Selection of suitable highway construction project delivery method by MCDM using fuzzy TOPSIS

by

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Engr. Zeeshan Ul Hassan

ABSTRACT

Construction projects are comprising of various risks and Project delivery method is one of them. Selection of an optimum project delivery method is a remarkable challenge for decision makers. None of any project delivery method is upright for all the projects and it depends on the nature and condition of projects. Various relevant factors are incorporated in this research for the decision makers to have some conclusion. Fuzzy TOPSIS technique has been applied for this multi criteria decision problem to evaluate the best suitable project delivery method. To achieve the targeted objective a framework has been developed incorporating the desired objective and determining factors to get the most suitable project delivery method for highway projects.

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Chapter 1

INTRODUCTION

1 Brief Description

A project delivery method is the way to procure any project by which any owner transfers the risk of designing and construction to some other party by incorporating few term and conditions to achieve the desired objectives. Accomplishment of project mainly depends upon the selection of project delivery method (Moon et al., 2011) . A project delivery system is the one in which Employer and contractor are contractually bound to have certain predetermined conditions to carry forward the project (An et al., 2018). Project delivery method is multifarious including design-bid-build, design-build and construction management at risk (Mahdi and Alreshaid, 2005). No absolute project delivery method is universally acceptable for all kind of projects (Mahdi and Alreshaid, 2005) , that depends on the condition and nature or project. Many factors that determines the selection of project delivery method with different types of combination of these factors would give us the different option about the most suitable project delivery method. To examine the best suitable project delivery method a multi criteria analysis and decision-making technique has to be incorporated.

1.1 MCDM

Multiple-criteria decision making is the technique in which we evaluate multiple conflicting variables to find out the most suitable decision regarding the cost, quality or selection of any one option. We in this research would use the MCDM to figure out the most sustainable project delivery method. Back in seventies MCDM was known as rational way to evaluate the best choice suitable between different alternatives (Bell et al., 1977). A multi criteria decision making is the technique in which multiple possible methods are evaluated to base on their importance to evaluate the most suitable solution of any problem. But in the construction industry we must face the real time and massive problems that include enormous number of variables to incorporate. MCDM technique helps us in those cases to assign proper weightage to each variable and find out its effect on the final selection. In our daily life we have different number of problems that have the multiple solution and options, but we in our mind analysis different options and their consequence to reach out to most suitable option. A multi criteria decision making is of two types, explicit and implicit (Hwang and Masud, 2012) . Explicit are of those types of problem that contains the finite number of alternatives. Each alternative has certain performance value and MCDM process is utilizes to find out the

best alternative. To solve explicit kind of MCDM problems classification or soring of the alternatives by assigning some ranking to the alternatives helps to solve these kinds of problems. Other type of MCDM problem is implicit kind of problem in which infinite or near to uncountable number of alternatives are available. To evaluate these kinds of alternatives we must use the Fuzzy number to assign linguistic value to each alternative. Fuzzy set theory was projected by Zadeh back in 1965, in which we can incorporate partially determining function by using linguistic variable and member ship function. Fuzzy set theory is slightly contradicting with the classical set theory which only incorporate either 0 or 1 but fuzzy set theory incorporates any value between 0 and 1. To evaluate these kinds of problem a mathematical model must be developed. There are different methods to solve MCDM problem, in this research we would focus on Technique for order prioritization by similarity to ideal solution (TOPSIS) method to find out the most reliable project delivery method for highway projects.

1.2 TOPSIS:

TOPSIS was projected by Hwang and Yoon back in 1981 to solve the multiple criteria decision problems, since the crisp set theory was not enough to make up to the right decision, because human thinking don't always work in just two-way possibilities. To evaluate these kind of problem Fuzzy TOPSIS is a beneficiary technique, which helps out in MCDM problems.(Ekmekçioğlu et al., 2010) uses alternative Fuzzy TOPSIS technique to find out the civil waster transfer energy and its site location. It works based on geometric distances between different alternatives. There are two kind of solution namely Positive ideal solution and negative ideal solution. Positive ideal solution should have the shortest geometric distance from its alternatives and the negative ideal should have the longest. This method works on assigning the score or weightage to each alternative and then calculating the distance between the geometric distance between that alternative and the ideal alternative. Normalization is often required to process these kinds of problems. Normalization is the technique of stats in which we organize data in the form of table and that reduces the dependency of the data. Intuitionistic Fuzzy TOPSIS set was beneficiary for many set of fields like, medical diagnoses (De et al., 2001) . There are two types of Fuzzy method, one that was presented by Chen in 2000 and other by Yuen in 2014, an extension of the fuzzy TOPSIS.

1.3 Level of Research Already Carried Out on the Proposed Topic:

Different project delivery methods have been identified over the past few decades. Different researchers have different opinions about the best project delivery method based on their hypothesis (Al Khalil, 2002) (Touran et al., 2010). A project delivery system is the one in which owner and contractor are contractually bound to have certain predetermined conditions to carry forward the project (An et al., 2018) . Selection of project delivery method plays a pivotal role in success of project (Moon et al., 2011) . A multi criteria decision making is of two types, explicit and implicit (Hwang and Masud, 2012) . The techniques used by different researchers include Analytical hierarchy process (Al Khalil, 2002) , Decision Support system (Mahdi and Alreshaid, 2005) , Fuzzy and risk analysis technique (Mostafavi and Karamouz, 2010) . For proto chemical project alternatives were ranked (Mostafavi and Karamouz, 2010) by using Closeness coefficient CC of Fuzzy TOPSIS technique. In one research it has been investigated that DB method offers greater price certainty and reduced cost growth than DBB (Shrestha et al., 2011) . Data collected from 100 waste water projects shows that project delivery method selection have an effect on the schedule and cost of the project (Bogus et al., 2010). Different researchers have worked on the selection of project delivery method because of its importance, following the legacy (Shane et al., 2012) worked on the collection of results obtained from water municipal authority to compare the results the results of Design Build and Design Bid Build method, data incorporated 31DB projects and 69 DBB projects. (Whyte) Works on the development of frame work for the comparison of project performance on the basis of different project delivery methods. (Francom et al., 2014) findings shows up that the potential attainment impact of APDM on trenchless construction projects, specifically reduction in expenses ranging from two to 44 percent. (Kent and Becerik-Gerber, 2010) works on the pros and cons of the project delivery method selection using the experts of construction professionals in addition to his own opinion.

1.4. Reasons / Justification for Selection of the Topic:

It has already been known that the construction industry is facing different kind of challenges and the selection of project delivery method is one of them. Best project delivery method would be that completes in time and with low cost, matching targeted schedules and fulfilling the design requirements with high level of quality.

1.4.1 Objectives:

- ✓ To identify the factors affecting selection of project delivery method.
- ✓ To prioritize the project delivery methods for highway projects using Multi Criteria Decision Making approach

- ✓ Develop a framework for the selection of appropriate project delivery method

1.4.2 Relevance to National Needs:

It is the major dilemma of our constriction industry that, there is very petite information available about the selection of project delivery method. Development of the model considering all the concerns of the relevant stake holder would help the successful completion of the project, project cost certainty and which would overall assist in the growth of the construction industry.

1.4.3 Advantages:

By making a choice among the most suitable project delivery method would help the construction industry to grow further. It is the major dilemma of our constriction industry that, there is very petite information available about the selection of project delivery method. Development of the model considering all the concerns of the relevant stake holder would help the successful completion of the project, project cost certainty and which would overall assist in the growth of the construction industry.

1.4.3 Areas of Application:

The study would be applicable for the construction industry in for the growth in both the public and private sector. By selecting the most suitable project delivery method would help both the contractor and the client in the successful completion of the project which would over all boast the construction industry.

Chapter 2

LITERATURE REVIEW

For construction industry time, efficiency, cost and production are key role to succeed in the competitive environment. (Chan et al., 2004)elaborate in his research that five major chunks of factors make the construction project successful and these are 1) project management, 2) External environment, 3) Project procedures, 4) Project related factors, 5) Human-related factors. Project management includes the project procurement management whose processes includes 1) Initiation and planning, 2) Selection and 3) contract writing.

2.1 Project Delivery method

To procure any project, first we must select the method of project delivery. Different method have been identified by different researchers like (Ibbs et al., 2003) explained three project delivery methods 1). Design Bid/Build, 2).Design/Build and 3).BOT. while (Thomsen, 1982) identified another method termed as construction management at risk (CMAR). While in the modern researches two other techniques have been identified integrated project delivery method (Kent and Becerik-Gerber, 2010) and public private partnership (Akintoye et al., 2008). The TOPSIS method applies n-dimensional Euclidean distance to rank the alternatives on the basis of their distance from ideal solution (Opricovic and Tzeng, 2004). Many infrastructure projects realized in Australia, New Zealand, Canada, Sweden and US use a common delivery model termed as the 'traditional model', or Design-Bid Build (DBB) (Pakkala, 2002). As from research it has been investigated that there is no close linkage between cost overrun and type of project delivery method (Creedy et al., 2010).Other than cost growth, the entire schedule related metrics of DBB are superior than the DB project delivery method (Hale et al., 2009, Ibbs et al., 2003). In another research it has been cited that Design Build design enactment with comparative to Design Bid Build by analyzing in eight different categories (Hyun et al., 2008). After validation through Pearson and Spearman's rankings correlation tests, it has been found out that the construction speed per lane of DB is speedy than the DBB, while there is no significant cost difference (Shrestha et al., 2011). The American Association of State Highway Transportation Officials AASHTO (2008) proposed to state highway agencies with four-step approach to selecting D-B projects by incorporating allocating risk, planning the evaluation, project goals, and jotting down the contract documents. In recent times, (Zeng et al., 2014) came up with an approach to selection of multiple project-delivery methods for multi project transportation systems entirely based on the fuzzy-theory method and fuzzy-simulation

algorithm. Majority of US highway projects are built by DBB delivery method (Beard et al., 2001). To come up with appropriate project delivery method for highway projects is very hard task to accomplish. Author developed a frame work for risk assessment of highway projects, further elaborating that the traditional DBB is risk averse in contrast to other types of project delivery method (Tran and Molenaar, 2015). (Tran et al., 2013) found out from case study that the design-build is optimal project delivery method for a bridge replacement project. The nature of project determines the appropriate project delivery method, like for bridge construction DB is best and horrible for its maintenance (Park and Kwak, 2017). Most highway infrastructure projects in Australia, Canada and Sweden adopt a common delivery model commonly known as the 'traditional model', or Design-Bid Build (DBB) (Pakkala, 2002).

This shows that the design/engineering services are carried out first, which leads to the procurement contract related to on site construction works based upon the design/engineering portion of the contract. But the main inconsistencies associated with the traditional DBB method are exceeding time constraints, lack if innovation and cost overruns. Because owner is at risk, there is a need to create better practices, that will make sure that owner needs should be met (Pakkala, 2002) . Adding more, the analysis suggests that there is no mutual relationship between the type of project delivery method and cost overrun. Projects that were dispatched by open contract, on contrary to negotiated price, were no less susceptible to significant cost overrun (Creedy et al., 2010). Author finds out the risk factors and cost variation for highway construction projects and identified that the execution speed per lane for design build is much faster as comparative to design bid build (Shrestha et al., 2012)

2.1.1 Design Bid/Build (Traditional Project Delivery method)

Design Bid/Build is customary and the traditional project delivery method. This type of project delivery method consist of three stages as the name suggests, 1) Design, 2) Bid or tender, 3) Build.

2.1.2 Design/Build

Design Build is the type of project delivery method that includes design and execution services provided by same entity known as design builder contractor. Instead of getting two contractors/contracts, in this type of project delivery method we only make agreement with one party. As we know main contractor is the party or the person hired to achieve some task. Design Build contractor can be further classified in two stages namely Architect led Design build and contactor led design build. The major difference between both is that, in the prior one architect is responsible for the change in the construction method, techniques, safety precautions and

necessarily measures while in the later one contractor is responsible for all of these responsibilities.

2.1.3 CMAR

CMAR is the abbreviation of construction management at risk. Construction management at risk is the type of project delivery method in which the possessor decides to incorporate a "construction manager", depending on the cost, nature, quality demands and nature of the project. In CMAR there is a difference comparing to DBB, because in CMAR the design team and construction manager are contractually bound to harmonize with each other, that is not observed during the practice of DBB (Francom et al., 2016) . In CMAR the construction manager who is the employer of the owner will be responsible for the project cost and the schedule of the project (Shane and Gransberg, 2010) . Since there is risk of project cost escalation due to involvement of construction manager. Owner with the coordination of construction manager set a (GMP) guaranteed maximum price. GMP is the set price usually by owner side to transfer the risk to contractor side, by this method the owner set a limit on the maximum price of project that can be escalated which includes the project cost and the fixed price other than the project cost.

2.1.4 Public private partnership:

Public private partnership or 3p is the type of project delivery method in which the two or more public and private parties' joint hands in the long terms to when they share their goals.

2.2 Fuzzy Logic:

Fuzzy logic in the decision logic in which the variable value variates between 0 to 1, 0 means false and 1 mean true. In the real state example, there are many problems that don't have only two option. But they many range any value between two opposite options. Fuzzy logic was under study since 1920 but Zadeh in 1965 presented the fuzzy logic and its explanation.

In contrast with the classical logic of only two possible outcomes, fuzzy logic comes in handy while dealing with the linguistic variable. Linguistic variable is any value between two pole end values. In linguistic term it can be expressed in term of adjective of adverb. For example, "its cold outside" there is no temperature gauge to standard to determine the coldness outside.

There are generally three steps to solve the fuzzy problem i.e.

1. Input all the variable into the membership function, it is known as fuzzification
2. Execute the membership function
3. De-fuzzification i.e. to obtain the crisp value set.

Crisp set is also classical set that has only two possible outputs contrary to fuzzy set. Fuzzy set has many practical applications especially for engineer because they come up with various planning and execution problems that have more than one possible outcome. Fuzzy logic helps them in evaluating those problems. Construction industry is the mixture of different variable factors that effects the outcome, the consequences can be determined by evaluating these factors using Fuzzy logic.

In this thesis we would use Fuzzy TOPSIS to determine the most suitable project delivery method for highway construction.

2.2.1 TOPSIS

TOPSIS is the type of multi criteria decision making technique. TOPSIS is technique for order preference by similarity to ideal situation. Fuzzy TOPSIS works based on positive ideal and negative ideal solution. It works because of normalization, i.e. normally arranging the criteria on the basis of their values to establish a priority list of the different criteria's. TOPSIS works on the basis of tradeoff criteria that means less desired results among any criteria can be compensated by desirable results in another criteria. There are following six stages of Fuzzy TOPSIS.

Step 1

Establishing a matrix to correlate the alternative and criteria. In the first step of Fuzzy TOPSIS, different weightages have been assigned to different criteria to sort them by their priority.

Let A= {A_1, A_2, A_3….A_m}(Zeng et al., 2014) are the different alternatives available and the criteria for selecting these alternatives are Y= {Y_1, Y_2, Y_3…….Y_n}.

Then in the first step of Fuzzy TOPSIS we are the alternatives and criteria for the selection in a matrix such that alternatives on the ordinate and criteria on the abscissa. Next, we assign the values to all alternatives according to their criteria. Let this matrix be denoted by D". Summation of all the values of same criteria is denoted by W".

Step 2:

It is a normalization step, in which we divide the value of matrix by their summation value within a criterion, i.e. W'. In the normalization process dependencies and less effective

information is skimmed by the above-mentioned process. Normalized values are always less than or equal to 1.

Step 3:

In this stage, we must develop a normalized decision matrix to achieve normalized performance value. For further analysis certain amount of weightage must be assigned to each criterion regarding their importance and impact on the selection of alternatives.

Step 4:

Next stage is the multiplication of normalized performance value and the weightage criteria of that criteria. So, by incorporating the weightage of criteria we have achieved weighted normalized decision matrix.

Step 5:

In this step of TOPSIS technique, quintessential best and ideal worst value is determined by considering the criteria and their impact on the alternatives. For example, Cost would have a negative impact in construction project selection mean the lowest cost on lowest normalized performance value would be ideal best for the project. On the other end if we consider quality then we would take maximum value as the ideal best for the project selection. These values are denoted by V_j^+ and V_j^- where former represents quintessential best and later represent the ideal worst value.

Step 6:

So, it's time to find the Euclidean distance of quintessential best and ideal worst value. It works on simple linear distant technique between any two points. Euclidean distance is denoted by $\mathbf{S_j^+}$ and $\mathbf{S_j^-}$, where former denotes the linear distance from that value and its best while donates the least distance between that value and its ideal worst. Following equation helps us to evaluate the best and worst quintessential values regarding questionable alternatives.

$$Sj^+ = \sqrt{\sum_{j=1}^{m} \left(V_{ij} - V_j^+\right)^2}$$

$$Sj^{-} = \sqrt{\sum_{j=1}^{m} \left(V_{ij} - V_j^{-}\right)^2}$$

Step 7:

In this final step performance score calculations are done to assign ranking to the available alternatives according to their importance. Performance score is denoted by $\mathbf{P_i}$, where

$$P_i = \frac{Si^{-}}{Si^{-} + Si^{+}}$$

Highest P_i value would be most suitable alternative for the desired project and lowest one would be least suitable alternative available. So, by this method most suitable project has been investigated.

Fuzzy TOPSIS have two techniques based on the accuracy of the result and these are Triangular Fuzzy TOPSIS and Trapezoidal Fuzzy TOPSIS.

2.2.1.1 Triangular Fuzzy TOPSIS:

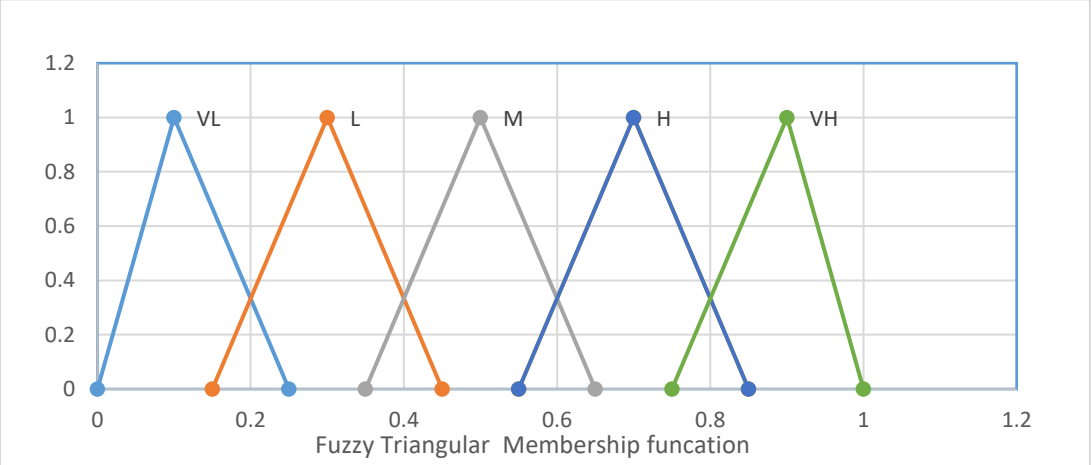
Triangular Fuzzy TOPSIS techniques are almost same as normal Fuzzy TOPSIS except in this technique we incorporate three values as the three-ends of triangle to reach out to most likely outcome of the solution. This technique is used to find out the more precise solution of multi criteria decision problem. This method is more likely to assign to attribute the alternatives instead of assigning the quantitative number. Fuzzy set is denoted by $\tilde{A}$, where,

$$\tilde{A} = \{(x, \mu_{A(x)})\}, \text{ where } \in X$$

$\mu_{A(x)}$ is the membership function, which shows the probability of finding the x within the universal set X. In this type of TOPSIS any attribute assign would have three values i.e. minimum, mode and maximum. The optimum solution would lie somewhere in that range. Following table would elaborate the above story line in more detail.

Rank	***Attribute priority***	***Membership functions***
Very Low (VL)	1	(0.00, 0.10, 0.25)
Low (L)	2	(0.15, 0.30, 0.45)
Medium (M)	3	(0.35, 0.50, 0.65)
High (H)	4	(0.55, 0.70, 0.85)
Very High (VH)	5	(0.75, 0.90, 1.00)

Remaining process would be same for the TOPSIS i.e. To normalized and develop the Euclidian distances from the best ideal and worst ideal solution as per the description provided above.



Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

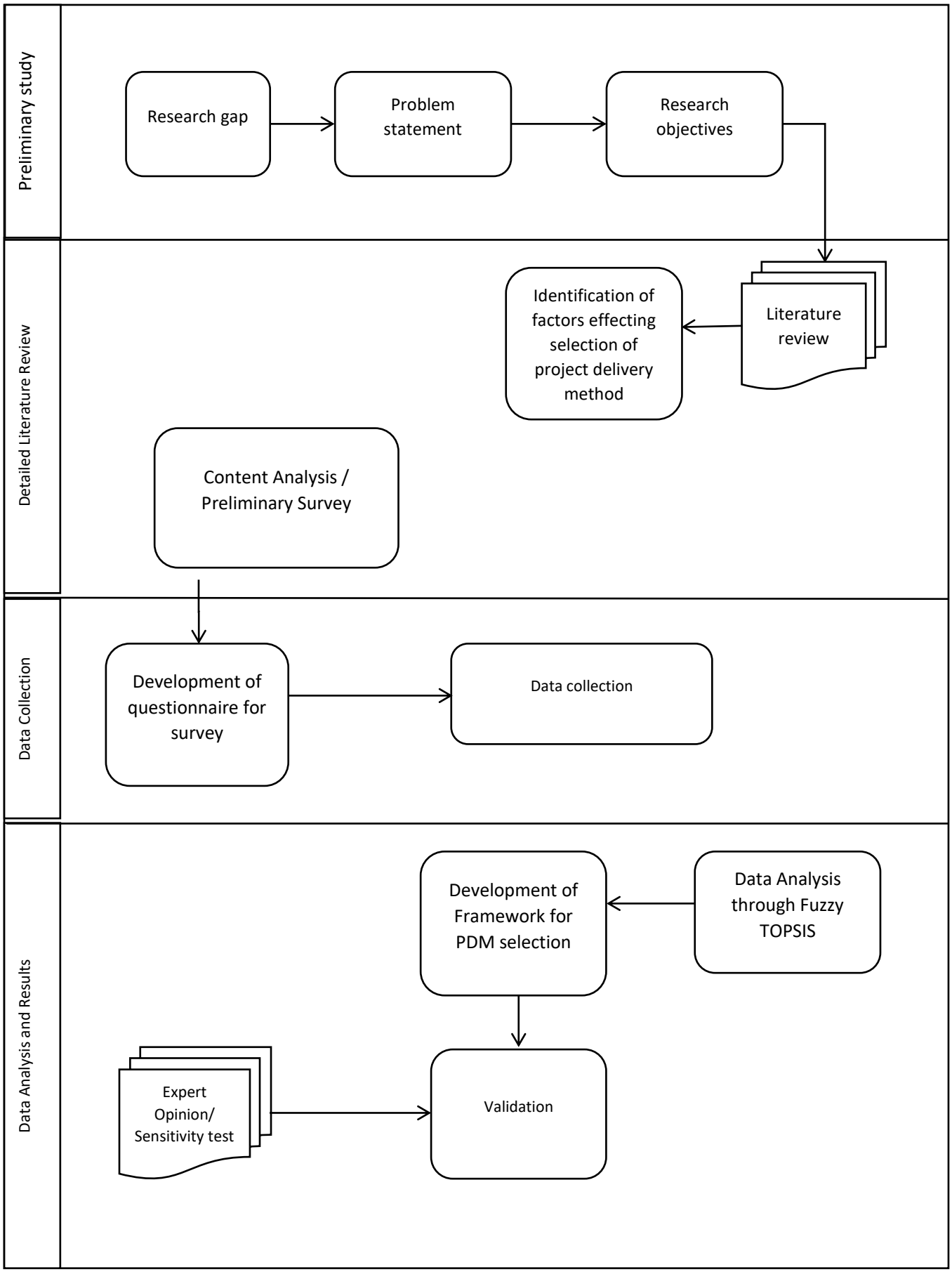
In this chapter we would be briefly explaining the steps and procedure of research process to achieve the targeted objectives. This chapter mainly comprises of research pattern, steps to evaluate the most appropriate project delivery method by using MCDM methodology.

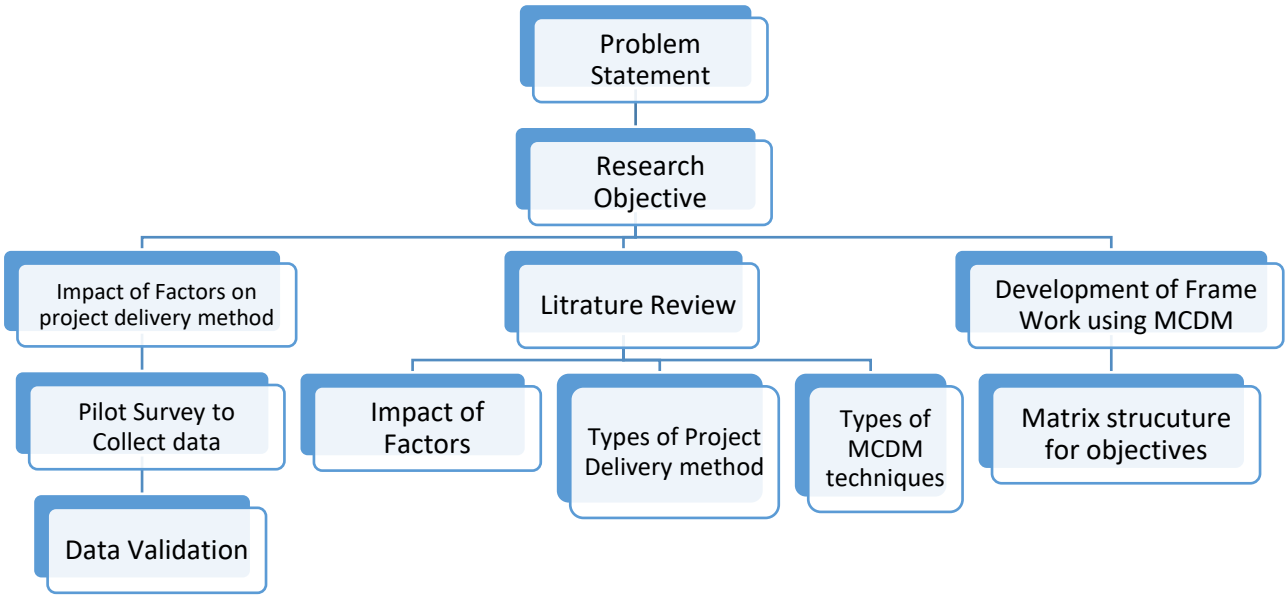
Methodology:

There are following steps:

1. Identifying the problem
2. Targeting the research objectives
3. Literature review
    a. Studying the different types of project delivery method.
    b. Studying the different types of MCDM techniques
    c. Studying of Fuzzy TOPSIS
4. Finding impact of different factors effecting the project delivery method by using Fuzzy TOPSIS technique.
5. Development of framework for that would help the out in choosing the most appropriate project delivery method by using Fuzzy TOPSIS.

The idea is to find out the most reliable project delivery method for highway projects. The data would include only for Pakistan but the same can done to international level to appropriately find out the right Project delivery method. This would help the construction industry by saving the most important resources for project.


Preliminary study
Research gap
Problem statement
Research objectives
Detailed Literature Review
Identification of factors effecting selection of project delivery method
Literature review
Content Analysis / Preliminary Survey
Data Collection
Development of questionnaire for survey
Data collection
Data Analysis and Results
Development of Framework for PDM selection
Data Analysis through Fuzzy TOPSIS
Expert Opinion/ Sensitivity test
Validation



Literature review is the vert initial stage of research phase. The basis objective of literature review to find the research gap and necessity to work on the research gap for the betterment of the construction industry. Different authors have different kind of thinking and their data may variate to various number of conditions.

Sr #	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24
F1	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	
F2		✓		✓		✓		✓				✓	✓	✓							✓	✓		✓
F3											✓	✓										✓		✓
F4	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	
F5	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
F6			✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
F7	✓	✓	✓	✓				✓				✓	✓	✓	✓		✓	✓		✓	✓		✓	
F8			✓	✓		✓	✓	✓		✓		✓	✓					✓		✓		✓		
F9	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓		
F10		✓	✓	✓			✓			✓	✓	✓	✓	✓		✓					✓			
F11	✓			✓			✓		✓		✓	✓			✓	✓					✓	✓		
F12		✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	
F13	✓	✓		✓				✓			✓	✓	✓	✓							✓		✓	✓
F14				✓	✓		✓					✓										✓		
F15			✓																					✓
F16				✓			✓				✓	✓	✓	✓								✓		
F17			✓	✓			✓	✓				✓					✓		✓	✓				✓
F18			✓															✓			✓			✓
F19		✓											✓								✓			
F20		✓	✓					✓															✓	✓
F21		✓		✓			✓		✓	✓	✓	✓	✓	✓							✓			
F22		✓		✓	✓					✓		✓	✓				✓		✓	✓	✓			✓
F23		✓											✓											
F24			✓															✓						
F25	✓						✓										✓				✓			
F26	✓				✓		✓	✓	✓	✓	✓	✓	✓		✓	✓						✓	✓	
F27						✓		✓			✓			✓										
F28	✓			✓	✓		✓	✓		✓		✓	✓	✓	✓			✓	✓					✓
F29													✓						✓					
F30												✓												
F31				✓		✓		✓		✓	✓	✓	✓		✓		✓				✓	✓		✓
F32				✓								✓												
F33						✓	✓				✓	✓									✓		✓	✓
F34							✓																	
F35							✓																✓	
F36							✓								✓								✓	
F37																				✓				
F38																								✓

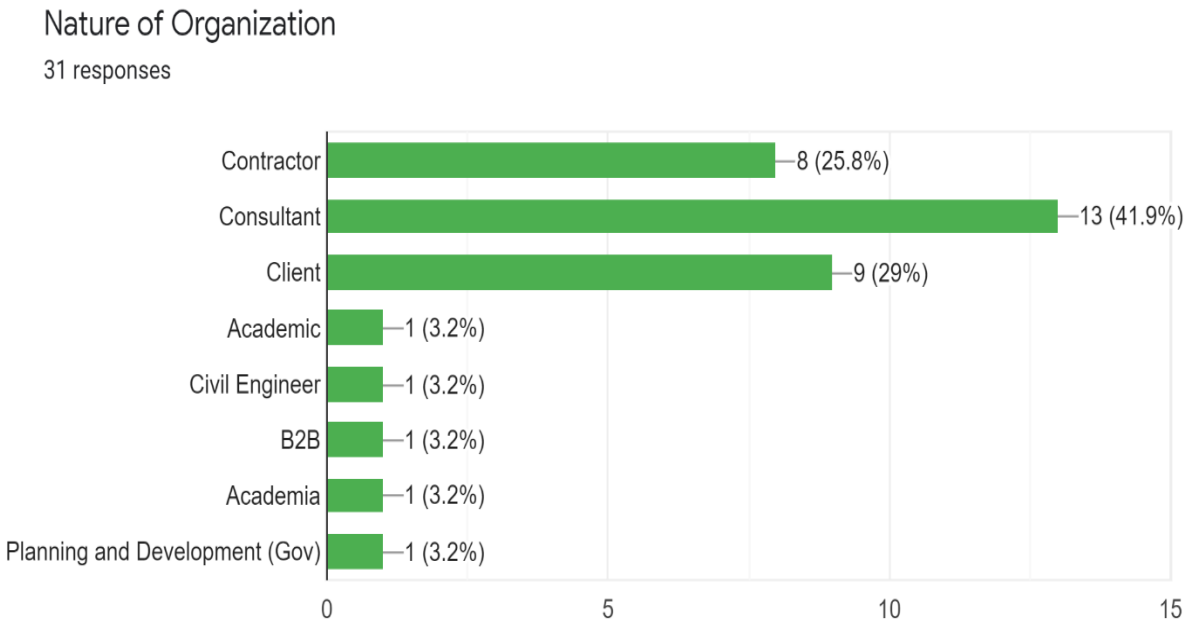
After the literature review, it has been identified the improper selection of project delivery method may cause waste of meaningful resources like cost and time etc., There are various factors that affect the selection of project delivery method for highway projects. Out of 24 research papers 38 factors has been identified to affect the selection of project delivery for highway project.

Following are the factors identified from the research papers, that effect the selection of project delivery method.

F1	Project Cost
F2	Cost Variation Probability
F3	Maintenance cost
F4	Project Schedule and its importance
F5	Complexity and initial risk
F6	Construction and managerial Risk
F7	Scope of Project and its clarity
F8	Ease of Scope Change incorporation
F9	Agency Experience and Character
F10	Experience and capability of contractor
F11	Design Quality
F12	Construction Quality Assurance
F13	Project location and its characteristics
F14	Coordination and Communication Challenges
F15	Agency Approvals and Regulations
F16	Likelihood of Disputes and claims
F17	Value Engineering
F18	Financial Guarantee
F19	Owner Willingness to take risk
F20	External environment and culture
F21	Market competitiveness
F22	Regulatory feasibility
F23	Technology availability
F24	Uniqueness of Project
F25	Owner Satisfaction
F26	Opportunity of Innovation

F27	Protect confidentiality
F28	In-house resources
F29	Political Impact
F30	Public opinion
F31	Owner Involvement and control over design
F32	Contractor input required in design
F33	Contract award process
F34	Agency workload
F35	Project safety
F36	HVAC Solution/ Sustainability
F37	Construction Sequencing
F38	Ease of receiving loan

A preliminary questionnaire was setup based on the above-mentioned factors to consider the respondent score. Initial questionnaire was floated in the construction industry responsible persons of different level in different sectors of construction industry. Following are the classification of the respondents, mostly respondents are from contractor, consultants and client at different positions. 35 responses were collected and 4 were disqualified and remaining responses are used in the content analysis after P and T test. Prior tests are used for the validation of the result.



The TOPSIS method inherits n-dimensional Euclidean distance which shows that it could represent some balance between total and individual satisfaction but uses it in a different way than VIKOR. Fuzzy VIKOR works based on the aggregating the fuzzy merits to reach out to minimum detachment from ideal solution. But, the eminent alternative by TOPSIS is the ideal in terms of the ranking index, which fails to imply that it is always the closest to the consummate solution. TOPIS method doesn't bring into account the relative importance of Euclidian distances.(Opricovic and Tzeng, 2004). While doing the comparative analysis with Fuzzy AHP it can be established that for the large scale multi-attributive problem, in which there are number of alternatives available, Fuzzy AHP would be time taking process because of the pair wise comparison with among the alternatives.

In the large-scale attributor problem in which case hundreds of alternatives are available and many criteria for selection alternatives. In that case pair wise comparison like in AHP is a tiresome job where TOPSIS comes in handy (Junior et al., 2014). In another research it has been found out that adding another alternative changes the ranking other while analyzing through Fuzzy AHP, whereas it remains the same, while analyzing through Fuzzy TOPSIS (Junior et al., 2014). After comparable analysis of Fuzzy TOPSIS with other multi criteria decision making techniques, Fuzzy TOPSIS is found affirmative in different criteria. A dam site selection case study cite TOPSIS as more reliable method because the results for the best site were of already constructed dams, on the other hand top 4 best sites for dam construction from AHP were not of the already constructed dams.(Jozaghi et al., 2018). TOPSIS has an advantage over other techniques because it does not work with subjectivities, but with the facts. The same can be said about PROMETHEE and ELECTRE, even they use subjectivity, the decision-making conclusions are based on facts or in mathematical procedures, as for instance PROMETHEE is a nonparametric outranking method for a finite set of alternatives (Bland and Altman, 1997) AHP and TOPSIS can be recognize as value measurement method. (Pires et al., 2011) . Fuzzy TOPSIS is handy while dealing with uncertainty problems and allow the provision for the development of well-structured framework but in parallel to this technique AHP is quite well-established to be applied for this purpose, because it can be applied for multiple problems while incorporating both qualitative and quantitative criteria(Pires et al., 2011). In comparison to VIKOR method it has been cited that the VIKOR method uses linear normalization, and the TOPSIS method uses vector normalization. The TOPSIS method brings about two ‘‘reference’’ points (+ & -), but it does not foresee the relative importance of the distances from these points (Opricovic and Tzeng, 2004). According to study, TOPSIS and COPRAS are opted as the best MCDM techniques for ranking the alternative materials in general practice. They concluded that

this TOPSIS needs minimal mathematical effort in contrast to comprehensive VIKOR (Jahan et al., 2011). (Sun et al., 2010) explains that TOPSIS is the perfect method in comparison of MCDM techniques in an aircraft selection problem. (Peng, 2015) showed that TOPSIS is the most suitable technique for earthquake vulnerability selection problem. TOPSIS can be attributive as it can be run without assigning weights to different criteria. Suppose that you must select a restaurant for dinner between three named A, B and C that you know well, and subject to two criteria: Quality and Price. You compare them and decide that Quality is more important than Price. Then you say: Between A and B, I choose restaurant A over B, because the first has a greater quality in food that B but is more expensive. That is, you sacrifice Price by a gain in quality (that is, you prefer to pay more in A, but gets better quality than in B). This is your trade-off, and it is fine. Now, you compare A with C, where the latter is a little cheaper than A, but its quality is slightly lower. Then you decide for C, that is you CHANGED your initial trade-off, and this is also OK. However, in AHP we select a trade-off from the very beginning and then we consider that it is constant for everything, and then we apply it to all the provided alternatives. Actual data for site selection of already constructed dams were used for comparative analysis by TOPSIS and AHP. Results showed the TOPSIS provide the best results because the alternative provided by TOPSIS are of already constructed dams, while already constructed dams were not in AHP top 4 four alternatives. From result it has been found out that TOPSIS is most appropriate for dam site selection, conclusion was drawn on the basis that, the alternatives come from TOPSIS for site selection has already been selected.(Jozaghi et al., 2018). Nonlinear relationship and distant ratios make it consider both positive and negative values, making it more reliable as this methodology is followed in Fuzzy TOPSIS. But, TOPSIS in its standard and original form is implicit and does not take account of uncertainty in the calculations related to final weightings. (Mousavi-Nasab and Sotoudeh-Anvari, 2017).(Jozaghi et al., 2018). (Mousavi-Nasab and Sotoudeh-Anvari, 2017).

TOPSIS strength and weakness:

Strengths:

1: It accepts input as any number of criteria and attributes.

2: Intuitive physical meaning based on consideration of distances from ideal solutions.

Weaknesses:

1: TOPSIS can give unrealistic results.

2: TOPSIS in its paradigm form is implicit and does not tackle uncertainty in weightings.(Gavade, 2014) .

The selection of most appropriate project delivery method for highway projects is very hard task to accomplish. Author developed a frame work for risk assessment of highway projects and after the analysis of results he was able to establish that traditional DBB is risk averse in comparison to other types of project delivery method (Tran and Molenaar, 2015) .

For example, some delivery methods including design-bid-build (DBB) are undoubtedly appropriate for low to medium management-related risk (e.g. miscommunication and poor coordination), and they become unreliable for high-risk conditions. Opposingly the design-build (DB) method can be catered in situations of high management-related risk (Al Nahyan et al., 2018). Other authors have contemplated the unit of analysis as interviews or diaries in their entity, and the amount of space allocated to a topic or an interaction under study(Downe-Wamboldt, 1992).

3.3 Preliminary Questionnaire:

A questionnaire is established to set up the preliminary survey. The survey is used to find the impact of 39 factors on the selection of project delivery method for selection of highway project delivery method. The survey is based on Likert scale that is based on 5-point scale, ranging from 1 to 5. Where 1 is equal to never, 2 is equal to rarely, 3 means sometimes, 4 is equal to often and 5 is depicting always.

3.3.1 Premilitary Survey:

A survey was conducted to sort out the most relevant factors through content analysis. 50 questioners have been floated and 31 responses were collected from construction related engineers. Out of those 90% responses are from the persons having 0 to 5 years of experience and 10% are having 5 to 10 year of experience. Sorting out in the way of nature of work, 26% respondents are from contractor side, 42% are consultant representatives, 29% are client representatives and remaining 3% are from other fields.

After collecting the results from google survey, analyzing through content analysis, I can reach out to most relevant 12 factors out of total 31 factors. Results are validated through ANOVA and T-test.

3.3.2 ANOVA test:

ANOVA test is used to reject the null hypothesis. The Null hypothesis is required to be rejected, that shows that there is significant difference between the group of two or more sets. The result can be used to select the data type acquired by Preto Rule. As the test show that there is no significant

difference between 40/60, 50/50 and 60/40 ratios so we can use any one of them. After consultation with the expert of academia 50/50 was used for the analysis.

3.3.3 Relative Importance Index (RII):

Relative importance index is used to the relatively importance of different factors contributing. MS Excel is used to find the RII of the contributing factors. This method works on the basis of respondents score and its importance.

$RII = \sum W / N*A$

Where,

W= Summation of different weight of like for 5-point Likert scale

$W=5*n1+4*n2+3*n3+2*n4+1*n5$

N= Total number of respondents

A= Maximum value of Likert scale

Values achieve from RII is used to rank the importance of different factors acquired from the respondents. But our result will not just be based on the respondent score, we also have to incorporate the academic score. To find out the most relevant factors contributing for the selection of project delivery method we have to move forward for combination mythology.

3.4 Content Analysis:

First of all, we have to normalized the respondent score. The normalization method is used to bring all the value on table that makes them easy for comparison. Normalization means the division of each value by the summation of total values of the all the group values. The summation of normalized value in a group is always equal to 1. The same method will be repeated for the literature score. The literature score that we have collected from 31 research papers is required to be normalized by the same method as mentioned prior. Now we are in position where we can make different kind of combinations to merge the literature and respondent scores. As the literature and experts of academia we have to set up 7 kinds of combination including 80/20, 70/30, 60/40, 50/50, 40/60, 30/70, 20/80. Where the prior value shows the weightage of literature score and later value show the weightage of respondent score for all the 38 factors achieved through literature review. Different combination of literature and respondent score are studied to sort out the most relevant factors impacting the selection of project delivery method. After analyzing the three combinations 40/60, 50/50, 60/40 as per advice of the professionals in the field of academia we are able to reach out the most relevant 12 factors with the cumulative score of 51.8% as per 50/50 rule. The final factors selected for data collection are as under.

These are the factors that are collected through the content analysis. The next step is to developing the final questionnaire and implement the results acquired in TOPSIS methodology.

1	Project Schedule and its importance
2	Complexity and initial risk
3	Project Cost
4	Construction Quality Assurance
5	Agency Experience and Character
6	Construction and managerial Risk
7	Scope of Project and its clarity
8	Owner Involvement and control over design
9	Design Quality
10	Cost Variation Probability
11	Experience and capability of contractor
12	In-house resources

These are the factors that are collected through the content analysis. The next step is to developing the final questionnaire and implement the results acquired in TOPSIS methodology.

3.5 Final Questionnaire:

The next step is to develop the final questionnaire based on the factors collected from content analysis on the preliminary questionnaire. The final questionnaire is setup on the google survey form using the multiple check box option. The questionnaire is so designed that the respondent will select the impact of above mentioned 12 factors on the 4 types of project delivery method. These methods are DB, DBB, CMAR and BOT. Respondent will input their opinions based on 5-point Likert scale. The values of Likert scale are 1 to 5, where 1 is equal to very low, 2 is equal to low, 3 is equal to average, 4 is equal to high and 5 is equal to very high. This questionnaire is floated among the experience's persons of the field. The data collected is formulated in the form of triangular TOPSIS table. Experts responded in the term of 5-point Likert Scale and these values are converted in the term of triangular TOPSIS value. Here is the link of the final questionnaire.

https://docs.google.com/forms/d/e/1FAIpQLSfeiCKHaTh9x07XvXwXO70-mdXHboneRXXRf2AZ9ApRAcR6qQ/viewform?vc=0&c=0&w=1

Chapter 4

RESULTS, ANALYSIS AND DISCUSSION

4.1 Introduction:

To choose the most appropriate project delivery method for selection of highway project delivery method, we have to develop the questionnaire from shortlisted factors, developed from content analysis by merging the respondent and literature score, the former was obtained from 31 respondents and later was compiled from 24 research papers. Respondents score was combination score from the user of different domain i.e. contractor, consultant and client. TOPSIS is the type of Multicriteria decision making technique. TOPSIS works on the basis on solution from positive ideal and negative ideal solutions.

4.2 Developing the Final questionnaire.

Final questionnaire is set up based on the content analysis after merging the literature and respondent score. The different combination of literature and respondent scores were developed, 50/50 ratio is used after consultation with the experts of academia. Cumulative score is used to sort out the most relevant factors. Above 50% score is used to sort out the most relevant factors. Out of 38 factors

4.2.1 Classification of respondent:

78 questionnaire has been floated in different users from different parts of construction industry and out of them 24 responses are collected. 3 of the responses are rejected due to untrustworthy data and final results are obtained on 21 responses. Respondent are from different backgrounds of construction field, i.e. contractor, consultant and client. As it can be seen from below circular chart that 47.6% respondents are from client, 28.6% are from consultant side while 19% are from contractor side and remaining are other fields. As the selection of project delivery method is very much related to type of owner/client. So, the results obtained are very much relevant to the topic of thesis. Various respondents from different working environment at various positions in different organizations participated in this project. As this topic is project based and related to execution team and most of the respondents are project Engineer comprising of 38% of the total respondents, while 14.3% are Planning engineers and Assistant Managers. Remaining respondent are from academic background or other sectors of execution sector of construction industry.

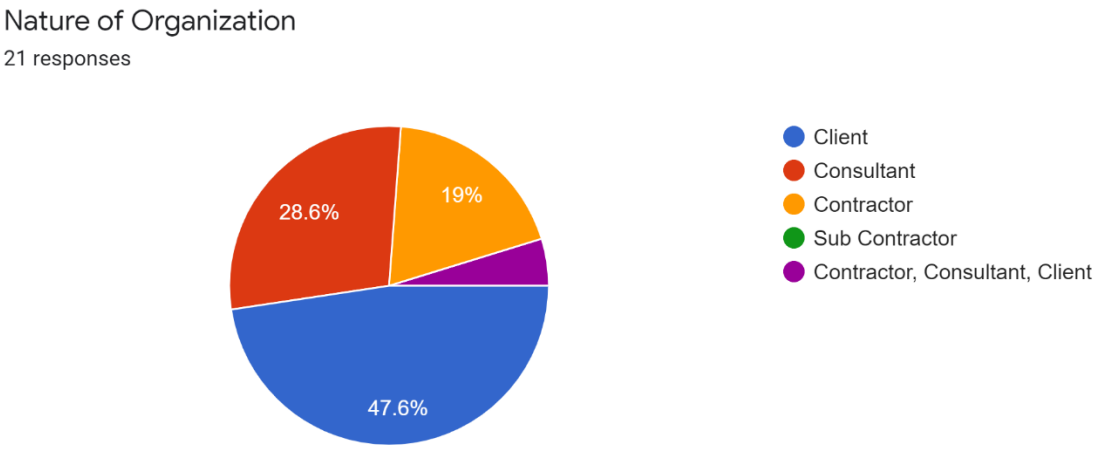


Figure 1 Distribution of the respondents construction industry sector

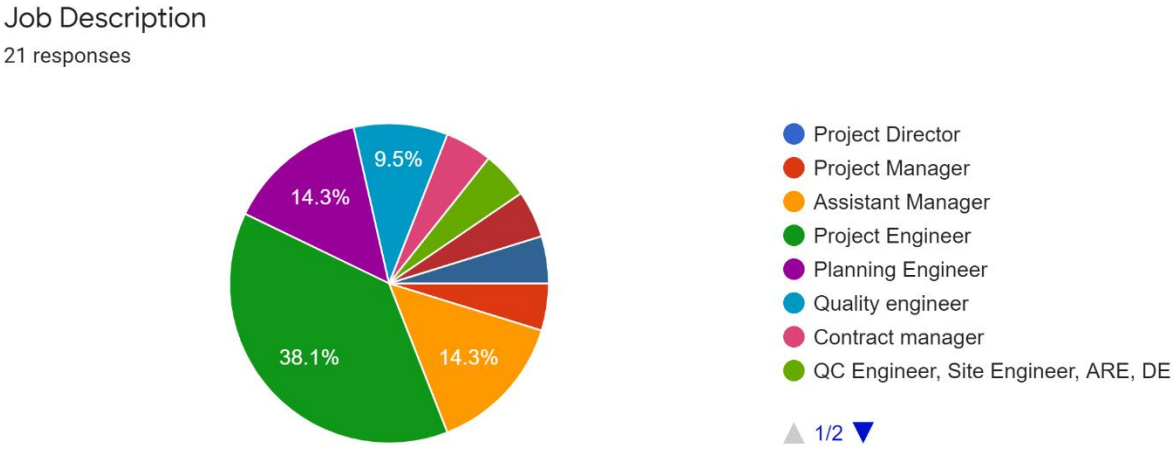


Figure 2 Respondent Nature of Work

User responded on the basis of 5-point Likert scale i.e. 1 to 5. Where 1 is very low, 2 is low, 3 is medium, 4 is high and 5 is very high.

Fuzzy TOPSIS works on the basis of intrinsic values and most two type of intrinsic value are used for the interpretation of data set, one is triangular method and the other is trapezoidal method. Prior has 3 end values while the latter ha 4 end values. In our calculations we have used triangular fuzzy TOPSIS, where values are equal to following in values.

Rank	Attribute priority	Membership functions
Very Low (VL)	**1**	**(0.00, 0.10, 0.25)**
Low (L)	**2**	**(0.15, 0.30, 0.45)**
Medium (M)	**3**	**(0.35, 0.50, 0.65)**
High (H)	**4**	**(0.55, 0.70, 0.85)**
Very High (VH)	**5**	**(0.75, 0.90, 1.00)**

Step 1:

At the very start of the analysis, we have to collect the score from respondent using google questionnaire, that is based on the 5-point Likert scale. After downloading the excel file from the google survey, we have to interpret the user responses using triangular Fuzzy TOPSIS. Then we have to find the cumulative score of all the respondents. The formula for prior is here.

Min (i), Average (j), Max (k)

The above formula is used to summarize the 21 respondents above mentioned from different background. Then we have to sort out the data received from the excel file. The sorting out is done by arranging the data of 4 different types of project delivery method of the same contributing factor for the purpose of result analysis. That will help out to sort out the data for the next step.

Step 2:

After sorting out the data as mentioned in the above-mentioned step, then we can move to next step and that is assigning weightages to each criterion effecting the selection of project delivery method. The weightage is will help out after the 4^{th} step of the analysis. Weightages are established from the content analysis i.e. the weightages are identified from the merging the literature and respondent score as mentioned in the methodology of content analysis. Following are the weightages of 12 most relevant factors.

Weightages	Factors
0.1145	Project Schedule and its Importance
0.1115	Project Complexity and Initial Risk
0.1097	Project Cost
0.0859	Project Construction Quality Assurance
0.0856	Owner Experience and Attribute
0.0839	Construction and Managerial Risk
0.0758	Scope of Project and its Clarity
0.0723	Owner Involvement and Control Over Design
0.0684	Design Quality
0.0653	Cost Variation Probability
0.0643	Experience and Capability of Contractor
0.0627	Client In-house Resources

Step 3:

After assigning weightages to all the contributing factors, we have to sort out the factors in two different types of impact. The two types of criteria are benefit and cost. The benefit factors are those, that create positive impact on the results like construction quality assurance. Better quality is beneficial for the project. The other type of cost factors is those, that create the negative impact on the results. Like the project complexity, it creates the negative impact on the project. Following are the sorting out the factors.

Cost	Project Schedule and its Importance
Cost	Project Complexity and Initial Risk
Cost	Project Cost
Benefit	Project Construction Quality Assurance
Benefit	Owner Experience and Attribute
Cost	Construction and Managerial Risk
Cost	Scope of Project and its Clarity
Benefit	Owner Involvement and Control Over Design
Benefit	Design Quality
Cost	Cost Variation Probability
Benefit	Experience and Capability of Contractor
Benefit	Client In-house Resources

Step 4:

Next stage is the normalization of the data. The methodology is different for the benefit and cost criteria.

$\overline{r_{ij}} = \left(\frac{a_{ij}}{cj^*}, \frac{b_{ij}}{cj^*}, \frac{c_{ij}}{cj^*}\right)$ and $Cj^* = max_i \{c_{ij}\}$ (benefit)

$\overline{r_{ij}} = \left(\frac{\bar{a}_j}{cj^*}, \frac{\bar{b}_j}{cj^*}, \frac{\bar{c}_j}{cj^*}\right)$ and $\bar{a}_j = min_i \{a_{ij}\}$ (Cost)

The above-mentioned equation is used to for the normalization of the results obtained from respondent score. The normalization process is different for the both benefit and cost sort of factors.

After Normalization the values we are able to do the further analysis. But there is still one thing remaining and that is assigning weightages.

Step 5:

After normalization the results shows that all the contributing factors have the same kind of impact on the result and that is not the case. As we have seen that in the content analysis that impact of all the factors are not the same on the subject topic. The impact may change due to various number of reasons. So, we have prioritized the factors on the basis of their impact by merging the literature and respondent score. The scores gave us the weightages of each factor on the total result. Those factors are used here for study. In this step we assign weightages to each of the normalized score for all the 12 factors and 4 types of project delivery methods. Now all the values are less than because of the multiplication of weightages to the values.

Step 6:

TOPSIS is the abbreviation of the technique for order of preference by similarity to ideal solution. So, it is very much clear from the name that it works on the basis of Euclidian distance from positive and negative ideal solution. In this step we sort out the most the positive and negative ideal solutions. In other words, we sort out the maximum and minimum values for each sort of contributing factor. Now we have to positive and negative ideal solution for each of the contributing factors, but that was not the purpose. The purpose of the this MCDM technique is to prioritize the most suitable kind of project delivery method. So, to serve the purpose we have to find out the distances of each criteria from the above obtained positive and negative ideal solutions.

Step 7:

Euclidian distances of each factor from positive and negative ideal solution is used to sort the most influencing project delivery method delivery method. The method is used to prioritize the most relevant project delivery method for the high way project delivery method. The distance for minimum, average and maximum value is used to find the distances from positive and negative ideal solutions. The process is done by square root method.

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}\left[(a_{1-}\, a_2),\ (b_{1-}\, b_2),\ (c_{1-}\, c_2)\right]}$$

Below is the depiction of the results from the above-mentioned equation. A* shows the positive values and A$^-$ shows the negative values of the alternatives from positive and negative ideal solutions.

D (A*) DBB	D (A-) DBB
D (A*) DB	D (A-) DB
D (A*) CMAR	D (A-) CMAR
D (A*) BOT	D (A-) BOT

Step 8:

The next step is to find the closeness coefficient Ci. The prior is used to find the distance from positive to negative ideal solution. To achieve the desired objectives, we have to summarize the positive and negative values.

$$d_i^* = \sum_{i=1}^{n} d(V_i^*)$$

$$d_j^- = \sum_{j=1}^{n} d(V_j^-)$$

The next step is to find the closeness coefficient of the values with the formula mentioned below.

$$CC_i = \frac{d_i^*}{(d_i^- + d_i^*)}$$

The maximum of CCi shows the most influencing factor relevant to topic of project. By analyzing the data received from the respondent the analysis shows that Design-Bid-Build is the most relevant factor for the selection of project delivery method of Highway projects.

By analyzing the data from the respondent, the Design-Build is found to be most suitable project delivery method for highway projects.

Closness Coefficeint	Cci DBB	0.492559	
	Cci DB	0.586273	
	Cci CMAR	0.406896	
	Cci BOT	0.465644	
Final Ranking of PDM	Cci DB	0.586273	1st
	Cci DBB	0.492559	2nd
	Cci BOT	0.465644	3rd
	Cci CMAR	0.406896	4th

Figure 3 Final Results

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction:

This is multicriteria decision making technique that was incorporated in this methodology for the selection of most relevant project delivery method of Highway projects. By analyzing the results obtained from respondents Design-Bid-Build is found to be most relevant factor for the selection of project delivery method for highway projects.

Until now we are able to find out Design-Bid-Build is the most influencing factor for the highway projects in Pakistan. Now it's time to hit the last objective of this research i.e. to develop a framework for the selection of Highway project delivery method.

Framework is way-out of achieving the thesis objective. There are various stages of this research and first one in to choose the domain/sector of construction industry for the choosing the selection of project delivery method. As already described that our topic is relevant to choosing the most appropriate project delivery method for the highway projects. From that point onwards the frameworks divided into two phases one is the selection of technique for solving multicriteria decision making technique and other is the choosing the types of project delivery method. As already discussed, out of various MCDM techniques, Fuzzy TOPSIS has been selected for the selection of project delivery method. Literature review has been done from 24 research papers for the literature score, out of these 38 contributing factors are sorted out for the selection of project delivery method for the highway projects. Then a questionnaire has been developed based on these 38 factors for the respondent score. After collecting the respondent score content analysis has been done on the basis of 50/50 combination of literature and respondent score. Cumulative weightages and RII of the factors were used to sort out the 12 most relevant factors effecting the selection of project delivery method. After the content analysis final questionnaire has been established and floated in the market for the expert's suggestion and after collecting the responses Fuzzy TOPSIS methodology has been applied to find out the most relevant project delivery method for the highway projects.

5.2 Development of Framework:

5.2.1 Problem statement:

Project delivery method is selected on very earlier basis and would affect the time, cost and quality of project. The 4 type of project delivery method incorporated in this research have their separate pros and cons. For example, while choosing DB method the same party is responsible for the designing and execution of the project and client are just for the sake of financial control. Prior method has advantage while selection for the fast projects, where the time resources and very much limited, similarly other project delivery method can be used for different situations, depending on the resources available and nature of project.

Frame Work:

1: Selection of factors effecting selection of project delivery method

2: Content Analysis

3: Validation of Results

4: Implementation of TOPSIS

5: Prioritization of project delivery methods

Framework:

1: Defining the types of project delivery methods.

2: Selection of decision criteria (38 factors)
(From past experience, literature review, expert opinion, regulations, client objectives)

3: Filtering the most relevant decision criteria (12 Factors)
(Content Analysis)

4: Finding the weightage of each decision criteria. (weightages after 50/50 rule)

The second part of framework is the MCDM technique used for the analysis. As already described with strong reasons Fuzzy TOPSIS is chosen for the selection of Highway project delivery method. Following is the breakdown of the technique used.

1: Define the Fuzzy type (Triangular and real number equation)

2: Define scale of preference and membership function (Define the linguistic value of triangular fuzzy TOPSIS)

3: Assigning fuzzy value to the decision criteria (from respondent score)

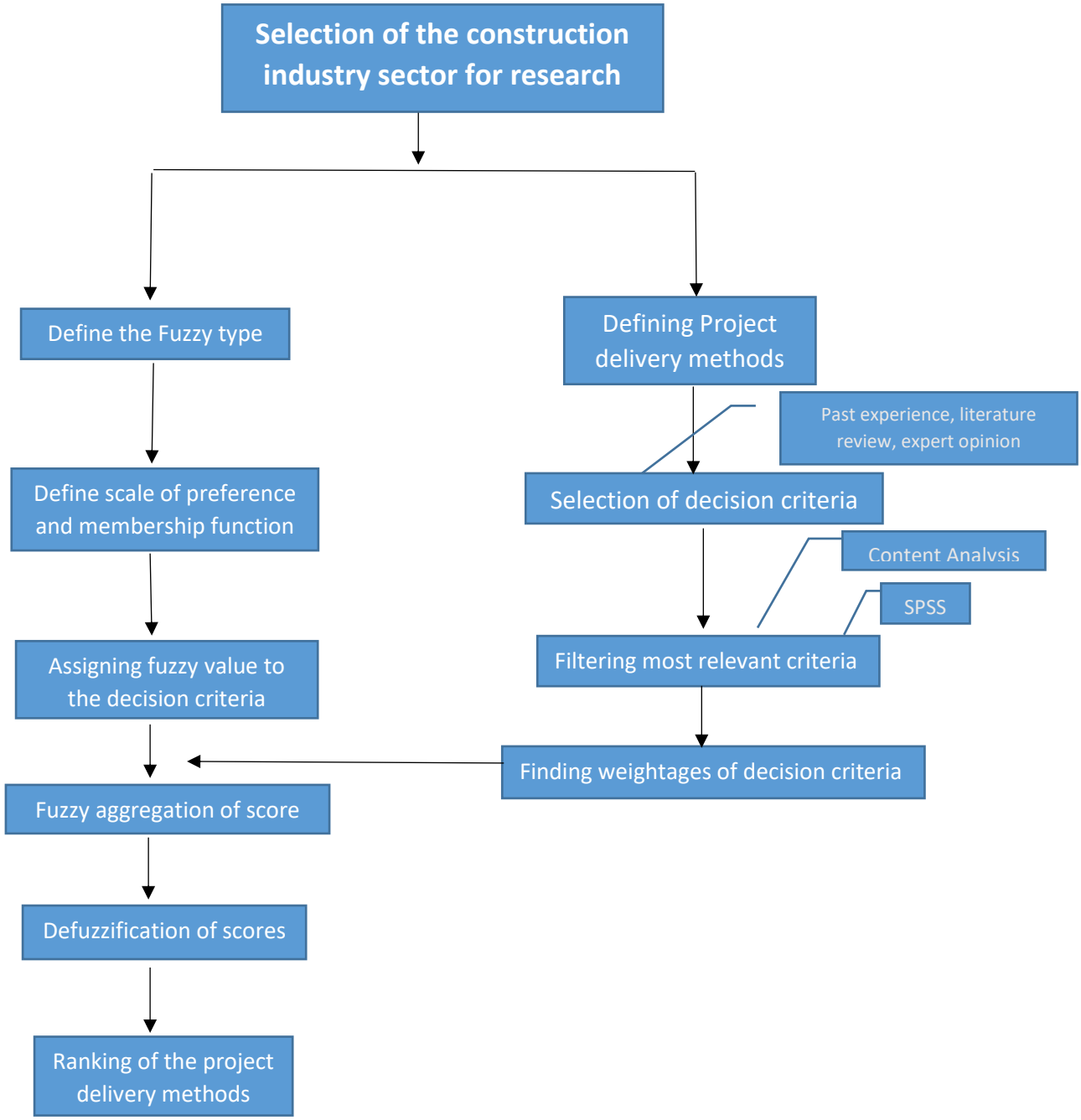
4: Fuzzy aggregation of score (assigning weightages and triangular summation formula)

5: defuzzification of scores (CPI + -, distances from + and -ve ideal solutions)

6: Ranking of the project delivery methods.

5.3 Recommendations and future direction:

It is recommended to use the framework developed above the data of the regions across the border to develop the statistical data for the future development of trade routes between different countries and Pakistan. As we already know China Pakistan Economic Collider work is in progress and by achieving the data mentioned above, we can save the resources provide.



Framework for the selection of Highway Project Delivery method.

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Project Delivery Method for Highway Projects

It has already been known that the construction industry is facing different kind of challenges and while dealing with large scale infrastructure development, it becomes a challenge to keep the cost and schedule on track. Selection of project delivery method is one of the reasons that can variate the said objectives. Best project delivery method would be that completes with in time and low cost, matching targeted schedules and fulfilling the design requirements while ensuring the quality standards.

The objective of this research is to find out the most appropriate Project Delivery method for Highway Projects. Four types of project delivery method are considered for this research including Design Bid Build, Design Build, Construction Management At Risk and Build Operate & Transfer. Questionnaire is designed to find the impact of contributing factors on each type of project delivery method. Your sincere support in completing this questionnaire is highly appreciated. Please feel free to add any comments / suggestions at the end or contact the below mentioned details in case of any clarification.

Regards

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Email ID: zeeshan.ul.hassan41@gmail.com

1: *Email address* * _____

2: Experience

4 to 7 years
8 to 10 years
11 to 15 years
16 to 20 years
21 and above

3: Nature of Organization

Other:
Client
Consultant
Contractor
Sub-Contractor

4: Job Description

Project Director
Project Manager
Assistant Manager
Project Engineer
Planning Engineer

Impact of Factors on 4 types of Project Delivery Method.

D-B-B: Design-Bid-Build
D-B: Design-Build
CMAR: Construction Management at Risk
BOT: Build Operate and transfer

Project Schedule and its Importance *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Project Complexity and Initial Risk *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Project Cost *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Project Construction Quality Assurance *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Owner Experience and Attribute *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Construction and Managerial Risk *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Scope of Project and its Clarity *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Owner Involvement and Control Over Design *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Design Quality *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Cost Variation Probability *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Experience and Capability of Contractor *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Client In-house Resources *

Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
DBB	◯	◯	◯	◯	◯
DB	◯	◯	◯	◯	◯
CMAR	◯	◯	◯	◯	◯
BOT	◯	◯	◯	◯	◯

Comments If any * _____