000	0.000
Health and Safety factors	EI	0.333	0.333	0.333	0.186	0.307	0.069	0.437	0.000	1.000	0.000	0.000	0.000	0.667	0.333	0.800	0.200
	HSP	0.333	0.333	0.333	0.170	0.284	0.073	0.473	0.000	1.000	0.000	0.000	0.000	0.250	0.750	0.667	0.333
Project Control Factors	PCM	0.333	0.333	0.333	0.124	0.324	0.079	0.472	0.000	0.000	1.000	0.000	0.000	0.667	0.333	0.250	0.750
	SAW	0.540	0.297	0.163	0.077	0.116	0.298	0.510	0.000	0.000	1.000	0.000	0.000	0.667	0.333	0.250	0.750
Performance Factors	PPE	0.540	0.297	0.163	0.137	0.315	0.079	0.469	0.000	0.000	0.000	1.000	0.000	0.200	0.800	0.333	0.667
	NKP	0.333	0.333	0.333	0.153	0.227	0.047	0.574	0.000	0.000	0.000	1.000	0.000	0.250	0.750	0.667	0.333
	ORU	0.540	0.297	0.163	0.111	0.327	0.053	0.509	0.000	0.000	0.000	1.000	0.000	0.500	0.500	0.333	0.667
	TSP	0.540	0.297	0.163	0.053	0.148	0.226	0.572	0.000	0.000	0.000	1.000	0.000	0.167	0.833	0.333	0.667
Quality Control factors	MDR	0.333	0.333	0.333	0.178	0.331	0.058	0.434	0.000	0.000	0.000	0.000	1.000	0.750	0.250	0.333	0.667
	QCM	0.333	0.333	0.333	0.056	0.154	0.247	0.543	0.000	0.000	0.000	0.000	1.000	0.333	0.667	0.250	0.750
	UES	0.333	0.333	0.333	0.145	0.308	0.057	0.490	0.000	0.000	0.000	0.000	1.000	0.667	0.333	0.667	0.333

Performance Factors				QC factors		
PPE	NKP	ORU	TSP	MDR	QCM	UES
0.473	0.073	0.284	0.170	0.625	0.238	0.137
0.543	0.068	0.252	0.137	0.691	0.218	0.091
0.473	0.073	0.284	0.170	0.625	0.238	0.137
0.273	0.088	0.529	0.109	0.320	0.558	0.122
0.172	0.072	0.431	0.325	0.540	0.163	0.297
0.435	0.097	0.286	0.182	0.540	0.163	0.297
0.319	0.075	0.451	0.155	0.594	0.157	0.249
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.365	0.181	0.394	0.060	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.297	0.540	0.163
0.491	0.120	0.075	0.313	0.157	0.594	0.249
0.196	0.373	0.076	0.355	0.558	0.122	0.320
0.093	0.266	0.144	0.497	0.238	0.625	0.137
0.073	0.170	0.473	0.284	0.558	0.122	0.320
0.485	0.068	0.280	0.167	0.558	0.122	0.320
0.476	0.155	0.315	0.055	0.627	0.094	0.280
0.288	0.081	0.477	0.154	0.400	0.200	0.400
0.270	0.079	0.174	0.477	0.238	0.626	0.136
0.093	0.305	0.143	0.459	0.625	0.137	0.238
0.068	0.280	0.167	0.485	0.559	0.122	0.319
0.068	0.274	0.197	0.460	0.537	0.099	0.364

Weighted Super matrix Case Study 1

		Alternatives			Cost Factors				Criteria		
		A	B	C	FRP	FC	LCC	PTP	Cost	H & S	PC
Alternatives	A	0.000	0.000	0.000	0.050	0.115	0.023	0.184	0.000	0.000	0.000
	B	0.000	0.000	0.000	0.046	0.112	0.027	0.187	0.000	0.000	0.000
	C	0.000	0.000	0.000	0.054	0.108	0.021	0.190	0.000	0.000	0.000
Cost Factors	FRP	0.081	0.018	0.031	0.069	0.099	0.018	0.014	0.073	0.000	0.000
	FC	0.038	0.070	0.021	0.067	0.090	0.027	0.016	0.073	0.000	0.000
	LCC	0.070	0.021	0.038	0.030	0.065	0.010	0.095	0.073	0.000	0.000
	PTP	0.070	0.038	0.021	0.047	0.039	0.014	0.101	0.073	0.000	0.000
Criteria	Cost	0.000	0.000	0.000	0.093	0.173	0.050	0.185	0.152	0.033	0.111
	H & S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.193	0.142	0.050
	PC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.167	0.025	0.153
	Performance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.201	0.029	0.078
	QC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.196	0.024	0.100
Health and Safety factors	EI	0.041	0.041	0.041	0.053	0.088	0.020	0.125	0.000	0.045	0.000
	HSP	0.041	0.041	0.041	0.049	0.081	0.021	0.135	0.000	0.045	0.000
Project Control factors	PCM	0.048	0.048	0.048	0.018	0.046	0.011	0.067	0.000	0.000	0.143
	SAW	0.077	0.042	0.023	0.011	0.017	0.043	0.073	0.000	0.000	0.143
Performance factors	PPE	0.071	0.039	0.022	0.040	0.091	0.023	0.136	0.000	0.000	0.000
	NKP	0.044	0.044	0.044	0.044	0.066	0.014	0.166	0.000	0.000	0.000
	ORU	0.071	0.039	0.022	0.032	0.095	0.015	0.148	0.000	0.000	0.000
	TSP	0.071	0.039	0.022	0.015	0.043	0.066	0.166	0.000	0.000	0.000
Quality Control factors	MDR	0.048	0.048	0.048	0.025	0.047	0.008	0.062	0.000	0.000	0.000
	QCM	0.048	0.048	0.048	0.008	0.022	0.035	0.078	0.000	0.000	0.000
	UES	0.048	0.048	0.048	0.021	0.044	0.008	0.070	0.000	0.000	0.000

QC factors			Performance Factors				PC factors		H & S Factors			
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance
0.016	0.027	0.072	0.046	0.077	0.020	0.129	0.140	0.047	0.018	0.037	0.000	0.000
0.010	0.025	0.079	0.037	0.069	0.018	0.148	0.140	0.047	0.018	0.037	0.000	0.000
0.016	0.027	0.072	0.046	0.077	0.020	0.129	0.124	0.062	0.014	0.041	0.000	0.000
0.015	0.070	0.040	0.024	0.117	0.020	0.060	0.059	0.118	0.055	0.018	0.000	0.000
0.037	0.021	0.068	0.072	0.096	0.016	0.038	0.141	0.035	0.049	0.024	0.000	0.000
0.037	0.021	0.068	0.040	0.063	0.021	0.096	0.118	0.059	0.049	0.024	0.000	0.000
0.031	0.020	0.075	0.034	0.100	0.017	0.071	0.133	0.044	0.049	0.024	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.132
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.167	0.021	0.094
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.167	0.000	0.000	0.106	0.049
0.000	0.000	0.000	0.030	0.197	0.090	0.182	0.000	0.000	0.000	0.000	0.066	0.125
0.082	0.270	0.148	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.053
0.019	0.046	0.012	0.050	0.012	0.019	0.079	0.015	0.060	0.077	0.154	0.000	0.000
0.025	0.009	0.043	0.057	0.012	0.060	0.032	0.025	0.050	0.174	0.058	0.000	0.000
0.020	0.089	0.034	0.071	0.021	0.038	0.013	0.107	0.036	0.048	0.095	0.000	0.000
0.046	0.017	0.080	0.041	0.068	0.024	0.010	0.107	0.036	0.048	0.095	0.000	0.000
0.043	0.017	0.076	0.032	0.054	0.013	0.094	0.087	0.044	0.053	0.013	0.000	0.051
0.038	0.013	0.085	0.011	0.061	0.030	0.092	0.044	0.087	0.050	0.017	0.000	0.051
0.054	0.027	0.054	0.030	0.093	0.016	0.056	0.087	0.044	0.033	0.033	0.000	0.051
0.019	0.085	0.032	0.093	0.034	0.015	0.052	0.087	0.044	0.055	0.011	0.000	0.051
0.034	0.020	0.089	0.066	0.020	0.044	0.013	0.095	0.048	0.036	0.107	0.143	0.000
0.046	0.017	0.080	0.069	0.024	0.040	0.010	0.107	0.036	0.095	0.048	0.143	0.000
0.052	0.014	0.077	0.066	0.028	0.039	0.010	0.048	0.095	0.048	0.095	0.143	0.000

Limiting Super matrix Case Study 1

Cost	Alternatives				
FRP	C	B	A		
0.036	0.024	0.033	0.045	A	Alternatives
0.036	0.024	0.033	0.045	B	
0.036	0.024	0.033	0.045	C	
0.036	0.024	0.033	0.045	FRP	Cost Factors
0.036	0.024	0.033	0.045	FC	
0.036	0.024	0.033	0.045	LCC	
0.036	0.024	0.033	0.045	PTP	
0.036	0.024	0.033	0.045	Cost	Criteria
0.036	0.024	0.033	0.045	H & S	
0.036	0.024	0.033	0.045	PC	
0.036	0.024	0.033	0.045	Performance	
0.036	0.024	0.033	0.045	QC	
0.036	0.024	0.033	0.045	EI	Health and Safety Factors
0.036	0.024	0.033	0.045	HSP	
0.036	0.024	0.033	0.045	PCM	Project Control factors
0.036	0.024	0.033	0.045	SAW	
0.036	0.024	0.033	0.045	PPE	Performance factors
0.036	0.024	0.033	0.045	NKP	
0.036	0.024	0.033	0.045	ORU	
0.036	0.024	0.033	0.045	TSP	
0.036	0.024	0.033	0.045	MDR	Quality Control factors
0.036	0.024	0.033	0.045	QCM	
0.036	0.024	0.033	0.045	UES	

Quality Control factors			Performance Factors				Project Control		Health and Safety		Criteria							
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP	LCC	FC
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063
0.030	0.034	0.059	0.043	0.056	0.024	0.052	0.095	0.049	0.050	0.049	0.030	0.021	0.036	0.009	0.040	0.098	0.022	0.063

Unweighted Super matrix Case Study 2

Performance Factors		PC factors		H & S Factors		Criteria					Cost Factors				Alternatives				
NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP	LCC	FC	FRP	C	B	A		
0.073	0.473	0.750	0.250	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.495	0.061	0.310	0.134	0.000	0.000	0.000	A	Alternatives
0.068	0.543	0.750	0.250	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.504	0.073	0.301	0.123	0.000	0.000	0.000	B	
0.189	0.351	0.667	0.333	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.510	0.056	0.290	0.145	0.000	0.000	0.000	C	
0.088	0.273	0.333	0.667	0.750	0.250	0.000	0.000	0.000	0.000	1.000	0.070	0.088	0.496	0.346	0.558	0.320	0.122	FRP	Cost Factors
0.072	0.172	0.800	0.200	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.080	0.136	0.451	0.334	0.540	0.297	0.163	FC	
0.097	0.435	0.667	0.333	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.473	0.052	0.324	0.152	0.122	0.320	0.558	LCC	
0.075	0.319	0.750	0.250	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.504	0.068	0.193	0.235	0.163	0.297	0.540	PTP	
0.000	0.000	0.000	0.000	0.000	0.000	0.144	0.263	0.222	0.066	0.305	0.370	0.100	0.345	0.185	0.000	0.000	0.000	Cost	Criteria
0.000	0.000	0.000	0.000	0.667	0.333	0.041	0.188	0.100	0.285	0.386	0.000	0.000	0.000	0.000	0.000	0.000	0.000	H & S	
0.000	0.000	0.667	0.333	0.000	0.000	0.211	0.099	0.305	0.051	0.334	0.000	0.000	0.000	0.000	0.000	0.000	0.000	PC	
0.181	0.365	0.000	0.000	0.000	0.000	0.132	0.251	0.157	0.059	0.401	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Performance	
0.000	0.000	0.000	0.000	0.000	0.000	0.254	0.105	0.201	0.049	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000	QC	
0.120	0.491	0.200	0.800	0.333	0.667	0.000	0.000	0.000	1.000	0.000	0.437	0.069	0.307	0.186	0.320	0.558	0.122	EI	H & S Factors
0.373	0.196	0.333	0.667	0.750	0.250	0.000	0.000	0.000	1.000	0.000	0.473	0.073	0.284	0.170	0.297	0.540	0.163	HSP	
0.266	0.093	0.750	0.250	0.333	0.667	0.000	0.000	1.000	0.000	0.000	0.472	0.079	0.324	0.124	0.320	0.558	0.122	PCM	PC factors
0.170	0.073	0.750	0.250	0.333	0.667	0.000	0.000	1.000	0.000	0.000	0.510	0.298	0.116	0.077	0.333	0.528	0.140	SAW	
0.068	0.485	0.667	0.333	0.800	0.200	0.000	1.000	0.000	0.000	0.000	0.469	0.079	0.315	0.137	0.238	0.625	0.137	PPE	Performance Factors
0.155	0.476	0.333	0.667	0.750	0.250	0.000	1.000	0.000	0.000	0.000	0.574	0.047	0.227	0.153	0.122	0.320	0.558	NKP	
0.081	0.288	0.667	0.333	0.500	0.500	0.000	1.000	0.000	0.000	0.000	0.509	0.053	0.327	0.111	0.249	0.594	0.157	ORU	
0.079	0.270	0.667	0.333	0.833	0.167	0.000	1.000	0.000	0.000	0.000	0.572	0.226	0.148	0.053	0.297	0.540	0.163	TSP	
0.305	0.093	0.667	0.333	0.250	0.750	1.000	0.000	0.000	0.000	0.000	0.434	0.058	0.331	0.178	0.320	0.558	0.122	MDU	QC factors
0.280	0.068	0.750	0.250	0.667	0.333	1.000	0.000	0.000	0.000	0.000	0.543	0.247	0.154	0.056	0.297	0.540	0.163	QCM	
0.274	0.068	0.333	0.667	0.333	0.667	1.000	0.000	0.000	0.000	0.000	0.490	0.057	0.308	0.145	0.286	0.571	0.143	UES	

UES	QCM	MDR	TSP	ORU
QC factors				
0.137	0.238	0.625	0.170	0.284
0.091	0.218	0.691	0.137	0.252
0.137	0.238	0.625	0.109	0.351
0.122	0.558	0.320	0.109	0.529
0.297	0.163	0.540	0.325	0.431
0.297	0.163	0.540	0.182	0.286
0.249	0.157	0.594	0.155	0.451
0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.060	0.394
0.163	0.540	0.297	0.000	0.000
0.249	0.594	0.157	0.313	0.075
0.320	0.122	0.558	0.355	0.076
0.137	0.625	0.238	0.497	0.144
0.320	0.122	0.558	0.284	0.473
0.320	0.122	0.558	0.167	0.280
0.280	0.094	0.627	0.055	0.315
0.400	0.200	0.400	0.154	0.477
0.136	0.626	0.238	0.477	0.174
0.238	0.137	0.625	0.459	0.143
0.319	0.122	0.559	0.485	0.167
0.364	0.099	0.537	0.460	0.197

Weighted Super matrix Case Study 2.

H & S	Criteria					Cost Factors				Alternatives				
EI	QC	Performance	PC	H & S	Cost	PTP	LCC	FC	FRP	C	B	A		
0.035	0.000	0.000	0.000	0.000	0.000	0.188	0.023	0.118	0.051	0.000	0.000	0.000	A	Alternatives
0.035	0.000	0.000	0.000	0.000	0.000	0.191	0.028	0.114	0.047	0.000	0.000	0.000	B	
0.040	0.000	0.000	0.000	0.000	0.000	0.193	0.021	0.110	0.055	0.000	0.000	0.000	C	
0.036	0.000	0.000	0.000	0.000	0.143	0.010	0.013	0.071	0.049	0.080	0.046	0.017	FRP	Cost Factors
0.048	0.000	0.000	0.000	0.000	0.143	0.011	0.019	0.064	0.048	0.077	0.042	0.023	FC	
0.048	0.000	0.000	0.000	0.000	0.143	0.068	0.007	0.046	0.022	0.017	0.046	0.080	LCC	
0.048	0.000	0.000	0.000	0.000	0.143	0.072	0.010	0.028	0.034	0.023	0.042	0.077	PTP	
0.000	0.072	0.132	0.111	0.033	0.152	0.185	0.050	0.173	0.093	0.000	0.000	0.000	Cost	Criteria
0.167	0.021	0.094	0.050	0.142	0.193	0.000	0.000	0.000	0.000	0.000	0.000	0.000	H & S	
0.000	0.106	0.049	0.153	0.025	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	PC	
0.000	0.066	0.125	0.078	0.029	0.201	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Performance	
0.000	0.127	0.053	0.100	0.024	0.196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	QC	
0.095	0.000	0.000	0.000	0.143	0.000	0.062	0.010	0.044	0.027	0.046	0.080	0.017	EI	H & S factors
0.036	0.000	0.000	0.000	0.143	0.000	0.068	0.010	0.041	0.024	0.042	0.077	0.023	HSP	
0.095	0.000	0.000	0.143	0.000	0.000	0.067	0.011	0.046	0.018	0.046	0.080	0.017	PCM	PC factors
0.095	0.000	0.000	0.143	0.000	0.000	0.073	0.043	0.017	0.011	0.048	0.075	0.020	SAW	
0.029	0.000	0.143	0.000	0.000	0.000	0.067	0.011	0.045	0.020	0.034	0.089	0.020	PPE	Performance factors
0.036	0.000	0.143	0.000	0.000	0.000	0.082	0.007	0.032	0.022	0.017	0.046	0.080	NKP	
0.071	0.000	0.143	0.000	0.000	0.000	0.073	0.008	0.047	0.016	0.036	0.085	0.022	ORU	
0.024	0.000	0.143	0.000	0.000	0.000	0.082	0.032	0.021	0.008	0.042	0.077	0.023	TSP	
0.107	0.143	0.000	0.000	0.000	0.000	0.062	0.008	0.047	0.025	0.046	0.080	0.017	MDU	QC factors
0.048	0.143	0.000	0.000	0.000	0.000	0.078	0.035	0.022	0.008	0.042	0.077	0.023	QCM	
0.095	0.143	0.000	0.000	0.000	0.000	0.070	0.008	0.044	0.021	0.041	0.082	0.020	UES	

QC factors			Performance Factors				PC factors		
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP
0.015	0.027	0.070	0.046	0.076	0.020	0.127	0.141	0.047	0.018
0.010	0.024	0.077	0.037	0.068	0.018	0.146	0.141	0.047	0.018
0.015	0.027	0.070	0.029	0.094	0.051	0.094	0.125	0.063	0.013
0.017	0.080	0.046	0.016	0.076	0.013	0.039	0.048	0.095	0.107
0.042	0.023	0.077	0.046	0.062	0.010	0.025	0.114	0.029	0.095
0.042	0.023	0.077	0.026	0.041	0.014	0.062	0.095	0.048	0.095
0.036	0.022	0.085	0.022	0.064	0.011	0.046	0.107	0.036	0.095
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.167	0.000
0.000	0.000	0.000	0.030	0.197	0.090	0.182	0.000	0.000	0.000
0.082	0.270	0.148	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.036	0.085	0.022	0.045	0.011	0.017	0.070	0.029	0.114	0.048
0.046	0.017	0.080	0.051	0.011	0.053	0.028	0.048	0.095	0.107
0.020	0.089	0.034	0.071	0.021	0.038	0.013	0.107	0.036	0.048
0.046	0.017	0.080	0.041	0.068	0.024	0.010	0.107	0.036	0.048
0.046	0.017	0.080	0.024	0.040	0.010	0.069	0.095	0.048	0.114
0.040	0.013	0.090	0.008	0.045	0.022	0.068	0.048	0.095	0.107
0.057	0.029	0.057	0.022	0.068	0.012	0.041	0.095	0.048	0.071
0.019	0.089	0.034	0.068	0.025	0.011	0.039	0.095	0.048	0.119
0.034	0.020	0.089	0.066	0.020	0.044	0.013	0.095	0.048	0.036
0.046	0.017	0.080	0.069	0.024	0.040	0.010	0.107	0.036	0.095
0.052	0.014	0.077	0.066	0.028	0.039	0.010	0.048	0.095	0.048

Limiting Super matrix Case Study 2.

Crit eria	Cost Factors				Alternatives				
Cost	PTP	LCC	FC	FRP	C	B	A		
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	A	Alternatives
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	B	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	C	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	FRP	Cost Factors
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	FC	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	LCC	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	PTP	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	Cost	Criteria
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	H & S	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	PC	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	Performance	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	QC	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	EI	H & S Factors
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	HSP	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	PCM	PC factors
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	SAW	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	PPE	Performance Factors
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	NKP	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	ORU	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	TSP	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	MDR	QC factors
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	QCM	
0.059	0.075	0.017	0.049	0.027	0.030	0.049	0.021	UES	

QC factors			Performance Factors				PC factors		H & S Factors					
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026
0.031	0.037	0.060	0.036	0.044	0.024	0.043	0.087	0.052	0.065	0.053	0.034	0.040	0.041	0.026

Unweighted Super matrix Case Study 3.

Alternatives				
C	B	A		
0.000	0.000	0.000	A	Alternatives
0.000	0.000	0.000	B	
0.000	0.000	0.000	C	
0.297	0.540	0.163	FRP	Cost Factors
0.163	0.540	0.297	FC	
0.122	0.320	0.558	LCC	
0.163	0.297	0.540	PTP	
0.000	0.000	0.000	Cost	Criteria
0.000	0.000	0.000	H & S	
0.000	0.000	0.000	PC	
0.000	0.000	0.000	Performance	
0.000	0.000	0.000	QC	
0.250	0.250	0.500	EI	H & S factors
0.157	0.249	0.594	HSP	
0.157	0.249	0.594	PCM	PC factors
0.163	0.297	0.540	SAW	
0.400	0.200	0.400	PPE	Performance factors
0.122	0.558	0.320	NKP	
0.163	0.297	0.540	ORU	
0.163	0.540	0.297	TSP	
0.297	0.163	0.540	MDR	QC factors
0.163	0.297	0.540	QCM	
0.297	0.163	0.540	UES	

QC factors			Performance Factors				PC factors		H & S Factors		Criteria					Cost Factors			
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Perfo rman	PC	H & S	Cost	PTP	LCC	FC	FRP
0.137	0.238	0.625	0.170	0.284	0.073	0.473	0.750	0.250	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.495	0.061	0.310	0.134
0.091	0.218	0.691	0.137	0.252	0.068	0.543	0.250	0.750	0.333	0.667	0.000	0.000	0.000	0.000	0.000	0.504	0.073	0.301	0.123
0.137	0.238	0.625	0.170	0.284	0.073	0.473	0.333	0.667	0.250	0.750	0.000	0.000	0.000	0.000	0.000	0.510	0.056	0.290	0.145
0.122	0.558	0.320	0.109	0.529	0.088	0.273	0.333	0.667	0.750	0.250	0.000	0.000	0.000	0.000	1.000	0.070	0.088	0.496	0.346
0.297	0.163	0.540	0.325	0.431	0.072	0.172	0.800	0.200	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.080	0.136	0.451	0.334
0.297	0.163	0.540	0.182	0.286	0.097	0.435	0.667	0.333	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.473	0.052	0.324	0.152
0.249	0.157	0.594	0.155	0.451	0.075	0.319	0.750	0.250	0.667	0.333	0.000	0.000	0.000	0.000	1.000	0.504	0.068	0.193	0.235
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.144	0.263	0.222	0.066	0.305	0.370	0.100	0.345	0.185
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.041	0.188	0.100	0.285	0.386	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.211	0.099	0.305	0.051	0.334	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.060	0.394	0.181	0.365	0.000	0.000	0.000	0.000	0.132	0.251	0.157	0.059	0.401	0.000	0.000	0.000	0.000
0.163	0.540	0.297	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.254	0.105	0.201	0.049	0.391	0.000	0.000	0.000	0.000
0.249	0.594	0.157	0.313	0.075	0.120	0.491	0.200	0.800	0.333	0.667	0.000	0.000	0.000	1.000	0.000	0.437	0.069	0.307	0.186
0.320	0.122	0.558	0.355	0.076	0.373	0.196	0.333	0.667	0.750	0.250	0.000	0.000	0.000	1.000	0.000	0.473	0.073	0.284	0.170
0.137	0.625	0.238	0.497	0.144	0.266	0.093	0.750	0.250	0.333	0.667	0.000	0.000	1.000	0.000	0.000	0.472	0.079	0.324	0.124
0.320	0.122	0.558	0.284	0.473	0.170	0.073	0.750	0.250	0.333	0.667	0.000	0.000	1.000	0.000	0.000	0.510	0.298	0.116	0.077
0.320	0.122	0.558	0.167	0.280	0.068	0.485	0.667	0.333	0.800	0.200	0.000	1.000	0.000	0.000	0.000	0.469	0.079	0.315	0.137
0.280	0.094	0.627	0.055	0.315	0.155	0.476	0.333	0.667	0.750	0.250	0.000	1.000	0.000	0.000	0.000	0.574	0.047	0.227	0.153
0.400	0.200	0.400	0.154	0.477	0.081	0.288	0.667	0.333	0.500	0.500	0.000	1.000	0.000	0.000	0.000	0.509	0.053	0.327	0.111
0.136	0.626	0.238	0.477	0.174	0.079	0.270	0.667	0.333	0.833	0.167	0.000	1.000	0.000	0.000	0.000	0.572	0.226	0.148	0.053
0.238	0.137	0.625	0.459	0.143	0.305	0.093	0.667	0.333	0.250	0.750	1.000	0.000	0.000	0.000	0.000	0.434	0.058	0.331	0.178
0.319	0.122	0.559	0.485	0.167	0.280	0.068	0.750	0.250	0.667	0.333	1.000	0.000	0.000	0.000	0.000	0.543	0.247	0.154	0.056
0.364	0.099	0.537	0.460	0.197	0.274	0.068	0.333	0.667	0.333	0.667	1.000	0.000	0.000	0.000	0.000	0.490	0.057	0.308	0.145

Weighted Super matrix Case Study 3.

Performance Factors			PC factors		H & S Factors		Criteria					Cost Factors				Alternatives				
ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP	LCC	FC	FRP	C	B	A		
0.066	0.017	0.109	0.126	0.042	0.015	0.029	0.000	0.000	0.000	0.000	0.000	0.223	0.028	0.140	0.060	0.000	0.000	0.000	A	Alternatives
0.058	0.016	0.125	0.042	0.126	0.015	0.029	0.000	0.000	0.000	0.000	0.000	0.228	0.033	0.136	0.055	0.000	0.000	0.000	B	
0.066	0.017	0.109	0.056	0.112	0.011	0.033	0.000	0.000	0.000	0.000	0.000	0.230	0.025	0.131	0.065	0.000	0.000	0.000	C	
0.076	0.013	0.039	0.048	0.095	0.107	0.036	0.000	0.000	0.000	0.000	0.143	0.010	0.013	0.071	0.049	0.042	0.077	0.023	FRP	Cost Factors
0.062	0.010	0.025	0.114	0.029	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.011	0.019	0.064	0.048	0.023	0.077	0.042	FC	
0.041	0.014	0.062	0.095	0.048	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.068	0.007	0.046	0.022	0.017	0.046	0.080	LCC	
0.064	0.011	0.046	0.107	0.036	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.072	0.010	0.028	0.034	0.023	0.042	0.077	PTP	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.132	0.111	0.033	0.152	0.185	0.050	0.173	0.093	0.000	0.000	0.000	Cost	Criteria
0.000	0.000	0.000	0.000	0.000	0.333	0.167	0.021	0.094	0.050	0.142	0.193	0.000	0.000	0.000	0.000	0.000	0.000	0.000	H & S	
0.000	0.000	0.000	0.334	0.167	0.000	0.000	0.106	0.049	0.153	0.025	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	PC	
0.197	0.090	0.182	0.000	0.000	0.000	0.000	0.066	0.125	0.078	0.029	0.201	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Performance	
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.053	0.100	0.024	0.196	0.000	0.000	0.000	0.000	0.000	0.000	0.000	QC	
0.011	0.017	0.070	0.029	0.114	0.048	0.095	0.000	0.000	0.000	0.143	0.000	0.062	0.010	0.044	0.027	0.036	0.036	0.071	EI	H & S factors
0.011	0.053	0.028	0.048	0.095	0.107	0.036	0.000	0.000	0.000	0.143	0.000	0.068	0.010	0.041	0.024	0.022	0.036	0.085	HSP	
0.021	0.038	0.013	0.107	0.036	0.048	0.095	0.000	0.000	0.143	0.000	0.000	0.067	0.011	0.046	0.018	0.022	0.036	0.085	PCM	PC factors
0.068	0.024	0.010	0.107	0.036	0.048	0.095	0.000	0.000	0.143	0.000	0.000	0.073	0.043	0.017	0.011	0.023	0.042	0.077	SAW	
0.040	0.010	0.069	0.095	0.048	0.114	0.029	0.000	0.143	0.000	0.000	0.000	0.067	0.011	0.045	0.020	0.057	0.029	0.057	PPE	Performance factors
0.045	0.022	0.068	0.048	0.095	0.107	0.036	0.000	0.143	0.000	0.000	0.000	0.082	0.007	0.032	0.022	0.017	0.080	0.046	NKP	
0.068	0.012	0.041	0.095	0.048	0.071	0.071	0.000	0.143	0.000	0.000	0.000	0.073	0.008	0.047	0.016	0.023	0.042	0.077	ORU	
0.025	0.011	0.039	0.095	0.048	0.119	0.024	0.000	0.143	0.000	0.000	0.000	0.082	0.032	0.021	0.008	0.023	0.077	0.042	TSP	
0.020	0.044	0.013	0.095	0.048	0.036	0.107	0.143	0.000	0.000	0.000	0.000	0.062	0.008	0.047	0.025	0.042	0.023	0.077	MDR	QC factors
0.024	0.040	0.010	0.107	0.036	0.095	0.048	0.143	0.000	0.000	0.000	0.000	0.078	0.035	0.022	0.008	0.023	0.042	0.077	QCM	
0.028	0.039	0.010	0.048	0.095	0.048	0.095	0.143	0.000	0.000	0.000	0.000	0.070	0.008	0.044	0.021	0.042	0.023	0.077	UES	

QC factors			
UES	QCM	MDR	TSP
0.015	0.025	0.066	0.039
0.010	0.023	0.074	0.032
0.015	0.025	0.066	0.039
0.017	0.080	0.046	0.016
0.042	0.023	0.077	0.046
0.042	0.023	0.077	0.026
0.036	0.022	0.085	0.022
0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.030
0.082	0.270	0.148	0.000
0.036	0.085	0.022	0.045
0.046	0.017	0.080	0.051
0.020	0.089	0.034	0.071
0.046	0.017	0.080	0.041
0.046	0.017	0.080	0.024
0.040	0.013	0.090	0.008
0.057	0.029	0.057	0.022
0.019	0.089	0.034	0.068
0.034	0.020	0.089	0.066
0.046	0.017	0.080	0.069
0.052	0.014	0.077	0.066

Limiting Super matrix Case Study 3.

		Alternatives			Cost Factors				Criteria					H & S Factors	
		A	B	C	FRP	FC	LCC	PTP	Cost	H & S	PC	Performo rman	QC	EI	HSP
Alternatives	A	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	B	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	C	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
Cost Factors	FCR	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	FC	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	LCC	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	PTP	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
Criteria	Cost	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	H & S	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	PC	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	Performance	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	QC	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
H & S factors	EI	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	HSP	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
PC factors	PCM	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	SAW	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
Performance factors	PPE	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	NKP	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	ORU	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	TSP	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
QC factors	MDR	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	QCM	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064
	UES	0.049	0.031	0.020	0.028	0.052	0.018	0.078	0.061	0.025	0.040	0.040	0.034	0.053	0.064

QC factors			Performance Factors				PC factors	
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055
0.031	0.037	0.060	0.036	0.043	0.023	0.042	0.082	0.055

Unweighted Super matrix Case Study 4.

Criteria			Cost Factors				Alternatives				
PC	H & S	Cost	PTP	LCC	FC	FRP	C	B	A		
0.000	0.000	0.000	0.428	0.094	0.316	0.163	0.000	0.000	0.000	A	Alternatives
0.000	0.000	0.000	0.469	0.079	0.315	0.137	0.000	0.000	0.000	B	
0.000	0.000	0.000	0.459	0.093	0.305	0.143	0.000	0.000	0.000	C	
0.000	0.000	1.000	0.070	0.088	0.496	0.346	0.558	0.122	0.320	FRP	Cost Factors
0.000	0.000	1.000	0.080	0.136	0.451	0.334	0.558	0.122	0.320	FC	
0.000	0.000	1.000	0.473	0.052	0.324	0.152	0.122	0.320	0.558	LCC	
0.000	0.000	1.000	0.504	0.068	0.193	0.235	0.137	0.238	0.625	PTP	
0.222	0.066	0.305	0.370	0.100	0.345	0.185	0.000	0.000	0.000	Cost	Criteria
0.100	0.285	0.386	0.000	0.000	0.000	0.000	0.000	0.000	0.000	H & S	
0.305	0.051	0.334	0.000	0.000	0.000	0.000	0.000	0.000	0.000	PC	
0.157	0.059	0.401	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Performance	
0.201	0.049	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000	QC	
0.000	1.000	0.000	0.437	0.069	0.307	0.186	0.143	0.286	0.571	EI	H & S factors
0.000	1.000	0.000	0.473	0.073	0.284	0.170	0.122	0.320	0.558	HSP	
1.000	0.000	0.000	0.472	0.079	0.324	0.124	0.122	0.320	0.558	PCM	PC factors
1.000	0.000	0.000	0.510	0.298	0.116	0.077	0.163	0.297	0.540	SAW	
0.000	0.000	0.000	0.469	0.079	0.315	0.137	0.200	0.200	0.600	PPE	Performance factors
0.000	0.000	0.000	0.574	0.047	0.227	0.153	0.333	0.333	0.333	NKP	
0.000	0.000	0.000	0.509	0.053	0.327	0.111	0.163	0.297	0.540	ORU	
0.000	0.000	0.000	0.572	0.226	0.148	0.053	0.140	0.333	0.528	TSP	
0.000	0.000	0.000	0.434	0.058	0.331	0.178	0.297	0.163	0.540	MDR	QC factors
0.000	0.000	0.000	0.543	0.247	0.154	0.056	0.163	0.297	0.540	QCM	
0.000	0.000	0.000	0.490	0.057	0.308	0.145	0.320	0.122	0.558	UES	

UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Perfo rman
QC factors			Performance Factors				PC factors		H & S Factors			
0.320	0.122	0.558	0.177	0.476	0.093	0.254	0.667	0.333	0.667	0.333	0.000	0.000
0.320	0.122	0.558	0.163	0.428	0.094	0.316	0.667	0.333	0.333	0.667	0.000	0.000
0.320	0.122	0.558	0.175	0.418	0.078	0.330	0.667	0.333	0.333	0.667	0.000	0.000
0.122	0.558	0.320	0.109	0.529	0.088	0.273	0.333	0.667	0.750	0.250	0.000	0.000
0.297	0.163	0.540	0.325	0.431	0.072	0.172	0.800	0.200	0.667	0.333	0.000	0.000
0.297	0.163	0.540	0.182	0.286	0.097	0.435	0.667	0.333	0.667	0.333	0.000	0.000
0.249	0.157	0.594	0.155	0.451	0.075	0.319	0.750	0.250	0.667	0.333	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.144	0.263
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.041	0.188
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333	0.000	0.000	0.211	0.099
0.000	0.000	0.000	0.060	0.394	0.181	0.365	0.000	0.000	0.000	0.000	0.132	0.251
0.163	0.540	0.297	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.254	0.105
0.249	0.594	0.157	0.313	0.075	0.120	0.491	0.200	0.800	0.333	0.667	0.000	0.000
0.320	0.122	0.558	0.355	0.076	0.373	0.196	0.333	0.667	0.750	0.250	0.000	0.000
0.137	0.625	0.238	0.497	0.144	0.266	0.093	0.750	0.250	0.333	0.667	0.000	0.000
0.320	0.122	0.558	0.284	0.473	0.170	0.073	0.750	0.250	0.333	0.667	0.000	0.000
0.320	0.122	0.558	0.167	0.280	0.068	0.485	0.667	0.333	0.800	0.200	0.000	1.000
0.280	0.094	0.627	0.055	0.315	0.155	0.476	0.333	0.667	0.750	0.250	0.000	1.000
0.400	0.200	0.400	0.154	0.477	0.081	0.288	0.667	0.333	0.500	0.500	0.000	1.000
0.136	0.626	0.238	0.477	0.174	0.079	0.270	0.667	0.333	0.833	0.167	0.000	1.000
0.238	0.137	0.625	0.459	0.143	0.305	0.093	0.667	0.333	0.250	0.750	1.000	0.000
0.319	0.122	0.559	0.485	0.167	0.280	0.068	0.750	0.250	0.667	0.333	1.000	0.000
0.364	0.099	0.537	0.460	0.197	0.274	0.068	0.333	0.667	0.333	0.667	1.000	0.000

Weighted Super matrix Case Study 4.

		LCC	FC	FRP	C	B	A
		Cost Factors			Alternatives		
Alternatives	A	0.043	0.143	0.073	0.000	0.000	0.000
	B	0.036	0.142	0.062	0.000	0.000	0.000
	C	0.042	0.138	0.065	0.000	0.000	0.000
Cost Factors	FRP	0.013	0.071	0.049	0.080	0.017	0.046
	FC	0.019	0.064	0.048	0.080	0.017	0.046
	LCC	0.007	0.046	0.022	0.017	0.046	0.080
	PTP	0.010	0.028	0.034	0.020	0.034	0.089
Criteria	Cost	0.050	0.173	0.093	0.000	0.000	0.000
	H & S	0.000	0.000	0.000	0.000	0.000	0.000
	PC	0.000	0.000	0.000	0.000	0.000	0.000
	Performance	0.000	0.000	0.000	0.000	0.000	0.000
	QC	0.000	0.000	0.000	0.000	0.000	0.000
H & S factors	EI	0.010	0.044	0.027	0.020	0.041	0.082
	HSP	0.010	0.041	0.024	0.017	0.046	0.080
PC factors	PCM	0.011	0.046	0.018	0.017	0.046	0.080
	SAW	0.043	0.017	0.011	0.023	0.042	0.077
Performance factors	PPE	0.011	0.045	0.020	0.029	0.029	0.086
	NKP	0.007	0.032	0.022	0.048	0.048	0.048
	ORU	0.008	0.047	0.016	0.023	0.042	0.077
	TSP	0.032	0.021	0.008	0.020	0.048	0.075
QC factors	MDR	0.008	0.047	0.025	0.042	0.023	0.077
	QCM	0.035	0.022	0.008	0.023	0.042	0.077
	UES	0.008	0.044	0.021	0.046	0.017	0.080

QC factors			Performance Factors				PC factors		H & S Factors		Criteria					
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP
0.034	0.013	0.059	0.041	0.110	0.022	0.058	0.112	0.056	0.029	0.015	0.000	0.000	0.000	0.000	0.000	0.193
0.034	0.013	0.059	0.038	0.099	0.022	0.073	0.112	0.056	0.015	0.029	0.000	0.000	0.000	0.000	0.000	0.212
0.034	0.013	0.059	0.040	0.096	0.018	0.076	0.112	0.056	0.015	0.029	0.000	0.000	0.000	0.000	0.000	0.207
0.017	0.080	0.046	0.016	0.076	0.013	0.039	0.048	0.095	0.107	0.036	0.000	0.000	0.000	0.000	0.143	0.010
0.042	0.023	0.077	0.046	0.062	0.010	0.025	0.114	0.029	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.011
0.042	0.023	0.077	0.026	0.041	0.014	0.062	0.095	0.048	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.068
0.036	0.022	0.085	0.022	0.064	0.011	0.046	0.107	0.036	0.095	0.048	0.000	0.000	0.000	0.000	0.143	0.072
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.132	0.111	0.033	0.152	0.185
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.167	0.021	0.094	0.050	0.142	0.193	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.167	0.000	0.000	0.106	0.049	0.153	0.025	0.167	0.000
0.000	0.000	0.000	0.030	0.197	0.090	0.182	0.000	0.000	0.000	0.000	0.066	0.125	0.078	0.029	0.201	0.000
0.082	0.270	0.148	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.053	0.100	0.024	0.196	0.000
0.036	0.085	0.022	0.045	0.011	0.017	0.070	0.029	0.114	0.048	0.095	0.000	0.000	0.000	0.143	0.000	0.062
0.046	0.017	0.080	0.051	0.011	0.053	0.028	0.048	0.095	0.107	0.036	0.000	0.000	0.000	0.143	0.000	0.068
0.020	0.089	0.034	0.071	0.021	0.038	0.013	0.107	0.036	0.048	0.095	0.000	0.000	0.143	0.000	0.000	0.067
0.046	0.017	0.080	0.041	0.068	0.024	0.010	0.107	0.036	0.048	0.095	0.000	0.000	0.143	0.000	0.000	0.073
0.046	0.017	0.080	0.024	0.040	0.010	0.069	0.095	0.048	0.114	0.029	0.000	0.143	0.000	0.000	0.000	0.067
0.040	0.013	0.090	0.008	0.045	0.022	0.068	0.048	0.095	0.107	0.036	0.000	0.143	0.000	0.000	0.000	0.082
0.057	0.029	0.057	0.022	0.068	0.012	0.041	0.095	0.048	0.071	0.071	0.000	0.143	0.000	0.000	0.000	0.073
0.019	0.089	0.034	0.068	0.025	0.011	0.039	0.095	0.048	0.119	0.024	0.000	0.143	0.000	0.000	0.000	0.082
0.034	0.020	0.089	0.066	0.020	0.044	0.013	0.095	0.048	0.036	0.107	0.143	0.000	0.000	0.000	0.000	0.062
0.046	0.017	0.080	0.069	0.024	0.040	0.010	0.107	0.036	0.095	0.048	0.143	0.000	0.000	0.000	0.000	0.078
0.052	0.014	0.077	0.066	0.028	0.039	0.010	0.048	0.095	0.048	0.095	0.143	0.000	0.000	0.000	0.000	0.070

Limiting Super matrix Case Study 4.

Performance Factors			PC factors		H & S Factors		Criteria					Cost Factors				Alternatives				
ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP	LCC	FC	FRP	C	B	A		
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	A	Alternatives
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	B	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	C	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	FRP	Cost Factors
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	FC	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	LCC	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	PTP	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	Cost	Criteria
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	H & S	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	PC	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	Performance	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	QC	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	EI	H & S factors
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	HSP	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	PCM	PC factors
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	SAW	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	PPE	Performance factors
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	NKP	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	ORU	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	TSP	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	MDR	QC factors
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	QCM	
0.047	0.023	0.037	0.085	0.052	0.065	0.052	0.034	0.040	0.040	0.025	0.061	0.076	0.019	0.052	0.029	0.022	0.025	0.053	UES	

QC factors			
UES	QCM	MDR	TSP
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036
0.033	0.036	0.059	0.036

Unweighted Super matrix Case Study 5.

		Alternatives		Cost Factors				Criteria					H & S Factors	
		A	B	FRP	FC	LCC	PTP	Cost	H & S	PC	Performance	QC	EI	HSP
Alternatives	A	0.000	0.000	0.137	0.315	0.079	0.469	0.000	0.000	0.000	0.000	0.000	0.667	0.333
	B	0.000	0.000	0.137	0.315	0.079	0.469	0.000	0.000	0.000	0.000	0.000	0.667	0.333
Cost Factors	FRP	0.333	0.667	0.346	0.496	0.088	0.070	1.000	0.000	0.000	0.000	0.000	0.250	0.750
	FC	0.333	0.667	0.334	0.451	0.136	0.080	1.000	0.000	0.000	0.000	0.000	0.333	0.667
	LCC	0.667	0.333	0.152	0.324	0.052	0.473	1.000	0.000	0.000	0.000	0.000	0.333	0.667
	PTP	0.667	0.333	0.235	0.193	0.068	0.504	1.000	0.000	0.000	0.000	0.000	0.333	0.667
Criteria	Cost	0.000	0.000	0.185	0.345	0.100	0.370	0.305	0.066	0.222	0.263	0.144	0.000	0.000
	H & S	0.000	0.000	0.000	0.000	0.000	0.000	0.386	0.285	0.100	0.188	0.041	0.333	0.667
	PC	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.051	0.305	0.099	0.211	0.000	0.000
	Performance	0.000	0.000	0.000	0.000	0.000	0.000	0.401	0.059	0.157	0.251	0.132	0.000	0.000
	QC	0.000	0.000	0.000	0.000	0.000	0.000	0.391	0.049	0.201	0.105	0.254	0.000	0.000
H & S Factors	EI	0.667	0.333	0.186	0.307	0.069	0.437	0.000	1.000	0.000	0.000	0.000	0.667	0.333
	HSP	0.667	0.333	0.170	0.284	0.073	0.473	0.000	1.000	0.000	0.000	0.000	0.250	0.750
PC factors	PCM	0.667	0.333	0.124	0.324	0.079	0.472	0.000	0.000	1.000	0.000	0.000	0.667	0.333
	SAW	0.667	0.333	0.077	0.116	0.298	0.510	0.000	0.000	1.000	0.000	0.000	0.667	0.333
Performance Factors	PPE	0.667	0.333	0.137	0.315	0.079	0.469	0.000	0.000	0.000	1.000	0.000	0.200	0.800
	NKP	0.500	0.500	0.153	0.227	0.047	0.574	0.000	0.000	0.000	1.000	0.000	0.250	0.750
	ORU	0.667	0.333	0.111	0.327	0.053	0.509	0.000	0.000	0.000	1.000	0.000	0.500	0.500
	TSP	0.667	0.333	0.053	0.148	0.226	0.572	0.000	0.000	0.000	1.000	0.000	0.167	0.833
QC factors	MDR	0.667	0.333	0.178	0.331	0.058	0.434	0.000	0.000	0.000	0.000	1.000	0.750	0.250
	QCM	0.500	0.500	0.056	0.154	0.247	0.543	0.000	0.000	0.000	0.000	1.000	0.333	0.667
	UES	0.667	0.333	0.145	0.308	0.057	0.490	0.000	0.000	0.000	0.000	1.000	0.667	0.333

QC factors			Performance Factors				PC factors	
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM
0.558	0.122	0.320	0.072	0.431	0.172	0.325	0.667	0.333
0.238	0.137	0.625	0.125	0.492	0.078	0.306	0.667	0.333
0.122	0.558	0.320	0.109	0.529	0.088	0.273	0.333	0.667
0.297	0.163	0.540	0.325	0.431	0.072	0.172	0.800	0.200
0.297	0.163	0.540	0.182	0.286	0.097	0.435	0.667	0.333
0.249	0.157	0.594	0.155	0.451	0.075	0.319	0.750	0.250
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.333
0.000	0.000	0.000	0.060	0.394	0.181	0.365	0.000	0.000
0.163	0.540	0.297	0.000	0.000	0.000	0.000	0.000	0.000
0.249	0.594	0.157	0.313	0.075	0.120	0.491	0.200	0.800
0.320	0.122	0.558	0.355	0.076	0.373	0.196	0.333	0.667
0.137	0.625	0.238	0.497	0.144	0.266	0.093	0.750	0.250
0.320	0.122	0.558	0.284	0.473	0.170	0.073	0.750	0.250
0.320	0.122	0.558	0.167	0.280	0.068	0.485	0.667	0.333
0.280	0.094	0.627	0.055	0.315	0.155	0.476	0.333	0.667
0.400	0.200	0.400	0.154	0.477	0.081	0.288	0.667	0.333
0.136	0.626	0.238	0.477	0.174	0.079	0.270	0.667	0.333
0.238	0.137	0.625	0.459	0.143	0.305	0.093	0.667	0.333
0.319	0.122	0.559	0.485	0.167	0.280	0.068	0.750	0.250
0.364	0.099	0.537	0.460	0.197	0.274	0.068	0.333	0.667

Weighted Super matrix Case Study 5.

		Criteria			Cost Factors				Alternatives	
		PC	H & S	Cost	PTP	LCC	FC	FRP	B	A
Alternatives	A	0.000	0.000	0.000	0.212	0.036	0.142	0.062	0.000	0.000
	B	0.000	0.000	0.000	0.212	0.036	0.142	0.062	0.000	0.000
Cost Factors	FRP	0.000	0.000	0.143	0.010	0.013	0.071	0.049	0.095	0.048
	FC	0.000	0.000	0.143	0.011	0.019	0.064	0.048	0.095	0.048
	LCC	0.000	0.000	0.143	0.068	0.007	0.046	0.022	0.048	0.095
	PTP	0.000	0.000	0.143	0.072	0.010	0.028	0.034	0.048	0.095
Criteria	Cost	0.111	0.033	0.152	0.185	0.050	0.173	0.093	0.000	0.000
	H & S	0.050	0.142	0.193	0.000	0.000	0.000	0.000	0.000	0.000
	PC	0.153	0.025	0.167	0.000	0.000	0.000	0.000	0.000	0.000
	Performance	0.078	0.029	0.201	0.000	0.000	0.000	0.000	0.000	0.000
	QC	0.100	0.024	0.196	0.000	0.000	0.000	0.000	0.000	0.000
H & S Factors	EI	0.000	0.143	0.000	0.062	0.010	0.044	0.027	0.048	0.095
	HSP	0.000	0.143	0.000	0.068	0.010	0.041	0.024	0.048	0.095
PC factors	PCM	0.143	0.000	0.000	0.067	0.011	0.046	0.018	0.048	0.095
	SAW	0.143	0.000	0.000	0.073	0.043	0.017	0.011	0.048	0.095
Performance Factors	PPE	0.000	0.000	0.000	0.067	0.011	0.045	0.020	0.048	0.095
	NKP	0.000	0.000	0.000	0.082	0.007	0.032	0.022	0.071	0.071
	ORU	0.000	0.000	0.000	0.073	0.008	0.047	0.016	0.048	0.095
	TSP	0.000	0.000	0.000	0.082	0.032	0.021	0.008	0.048	0.095
QC factors	MDR	0.000	0.000	0.000	0.062	0.008	0.047	0.025	0.048	0.095
	QCM	0.000	0.000	0.000	0.078	0.035	0.022	0.008	0.071	0.071
	UES	0.000	0.000	0.000	0.070	0.008	0.044	0.021	0.048	0.095

QC factors			Performance Factors				PC factors		H & S Factors			
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance
0.059	0.013	0.034	0.017	0.099	0.040	0.075	0.112	0.056	0.015	0.029	0.000	0.000
0.025	0.015	0.066	0.029	0.113	0.018	0.070	0.112	0.056	0.015	0.029	0.000	0.000
0.017	0.080	0.046	0.016	0.076	0.013	0.039	0.048	0.095	0.107	0.036	0.000	0.000
0.042	0.023	0.077	0.046	0.062	0.010	0.025	0.114	0.029	0.095	0.048	0.000	0.000
0.042	0.023	0.077	0.026	0.041	0.014	0.062	0.095	0.048	0.095	0.048	0.000	0.000
0.036	0.022	0.085	0.022	0.064	0.011	0.046	0.107	0.036	0.095	0.048	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.132
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.167	0.021	0.094
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.334	0.167	0.000	0.000	0.106	0.049
0.000	0.000	0.000	0.030	0.197	0.090	0.182	0.000	0.000	0.000	0.000	0.066	0.125
0.082	0.270	0.148	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.127	0.053
0.036	0.085	0.022	0.045	0.011	0.017	0.070	0.029	0.114	0.048	0.095	0.000	0.000
0.046	0.017	0.080	0.051	0.011	0.053	0.028	0.048	0.095	0.107	0.036	0.000	0.000
0.020	0.089	0.034	0.071	0.021	0.038	0.013	0.107	0.036	0.048	0.095	0.000	0.000
0.046	0.017	0.080	0.041	0.068	0.024	0.010	0.107	0.036	0.048	0.095	0.000	0.000
0.046	0.017	0.080	0.024	0.040	0.010	0.069	0.095	0.048	0.114	0.029	0.000	0.143
0.040	0.013	0.090	0.008	0.045	0.022	0.068	0.048	0.095	0.107	0.036	0.000	0.143
0.057	0.029	0.057	0.022	0.068	0.012	0.041	0.095	0.048	0.071	0.071	0.000	0.143
0.019	0.089	0.034	0.068	0.025	0.011	0.039	0.095	0.048	0.119	0.024	0.000	0.143
0.034	0.020	0.089	0.066	0.020	0.044	0.013	0.095	0.048	0.036	0.107	0.143	0.000
0.046	0.017	0.080	0.069	0.024	0.040	0.010	0.107	0.036	0.095	0.048	0.143	0.000
0.052	0.014	0.077	0.066	0.028	0.039	0.010	0.048	0.095	0.048	0.095	0.143	0.000

Limiting Super matrix Case Study 5.

Cost Factors			Alternatives			
LCC	FC	FRP	B	A		
0.018	0.052	0.028	0.039	0.061	A	Alternatives
0.018	0.052	0.028	0.039	0.061	B	
0.018	0.052	0.028	0.039	0.061	FRP	Cost Factors
0.018	0.052	0.028	0.039	0.061	FC	
0.018	0.052	0.028	0.039	0.061	LCC	
0.018	0.052	0.028	0.039	0.061	PTP	
0.018	0.052	0.028	0.039	0.061	Cost	Criteria
0.018	0.052	0.028	0.039	0.061	H & S	
0.018	0.052	0.028	0.039	0.061	PC	
0.018	0.052	0.028	0.039	0.061	Performance	
0.018	0.052	0.028	0.039	0.061	QC	
0.018	0.052	0.028	0.039	0.061	EI	H & S Factors
0.018	0.052	0.028	0.039	0.061	HSP	
0.018	0.052	0.028	0.039	0.061	PCM	PC factors
0.018	0.052	0.028	0.039	0.061	SAW	
0.018	0.052	0.028	0.039	0.061	PPE	Performance Factors
0.018	0.052	0.028	0.039	0.061	NKP	
0.018	0.052	0.028	0.039	0.061	ORU	
0.018	0.052	0.028	0.039	0.061	TSP	
0.018	0.052	0.028	0.039	0.061	MDR	QC factors
0.018	0.052	0.028	0.039	0.061	QCM	
0.018	0.052	0.028	0.039	0.061	UES	

QC factors			Performance Factors				PC factors		H & S Factors		Criteria						
UES	QCM	MDR	TSP	ORU	NKP	PPE	SAW	PCM	HSP	EI	QC	Performance	PC	H & S	Cost	PTP
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077
0.035	0.036	0.057	0.034	0.047	0.024	0.038	0.084	0.052	0.064	0.053	0.034	0.040	0.040	0.025	0.061	0.077