CHAPTER – 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The current status of the infrastructure projects has been studied in this research work. This thesis attempts to contribute towards developing some methods and tools which will eventually be useful to the owners and /or contractors for timely completion of construction projects at a reasonable cost and of a specified quality. For this purpose it first attempts to critically review the literature to identify and describe generally accepted construction management knowledge. To identify the principle causes of delay and to know the perceptions of three main participants; owner, consultant and contractor to the factors causing delay field survey has been conducted by postal questionnaire and personal interviews.

A further postal survey is done to identify the CSF’s for BOT projects. A transparent procedure for ranking the BOT promoters for prequalification and a decision support system is developed using multi attribute decision theory and the AHP. Research processes included a wide range of survey of published literature in diverse areas of construction management- risk associated with major infrastructure projects, causes of delay, critical success factors, lessons from worldwide BOT practices, selection of a suitable contractor and best value selection models.

Two hundred and twenty organizations where contacted out of which 90 responded. Postal survey was also made to identify the critical success factors for the construction projects. The research also included the identification of financial strategies that the government should deal with for BOT mechanism to work smoothly. Finally a procedure was developed for selecting and ranking BOT promoters during prequalification using
AHP. The study developed a decision support system to provide best value to the public procurer based on a multi objective decision making methodology.

In this chapter, the methodology of the research undertaken is discussed to achieve the objectives of this thesis.

### 3.2 DATA COLLECTION THROUGH FIELD SURVEY

Field Survey is done to study the prevalent environment that entails the sphere of uncertainty in the execution of various phases of a construction project. This survey is done to have first hand information, essential to be aware of the problems encountered in the construction projects. The objective of doing a field survey in this study is to validate the findings of the literature review.

Postal surveys were conducted to find the extent and the factors causing time over runs in construction projects including BOT projects. The analysis of survey is done by Relative Importance Index (RII) method.

For the survey a questionnaire was prepared in three parts. The first part contains six important questions that are relevant in forming the opinion on the degree of time overruns in various organizations. The second part of the questionnaire is based on the possible factors causing time-overruns for traditional projects where as the third part contains the questionnaire based on possible factors causing time overruns for BOT projects. Both second and third questionnaire consists of 47 factors each which were identified from the literature survey. These factors are grouped into five different categories: i) project related; ii) owner related; iii) contractor related; iv) consultant related; and v) external factors.
The questionnaire was sent to the owners, contractors and consultants who are actively associated with the construction activities and possessing sufficient experience in the field of construction.

The respondents were asked to give their opinion regarding the extent of time-overrun in part one. In part two the respondents were asked to assess the effect of each factor on the time-overrun of the project separately for traditional and BOT projects, on a scale of 1 to 5 depending upon its effect, 5 being the most important and 1 the least.

Two hundred and twenty organizations were contacted out of which ninety responded. Many of the respondents are leading construction, consultancy and government organizations. Only experts holding senior positions in the organizations were approached for answering the questionnaire. This was done to preserve the quality of the opinions gathered in the survey. The experts were made to understand that their responses should not be biased towards any particular project whether it was highly successful or highly disastrous.

Throughout the questionnaires, the concept of importance is interpreted in a generic way and is comparable to preference, dominance, and similar relationships. To ensure consistency throughout by the respondents, the definition of the factors had been provided in the questionnaire. The questionnaires were designed in a manner that will help in the preservation of integrity and consistency in the data. To secure good quality data, a brief presentation with regard to the object and methodology of the study was made to every respondent individually. The respondents were specifically reminded of the importance of observing consistency in their answers when point wise comparison was made. They were made to understand that their responses should not be biased toward any particular project.
whether it was highly successful or highly disastrous. The questionnaires and the complete list of respondents for the field surveys are given in Appendix 1, 2, 3 and 4 respectively.

The data received in the second questionnaire was analyzed by Relative Importance Index (RII) method to determine the relative importance of i) the factors causing time overruns of the projects; and ii) critical success factors for BOT projects, identified by the literature survey. Some questions intended to capture background information of the respondents.

\[
RII = \frac{\text{Sum of weights} (W1 + W2 + W3 + \ldots + Wn)}{A \times N}
\]

where \( W \) = weights given to each factor by the respondents and will ranges from 1 to 5 where ‘1’ is less significant and ‘5’ is extremely significant. \( A \) = highest weight (i.e. 5 in this case), and \( N \) = total number of respondents.

The Analytical Hierarchy Process (AHP) method has been adopted in this study to identify Critical Success Factors (CSFs) for projects, presenting a hierarchical model. A hierarchical model for project success was taken based on a typical project environment in which the success-related factors were grouped into different level of hierarchies. In the third questionnaire, questions raised invited the respondents to consider the relative importance of a pair of success-related factors for BOT projects, based on the nine-point scale summarized in Table 3.1. In each section, the respondents were asked to begin by comparing factors at the bottom level of the sub-hierarchy. This bottom-to-top approach was made to assist the respondents to apprehend the collective significance of lower level factors as they proceed upward in the construction project success hierarchy.

### 3.2.1 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a decision-aiding method developed by Saaty [86]. It aims at quantifying relative priorities for a given set of alternatives on a ratio
scale, based on the judgment of the decision maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of the alternatives in the decision-making process. Decision-makers base judgments on knowledge and experience, and then make decisions accordingly. The AHP approach agrees well with the behavior of a decision-maker. In the present work, AHP was used to rank the critical success factors from the data obtained through field survey and to rank the bidders/applicants during pre-qualification process in BOT projects. The following steps were applied by the author to analyze the data:

1. Define the problem and determine its goal.

2. Structure the hierarchy from the top (the objectives from a decision-maker’s viewpoint) through the intermediate levels (criteria on which subsequent level depend) to the lowest level which usually contains the list of alternatives.

3. Construct a set of pair-wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 3.1. The pair-wise comparison are done in terms of which element dominates the other.

4. There are n (n-1) judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.

5. Hierarchical synthesis is then used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

6. Having made all the pair-wise comparisons, the consistency is determined by using the eigen value, $\lambda_{\text{max}}$, to calculate the consistency index, CI as follows: $\text{CI} = (\lambda_{\text{max}} - n) / (n-1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) as CI/RI, taking the appropriate value of CI from Table 3.2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

7. Steps 3-6 are performed for all levels in the hierarchy.
Table 3.1: Pair-wise comparison scale for AHP preferences

<table>
<thead>
<tr>
<th>Level of Importance</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
</tr>
<tr>
<td>3</td>
<td>Weak importance of one over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
</tr>
<tr>
<td>9</td>
<td>Absolute Importance</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between adjacent scale values</td>
</tr>
</tbody>
</table>

Table 3.2: Average random consistency (RI)

<table>
<thead>
<tr>
<th>Size of matrix</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random consistency</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.9</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
</tr>
</tbody>
</table>

3.2.2 Agreement Analysis

The ranking of critical success factors for BOT projects is calculated independently, based on the responses to the two questionnaires developed specifically for the purpose, by two different methods, Relative Importance Index method and Analytical Hierarchy Process.

In view of the difference in the ranking of CSFs identified, it is imperative to measure the agreement in the ranking of these factors analyzed by the two different methods. A quantitative method for rank agreement analysis is used. In this method, the “rank agreement factor” (RAF) is used. The RAF shows the average absolute difference in the ranking of the factors between two groups.

For any two groups, let the rank of the ith item in group 1 be $R_{i1}$ and in group 2 be $R_{i2}$, $N$ be the number of items, and $j=N−i+1$. 
The RAF is defined as,

\[
\text{RAF} = \frac{\sum_{i=1}^{N} |R_{i1} - R_{i2}|}{N}
\]

The maximum rank agreement factor (RAFmax) is defined as

\[
\text{RAF}_{\text{max}} = \frac{\sum_{i=1}^{N} |R_{i1} - R_{j2}|}{N}
\]

The percentage disagreement (PD) is defined as

\[
\text{PD} = \frac{\sum_{i=1}^{N} |R_{i1} - R_{i2}|}{\sum_{i=1}^{N} |R_{i1} - R_{j2}|} \times 100.
\]

The percentage agreement (PA) is defined as

\[
\text{PA} = 100 - \text{PD}
\]

3.2.3 Decision Support System

A decision support system was built over the MS Excel. This software implements the Fuzzy composite programming methodology through the relative weighing scheme elaborated upon previously. The software can handle multiple projects simultaneously and independently.

3.2.4 Sensitivity Analysis

The sensitivity analysis for ranking of bidders/applicants during prequalification process is built over MS Excel platform. This software implements the composite programming methodology through the relative weighing scheme. The software is validated with the help of a suitable example.

3.3 CONCLUSION

The methodology mainly used for achieving the different objectives of the thesis is discussed in this chapter. For the identification of the critical success factors the analytical hierarchical model is used as the main method. For the identification of causes
of delay and CSF relative importance index (RII) method is used. To validate the results agreement analysis has been made for identification of CSF’s.