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Application of Analytical Hierarchy Process to Analyse Delay in Commercial Construction Project in Nashik City

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Abstract: The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematical analysis. It has copious applications in group decision making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry and education. The main feature of AHP is its inherent capability of systematically dealing with a vast number of intangible and non-quantifiable attributes, as well as with tangible and subjective factors. To simplify the critical situations by analyzing the parameters affecting the selection, the 'Analytic Hierarchy Process' is utilized.
Keywords: Analytic Hierarchy Process (AHP), Causes of delay, Consistency Index (CI)

I. INTRODUCTION

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematical analysis. It is a multi-attribute decision making tool developed by Thomas L. Saaty in the 1970s. It has particular applications in group decision making& prioritization and is used around the world in a wide variety of decision situations, in fields such as government, business, industry and education. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way.

A. Objectives

1) To study the fundamentals of Analytical Hierarchy Process and its application.
2) To study and identify the various factors causes delay in construction.
3) Develop an AHP model for evaluation of factors causes delay in construction projects.
4) Suggest and recommending the factors for improvement.

II. METHODOLOGY

A. AHP Process

Saaty proposed the following steps for applying the AHP [15]

a) Define the problem and determine its goal.
b) Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criterion on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.
c) Construct a set of pairwise 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 comparisons are done in terms of which element dominates the other.
d) There are **n(n-1)/2** judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pairwise comparison.
e) Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criterion and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
f) Having made all the pairwise comparisons, the consistency is determined by using the Eigen value, E, to calculate the Consistency Index, CI as follows:

$$CI= (E - n)/(n - 1)$$

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Where n is the matrix size.
Judgment consistency can be checked by taking the Consistency Ratio (CR) of CI with the appropriate value in 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.

g) Steps 3 to 6 are performed for all levels in the hierarchy.

1) Command Area

Table 2.1 Relative Measurement Scale

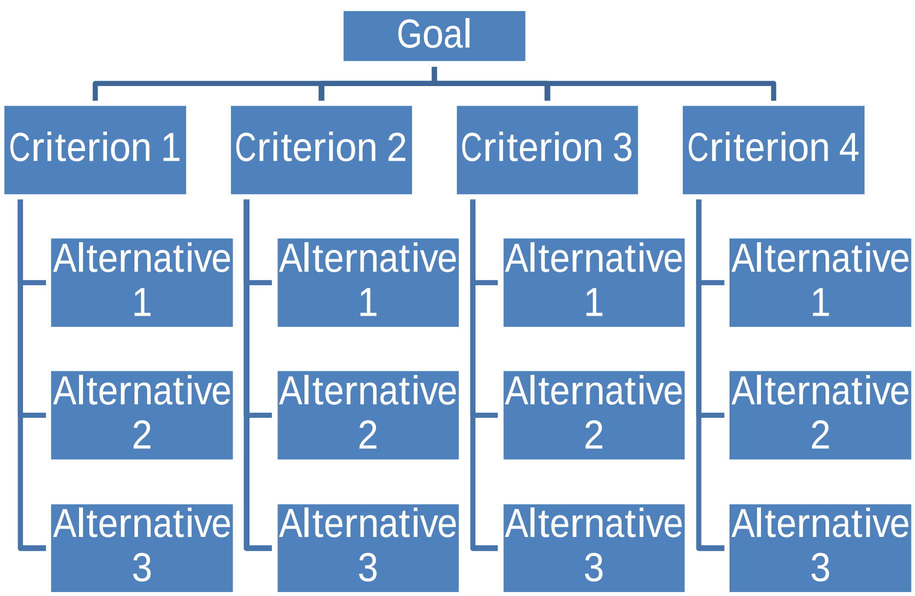
Acceptance Level	Judgements	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Marginally strong	Experience and judgments slightly favour one activity over another
5	Strong	Experience and judgments strongly favour one activity over another
7	Very strong	An activity is strongly favoured and its dominance is demonstrated in practice
9	Extremely strong	The evidence favouring one activity over another is of the highest possible order of affirmation

Table 2.2 Average Random Consistency

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.59	0.9	1.12	1.24	1.32	1.41	1.45	1.49

2) Modelling Hierarchy

The first step in the analytic hierarchy process is to model the problem as a hierarchy. In performing this, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires.



III. DATA COLLECTION

The most crucial objective of this work is to identify the factors causes the delay in construction in Indian context and to rank them using Analytical Hierarchy Process tool of ranking and evaluation. With the help of previous literature work done on causes of delay, improvement at different places around the globe, interviews and interaction with construction practitioners and academicians, hereby twenty seven 27 factors influencing delay in construction are proposed. Further, with the help of AHP tool and the structured questionnaire survey of experienced 30 Project Managers working at Mega sites in Nasik City.

A. *Planning for Questionnaire Survey*

The prime objective of questionnaire survey is the data collection and to get the opinions by asking structured set of questions to the top construction practitioners and project managers and also the labour workforce of most trending residential mega projects in Nashik City which is one of the fastest developing cities in India. Also the city has started its progress towards being promoted into a 'Smart City'. From recent five years, construction of number of mega housing projects within the city has been observed to be commenced with a great boom. People in Nashik have started to prefer the mini city residential projects where they can get a secure, peaceful, cheerful and modern standard of living with numerous amenities to support living.

So, with this change in construction sector in Nashik, many factors are causing delay for respective work. To minimize the delay we done questionnaire survey among 27 factors which causes delay in construction projects by making pairwise comparison. The respondents were permitted to response the questionnaire at their personal ease. They were given proper instructions and guidelines regarding the process of pairwise comparison made in Analytical Hierarchy Process. The list of respondents is given below which consists of 30 projects from which the responses from first 20 respondents are considered.

Table 3.1 Respondents for Questionnaire Survey

	Project	Construction Firm	Location
A	The Viridian Valleys	Suyojit Buildcon	Chandsi, Nashik
B	The Metrozone	Sanklecha Const.	Pathardi, Nashik
C	Aaryawarta	Paranjpe Constructions	Cidco, Nashik
D	Ekta Greenville	Ekta Group	Pathardi, Nashik
E	Parksyde Homes	Jaikumar Real Estate	Near KKWCOE
F	Nature's Pride	Bagad Properties	Chandsi, Nashik
G	Nature's Bliss	Bagad Properties	Chandsi, Nashik
H	Ashok Royale	Ashok Realty	Ashoka Marg
I	Samraat Tropicano	Samraat Group	Gangapur Road
J	Ashok Astoria	Peninsula Land Limited	Gangapur Gaon,
K	Samraat Nucleas	Samraat Group	Bhabha Nagar
L	Amit's Eka	Amit Enterprises	Pathardi, Nashik
M	The Imperial	Suyash Developer	Chandsi, Nashik
N	Karmaa Galaxy	Karmaa Builders	Tapovan, Nashik
O	Karda's Hari OM II	Karda Constructions	Pathardi, Nashik
P	Shree Tirumala Riviera	Roongta Group	Navshya Ganpati
Q	Samraat Gokuldham	Samraat Group	Hirawadi, Nashik
R	Samraat Symphony I	Samraat Group	Pathardi, Nashik
S	Malpani Saffron	Malpani Group	Pathardi, Nashik
T	Samraat Symphony II	Samraat Group	Pathardi, Nashik

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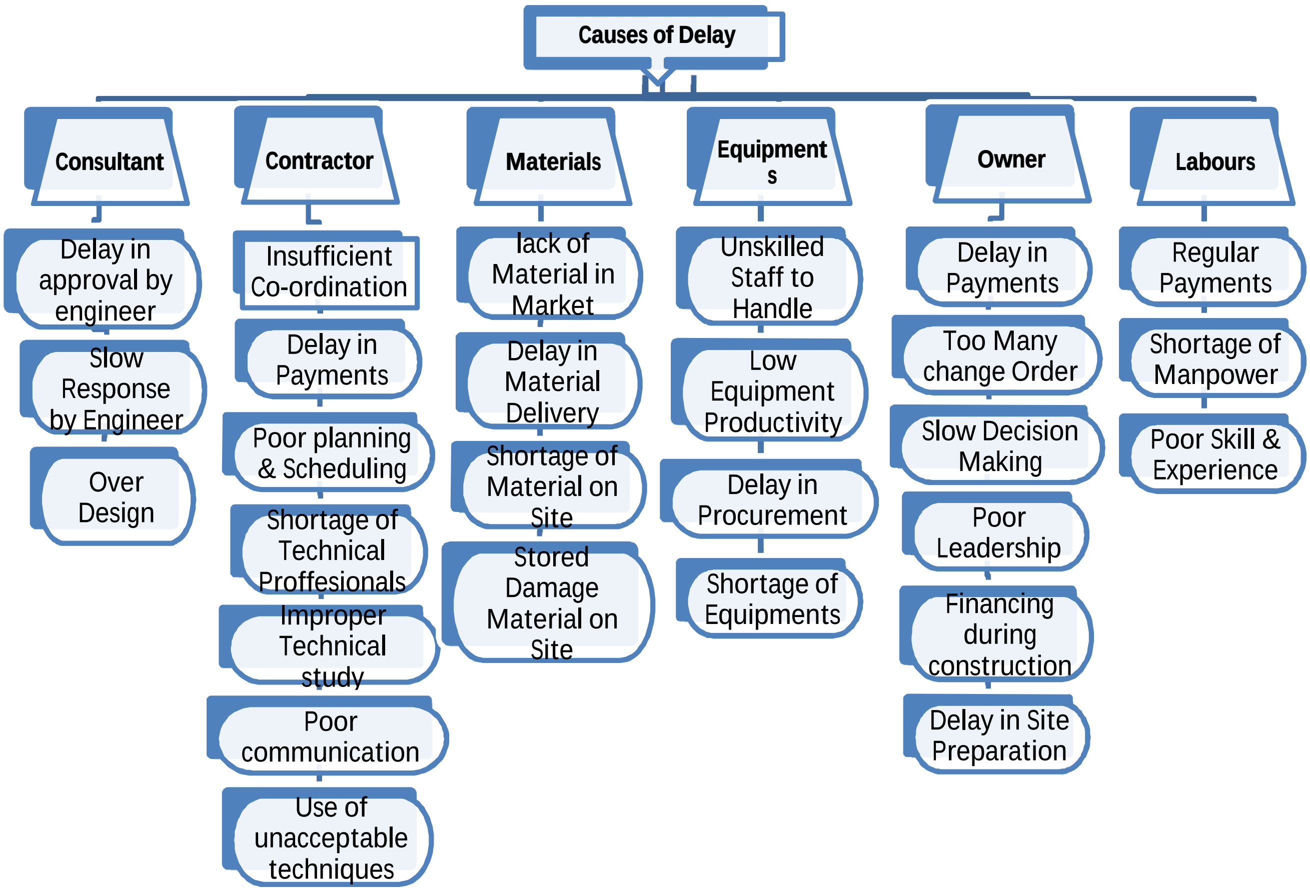
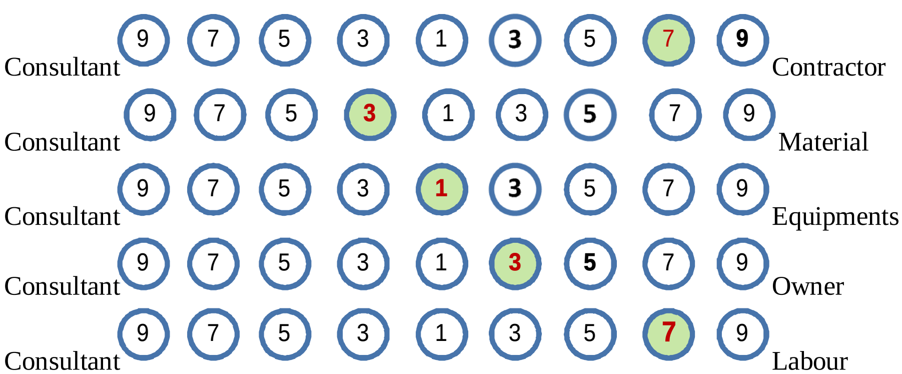
Causes of delay



B. Average Pairwise Comparison obtained from Questionnaire Survey

1) Level I Comparison(20 Respondents)



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Contractor	9	7	5	**3**	1	3	5	7	9	Material
Contractor	9	7	5	3	**1**	3	5	7	9	Equipments
Contractor	9	7	**5**	3	1	3	5	7	9	Owner
Contractor	9	7	5	3	1	**3**	5	7	9	Labour
Material	9	7	**5**	3	1	3	5	7	9	Equipments
Material	9	7	5	**3**	1	3	5	7	9	Owner
Material	9	7	5	3	1	3	**5**	7	9	Labour
Equipments	9	7	5	3	1	3	5	**7**	9	Owner
Equipments	9	7	5	3	1	3	5	7	**9**	Labour
Owner	9	7	5	3	1	3	**5**	7	9	Labour

2) Level II Comparison

Under Consultant

Delay in Approval by Engineer	9	**7**	5	3	1	3	5	7	9	Slow Response by Engineer
Delay in Approval by Engineer	9	7	5	3	1	3	**5**	7	9	Over Design
Slow Response by Engineer	9	7	5	3	1	3	**5**	7	9	Over Design

Under Contractor

Insufficient Co-ordination	9	**7**	5	3	1	3	5	7	9	Delay in Payments
Insufficient Co-ordination	9	7	5	3	**1**	3	5	7	9	Poor Planning & Scheduling
Insufficient Co-ordination	9	7	5	**3**	1	3	5	7	9	Shortage of Technical Professional
Insufficient Co-ordination	9	**7**	5	3	1	3	5	7	9	Inproper Technical Study
Insufficient Co-ordination	9	7	**5**	3	1	3	5	7	9	Poor Communication
Insufficient Co-ordination	9	**7**	5	3	1	3	5	7	9	Use Of Unacceptable Techniques
Delay in Payments	9	7	5	3	1	**3**	5	7	9	Poor Planning & Scheduling
Delay in Payments	9	7	5	**3**	1	3	5	7	9	Shortage of Technical Professional

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Delay in Payments	9	**7**	5	3	1	3	5	7	9	Inproper Technical Study
Delay in Payments	9	7	5	**3**	1	3	5	7	9	Poor Communicati
Delay in Payments	9	**7**	5	3	1	3	5	7	9	Use Of Unacceptable Technique
Poor Planning & Scheduling	9	**7**	5	3	1	3	5	7	9	Shortage of technical professional
Poor Planning & Scheduling	9	7	**5**	3	1	3	5	7	9	Inproper Technical Study
Poor Planning & Scheduling	9	7	5	3	1	3	**5**	7	9	Poor Communication
Poor Planning & Scheduling	9	7	**5**	3	1	3	5	7	9	Use Of Unacceptable Techniques
Shortage of Technical Professional	9	7	**5**	3	1	3	5	7	9	Inproper Technical Study
Shortage of Technical Professional	9	7	5	3	1	3	**5**	7	9	Poor Communication
Shortage of Technical Professional	9	7	**5**	3	1	3	5	7	9	Use Of Unacceptable Techniques
Inproper Technical Study	9	7	5	3	1	3	5	**7**	9	Poor Communication
Inproper Technical Study	9	7	5	**3**	1	3	5	7	9	Use Of Unacceptable Techniques
Poor Communication	9	**7**	5	3	1	3	5	7	9	Use Of Unacceptable Techniques

Under Materials

Lack of Material	9	7	5	3	1	3	**5**	7	9	Delay in Delivery
Lack of Material	9	7	5	3	1	3	**5**	7	9	Shortage of Site Material
Lack of Material	9	7	5	**3**	1	3	5	7	9	Stored Damage Material
Delay in Delivery	9	7	5	3	**1**	3	5	7	9	Shortage of Site Material
Delay in Delivery	9	7	**5**	3	1	3	5	7	9	Stored Damage Material
Shortage of Site Material	9	7	**5**	3	1	3	5	7	9	Stored Damage Material

Under Equipments

Unskilled Staff	9	7	5	3	**1**	3	5	7	9	Low Productivity
Unskilled Staff	9	7	5	**3**	1	3	5	7	9	Delay in Procurement
Unskilled Staff	9	7	5	3	1	3	5	**7**	9	Shortage of Equipments
Low Productivity	9	7	5	**3**	1	3	5	7	9	Delay in Procurement

Low Productivity	9	7	5	3	1	3	**5**	7	9	Shortage of Equipments
Delay in Procurement	9	7	5	3	1	3	5	**7**	9	Shortage of Equipments

Under Owner

Delay In Payments	9	7	5	3	1	**3**	5	7	9	Too many change Order
Delay In Payments	9	7	**5**	3	1	3	5	7	9	Slow Decision Making
Delay In Payments	9	7	**5**	3	1	3	5	7	9	Poor Leadership
Delay In Payments	9	7	5	**3**	1	3	5	7	9	Financing During Construction
Delay In Payments	9	7	5	**3**	1	3	5	7	9	Delay in Site Preparation
Too many change Order	9	**7**	5	3	1	3	5	7	9	Slow Decision making
Too many change Order	9	7	**5**	3	1	3	5	7	9	Poor Leadership
Too many change Order	9	7	5	**3**	1	3	5	7	9	Financing During Construction
Too many change Order	9	7	5	3	1	**3**	5	7	9	Delay in Site Preparation
Slow Decision Making	9	7	5	3	**1**	3	5	7	9	Poor Leadership
Slow Decision Making	9	7	5	3	1	**3**	5	7	9	Financing During Construction
Slow Decision Making	9	7	5	3	1	3	**5**	7	9	Delay in Site Preparation
Poor Leadership	9	7	5	3	1	3	**5**	7	9	Financing During Construction
Poor Leadership	9	7	5	3	1	**3**	5	7	9	Delay in Site Preparation
Financing During Construction	9	7	5	3	1	**3**	5	7	9	Delay in Site Preparation

Under Labour

Regular Payments	9	7	5	3	1	3	**5**	7	9	Shortage of Manpower
Regular Payments	9	7	**5**	3	1	3	5	7	9	Poor Skill & Experiance
Shortage of Manpower	9	**7**	5	3	1	3	5	7	9	Poor Skill & Experiance

C. AHP Model for Factor Causes Delay

1) Level I

A: Consultant
B: Contractor
C: Materials

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D: Equipments
E: Owner
F: Labours

Pairwise comparison matrix for Level I

Level I	A	B	C	D	E	F
A	1	7	1/3	1	3	7
B	7	1	1/3	1	1/5	3
C	3	3	1	1/5	1/3	5
D	1	1	5	1	7	9
E	1/3	5	3	1/7	1	5
F	1/7	1/3	1/5	9	1/5	1
Total	12.47	17.33	9.87	12.34	11.73	30

Synthesized matrix for Level I

Level I	A	B	C	D	E	F	Eigen Vector
A	0.0803	0.4039	0.0337	0.0810	0.2557	0.2333	0.1413
B	0.5613	0.0577	0.0337	0.0810	0.0170	0.1000	0.1813
C	0.2405	0.1731	0.1013	0.0162	0.0284	0.1666	0.1610
D	0.803	0.0577	0.5065	0.0810	0.5967	0.3000	0.1429
E	0.0267	0.2885	0.3039	0.0115	0.0852	0.1600	0.1559
F	0.0114	0.1920	0.2022	0.7293	0.0170	0.1000	0.2116

Weighted sum matrix

$$0.1413\begin{bmatrix}1\\7\\3\\1\\1/3\\1/7\end{bmatrix} +0.1813\begin{bmatrix}7\\1\\3\\1\\5\\1/3\end{bmatrix} +0.1610\begin{bmatrix}1/3\\1/3\\1\\5\\3\\1/3\end{bmatrix} +0.1429\begin{bmatrix}1\\1\\1/5\\1\\1/7\\9\end{bmatrix}$$

$$+0.1559\begin{bmatrix}3\\1/5\\1/3\\7\\1\\1/7\end{bmatrix} +0.2116\begin{bmatrix}7\\3\\5\\9\\5\\1\end{bmatrix} = \begin{bmatrix}1.5558\\0.0329\\2.2205\\0.2662\\2.6709\\1.6416\end{bmatrix}$$

$$\text{Eigen Value} = \frac{\frac{1.5558}{0.1413}+\frac{0.0329}{0.1813}+\frac{2.2205}{0.1610}+\frac{0.2662}{0.1429}+\frac{2.6709}{0.1559}+\frac{1.6416}{0.2116}}{6}$$

Eigen Value = 6.32

Consistency Index = $\frac{E - n}{n-1} = \frac{6.32-6}{6-1} = 0.064$

Random Index = 1.24

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}}$ = 0.051

= 0.051< 0.1..................... Hence the judgements are acceptable

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Level II

1) Under Consultant

A: Delay in Approval by Engineer

B: Slow Response by Engineer Regarding Testing

C: Over Design

Pairwise comparison matrix for competency

Consultant	A	B	C
A	1	1/5	5
B	5	1	5
C	1/5	1/5	1
Total	6..2	1.4	11

Synthesized matrix for competency

Consultant	A	B	C	Eigen Vector
A	0.1219	0.1066	0.8064	0.3132
B	0.8536	0.7426	0.8064	0.1393
C	0.0243	0.1492	0.1612	0.1115

Weighted sum matrix

$$0.3132\begin{bmatrix}1\\7\\1/7\end{bmatrix} + 0.1393\begin{bmatrix}1/7\\1\\1/5\end{bmatrix} + 0.1115\begin{bmatrix}5\\5\\1\end{bmatrix} = \begin{bmatrix}1.0145\\3.7726\\0.3199\end{bmatrix}$$

$$\text{Eigen Value} = \frac{\frac{1.0145}{0.3132} + \frac{3.7726}{0.1393} + \frac{0.1115}{0.1115}}{3}$$

Eigen Value = 3.0331

$$\text{Consistency Index} = \frac{E - n}{n-1} = \frac{3.0331-3}{3-1} = 0.0165$$

Random Index = 0.58

$$\text{Consistency Ratio} = \frac{\text{Consistency Index}}{\text{Random Index}} = 0.0165$$

= 0.0165< 0.1.................... Hence the judgements are acceptable

2) Under Contractor

A: Insufficient Co-ordination

B: Delay in Payments to Sub Contractor

C: Poor Planning & Scheduling of Work

D: Shortage of Technical Professionals

E: Improper Technical Study

F: Poor Communication with Suppliers

G: Use of Unacceptable Techniques

Pairwise comparison matrix for Contractor

Contractor	A	B	C	D	E	F	G
A	1	1/7	1	1/3	1/7	1/5	1/7
B	7	1	3	1/3	1/7	1/3	1/7
C	1	1/3	1	1/7	1/5	5	1/5
D	3	3	7	1	1/5	5	1/5

E	7	7	5	5	1	7	1/3
F	5	3	1/5	1/5	1/7	1	1/7
G	7	7	5	5	3	7	1
Total	31	21.47	22.2	12.09	4.62	25.53	1.96

Synthesized matrix for Contractor

Contractor	A	B	C	D	E	F	G	Eigen Vector
A	0.0322	0.0066	0.0450	0.0275	0.0309	0.0078	0.0728	0.3676
B	0.2258	0.0465	0.1357	0.0275	0.0309	0.0130	0.0728	0.0788
C	0.0322	0.0155	0.0450	0.0118	0.0432	0.1958	0.1020	0.2304
D	0.0967	0.1397	0.3153	0.0827	0.0432	0.1958	0.1020	0.1788
E	0.2258	0.3260	0.2252	0.0135	0.2164	0.2795	0.1700	0.0165
F	0.1612	0.1397	0.0090	0.0165	0.0309	0.0391	0.0728	0.0800
G	0.2258	0.3260	0.2252	0.4135	0.6493	0.2745	0.5702	0.0327

Weighted sum matrix

$$0.3676\begin{bmatrix}1\\7\\1\\3\\7\\5\\7\end{bmatrix}+0.3036\begin{bmatrix}1/7\\1\\1/3\\3\\7\\3\\7\end{bmatrix}+0.2304\begin{bmatrix}1\\3\\1\\7\\5\\1/5\\5\end{bmatrix}+0.1788\begin{bmatrix}1/3\\1/3\\1/7\\1\\5\\1/5\\5\end{bmatrix}$$

$$+0.0165\begin{bmatrix}1/7\\1/7\\1/5\\1/5\\1\\1/7\\3\end{bmatrix}+0.080\begin{bmatrix}1/5\\1/3\\5\\5\\7\\1\\7\end{bmatrix}+0.0327\begin{bmatrix}1/7\\1/7\\1/5\\1/5\\1/3\\1/7\\1\end{bmatrix}=\begin{bmatrix}0.4776\\0.3661\\1.1345\\0.2225\\1.3318\\0.9176\\1.3860\end{bmatrix}$$

Eigen Value

$$=\frac{\frac{0.4776}{0.3676}+\frac{0.3661}{0.3036}+\frac{1.1345}{0.2304}+\frac{0.2225}{0.1788}+\frac{0.3318}{0.0165}+\frac{0.9176}{0.1080}+\frac{0.386}{0.0327}}{7}$$

Eigen Value = 7.7415

Consistency Index = $\frac{E-n}{n-1} = \frac{7.7415-7}{7-1} = 0.1235$

Random Index = 1.32

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}} = 0.093$

= 0.093< 0.1..................... Hence the judgements are acceptable

3) Under Material

A: Lack of Material in Market

B: Delay in Material Delivery

C: Shortage of Material Onsite
D: Stored Damaged Material Onsite

Pairwise comparison matrix for Material

Material	A	B	C	D
A	1	5	5	1/3
B	1/5	1	1	1/5
C	1/5	1	1	1/5
D	3	5	7	1
Total	4.4	12	14	1.73

Synthesized matrix for Material

Material	A	B	C	D	Eigen Vector
A	0.2272	0.4166	0.4166	0.3526	0.0328
B	0.0454	0.0833	0.0833	0.1156	0.2755
C	0.0454	0.0833	0.0833	0.1156	0.3188
D	0.6818	0.4166	0.4166	0.5780	0.0329

Weighted sum matrix

$$0.0328\begin{bmatrix}1\\1/5\\1/5\\3\end{bmatrix}+0.2755\begin{bmatrix}5\\1\\1\\5\end{bmatrix}+0.3188\begin{bmatrix}5\\1\\1\\7\end{bmatrix}+0.1788\begin{bmatrix}1/3\\1/5\\1/5\\1\end{bmatrix}=\begin{bmatrix}1.3015\\0.6074\\0.6337\\1.3740\end{bmatrix}$$

Eigen Value

$$= \frac{\frac{0.0328}{1.3015}+\frac{0.2755}{0.6074}+\frac{0.3188}{0.6337}+\frac{0.0329}{1.3740}}{4}$$

Eigen Value = 4.1530

Consistency Index = $\frac{E - n}{n-1} = \frac{4.1530-4}{4-1}$ = 0.0510

Random Index = 0.9

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}}$ = 0.063

= 0.063< 0.1.................... Hence the judgements are acceptable

4) Under Equipments
A: Unskilled Staff to Handle Equipments
B: Low Productivity by Equipments
C: Delay in Procurement
D: Shortage of Equipments
Pairwise comparison matrix for Equipments

Equipments	A	B	C	D
A	1	1	1/3	7
B	1	1	1/3	5
C	3	3	1	7
D	1/7	1/5	1/7	1
Total	5.14	5.2	1.80	20

Synthesized matrix for Equipments

Equipments	A	B	C	D	Eigen Vector
A	0.1945	0.1923	0.1851	0.3500	0.0786
B	0.1945	0.1923	0.1851	0.2500	0.0681
C	0.5836	0.5769	0.5555	0.3500	0.0670
D	0.0377	0.0384	0.0793	0.0500	0.3571

Weighted sum matrix

$$0.0786\begin{bmatrix}1\\1\\3\\1/7\end{bmatrix}+0.0681\begin{bmatrix}1\\1\\3\\1/5\end{bmatrix}+0.0670\begin{bmatrix}1/3\\1/3\\1\\1/7\end{bmatrix}+0.3571\begin{bmatrix}7\\5\\7\\1\end{bmatrix}=\begin{bmatrix}2.6687\\0.5261\\0.3006\\0.3915\end{bmatrix}$$

Eigen Value =

$$\frac{\frac{0.0786}{0.6687}+\frac{0.0681}{0.5261}+\frac{0.0670}{0.3006}+\frac{0.3571}{0.3915}}{4}$$

Eigen Value = 4.3234

Consistency Index = $\frac{E-n}{n-1} = \frac{4.3234-4}{4-1} = 0.080$

Random Index = 0.9

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}} = 0.088$

= 0.088< 0.1.................... Hence the judgements are acceptable

5) Under Owner

A: Delay in Contractor's Payment
B: Too Many Change Order
C: Slowness in Decision Making
D: Poor Leadership
E: Financing during Construction
F: Delay in Site Preparation

Pairwise comparison matrix for Owner

Owner	A	B	C	D	E	F
A	1	3	1/5	1/5	1/3	1/3
B	1/3	1	1/7	1/5	1/3	3
C	5	7	1	1	3	5
D	5	5	1	1	5	3
E	3	3	1/3	1/5	1	3
F	3	1/3	1/5	1/3	1/3	1
Total	17.33	19.33	2.87	2.93	10.00	15.33

Synthesized matrix for Owner

Owner	A	B	C	D	E	F	Eigen Vector
A	0.0577	0.1551	0.0696	0.0682	0.0333	0.0217	0.3696
B	0.0192	0.0517	0.0497	0.0682	0.3333	0.1956	0.3957
C	0.2885	0.3621	0.3484	0.3412	0.3000	0.3261	0.3496
D	0.2885	0.2586	0.3484	0.3412	0.5000	0.1956	0.0644
E	0.1731	0.1551	0.1161	0.0682	0.1000	0.1956	0.0488
F	0.1731	0.0172	0.0696	0.1137	0.0333	0.0652	0.0819

Weighted sum matrix

$$0.3696\begin{bmatrix}1\\1/3\\5\\5\\3\\3\end{bmatrix}+0.3957\begin{bmatrix}3\\1\\7\\5\\3\\1/3\end{bmatrix}+0.3496\begin{bmatrix}1/5\\1/7\\1\\1\\1/3\\1/5\end{bmatrix}+0.0644\begin{bmatrix}1/5\\1/5\\1\\1\\1/5\\1/3\end{bmatrix}$$

$$+0.0488\begin{bmatrix}1/3\\1/3\\3\\5\\1\\1/3\end{bmatrix}+0.0819\begin{bmatrix}1/3\\3\\5\\3\\3\\1\end{bmatrix}=\begin{bmatrix}1.6828\\0.8436\\0.5181\\1.4730\\0.7198\\1.4302\end{bmatrix}$$

$$\text{Eigen Value} = \frac{\frac{0.3696}{1.6828}+\frac{0.3957}{0.8436}+\frac{0.3496}{0.5818}+\frac{0.0644}{1.4730}+\frac{0.0488}{0.7198}+\frac{0.0819}{1.4002}}{6}$$

Eigen Value = 6.19

Consistency Index = $\frac{E - n}{n-1} = \frac{6.19-6}{6-1} = 0.038$

Random Index = 1.24

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}}$ = 0.030

= 0.030< 0.1..................... Hence the judgements are acceptable

6) Under Labour

A: Regular Payments

B: Shortage of Manpower

C: Poor Skill & Experienc

Pairwise comparison matrix for Labour

Labour	A	B	C
A	1	5	1/9
B	1/5	1	1/7
C	1/9	7	1
Total	10.2	13	1.25

Synthesized matrix for Labour

Labour	A	B	C	Eigen Vector
A	0.0980	0.3846	0.0888	0.0349
B	0.0196	0.0769	0.1142	0.4232
C	0.8823	0.5384	0.8000	0.2305

Weighted sum matrix

$$0.0349 \begin{bmatrix} 1 \\ 1/5 \\ 9 \end{bmatrix} + 0.4232 \begin{bmatrix} 5 \\ 1 \\ 7 \end{bmatrix} + 0.2305 \begin{bmatrix} 1/9 \\ 1/7 \\ 1 \end{bmatrix} = \begin{bmatrix} 2.1765 \\ 0.4631 \\ 0.3507 \end{bmatrix}$$

Eigen Value

$$= \frac{\frac{0.0349}{2.1765} + \frac{0.4232}{0.4631} + \frac{0.2305}{0.3507}}{3}$$

Eigen Value = 3.109

Consistency Index = $\frac{E-n}{n-1} = \frac{3.109-3}{3-1} = 0.054$

Random Index = 0.59

Consistency Ratio = $\frac{\text{Consistency Index}}{\text{Random Index}} = 0.092$

= 0.092< 0.1..................... Hence the judgements are acceptable

Table 3.2 Local Priorities for Hierarchy's Criterions. [Table A]

Criterions	Local Priorities	Sub-Criterions	Local Priorities	Rank
Consultnt	0.1413	Delay in approval by engineer	0.3132	8
		Slow response by engineer	0.1393	14
		Over design	0.1115	15
Contractor	0.1813	Insufficient co-ordination	0.3676	4
		Delay in payments of sub contractor	0.3036	9
		Poor planning & scheduling	0.2304	12
		Shortage of technical professionals	0.1788	13
		Improper technical study	0.0165	27
		Poor communication with suppliers	0.0800	17
		Use of unacceptable techniques	0.0327	26
Material	0.1610	Lack of material in market	0.0328	25
		Delay in material delivery	0.2755	10
		Shortage of material onsite	0.3188	7
		Stored damage materials onsite	0.0329	24
Equipment	0.1429	Unskill staff	0.0786	18
		Low productivity by equipments	0.0681	19
		Delay in procurement of equipments	0.0670	20
		Shortage of equipments	0.357	5
Owner	0.1559	Delay in contractor's payment	0.3696	3
		Too many change order	0.3957	2
		Slowness in decision making	0.3496	6
		Poor leadership	0.0644	21
		Financing during construction	0.0488	22
		Delay in site preparation	0.0819	16
Labour	0.2116	Regular payments	0.0349	23
		Shortage of manpower	0.4232	1
		Poor skill & experience	0.2305	11

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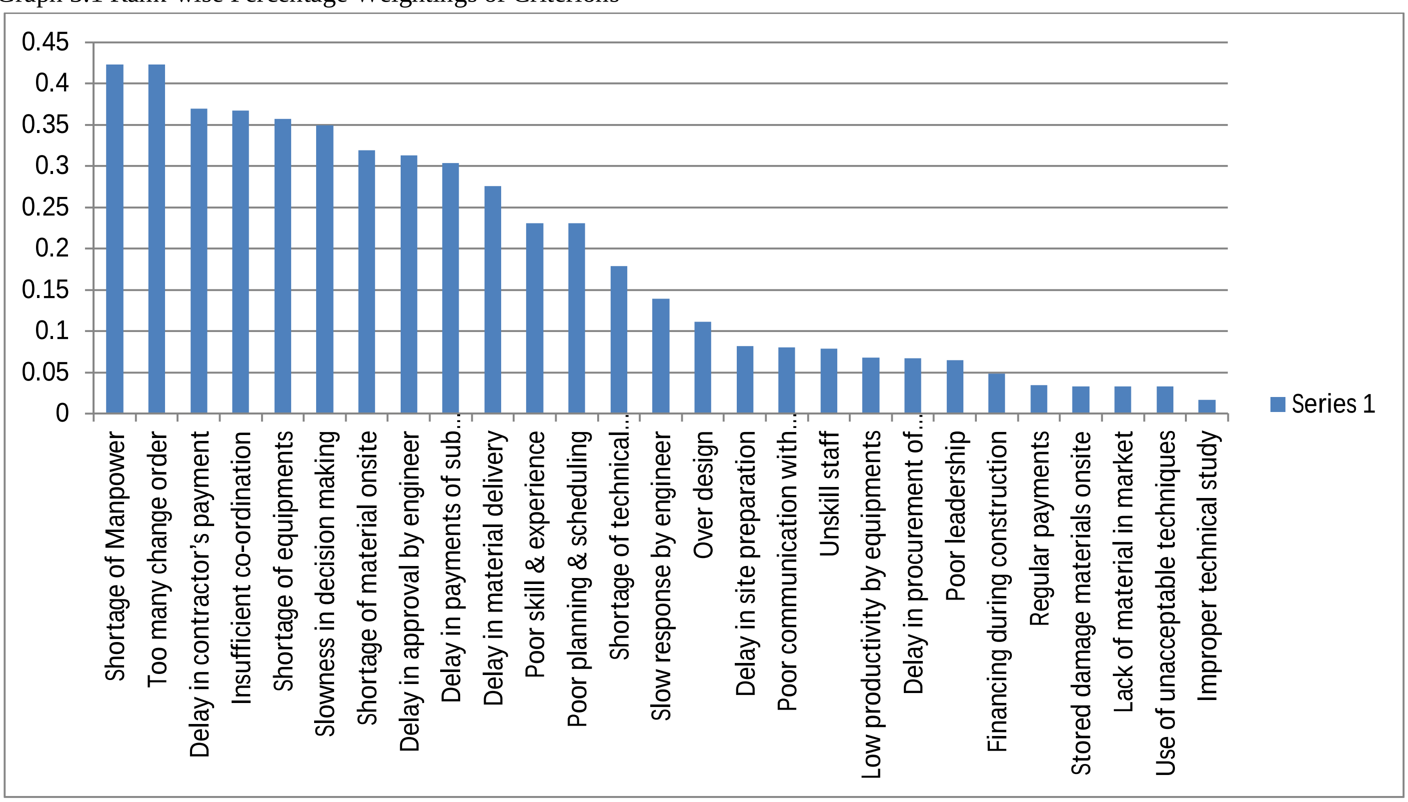
The Table 4.2 indicates the derived local priorities of all criterions along with ranks for each criterion.

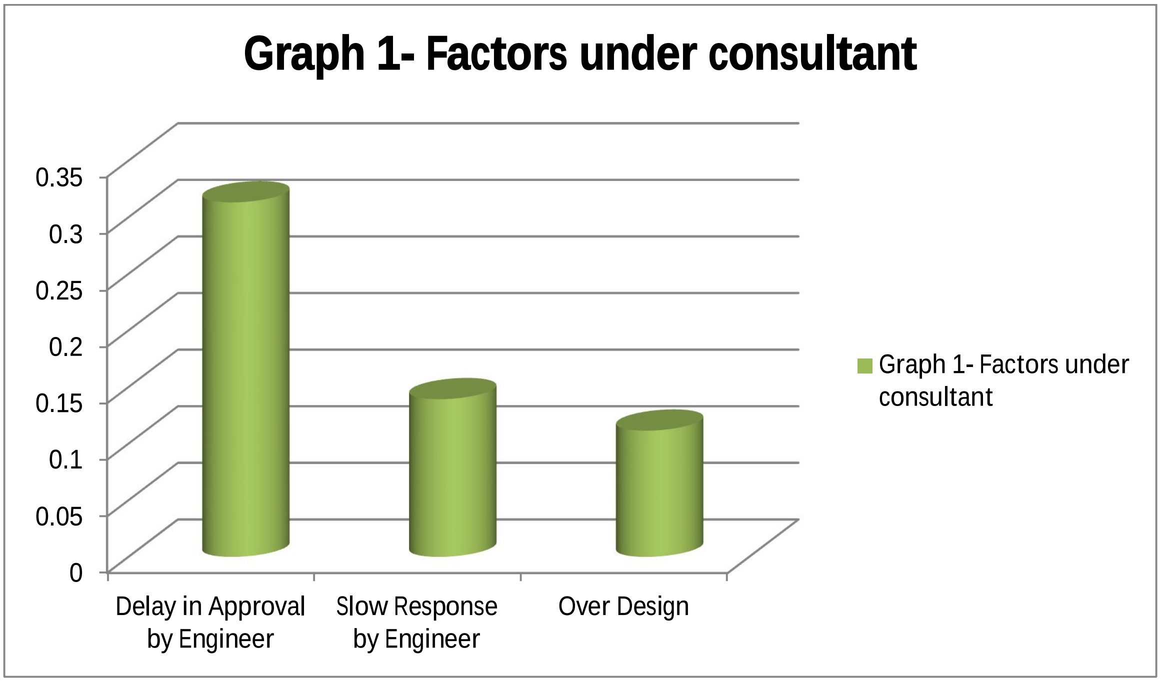
Table 3.3 Rankings of Hierarchy's Criterions [Table B]

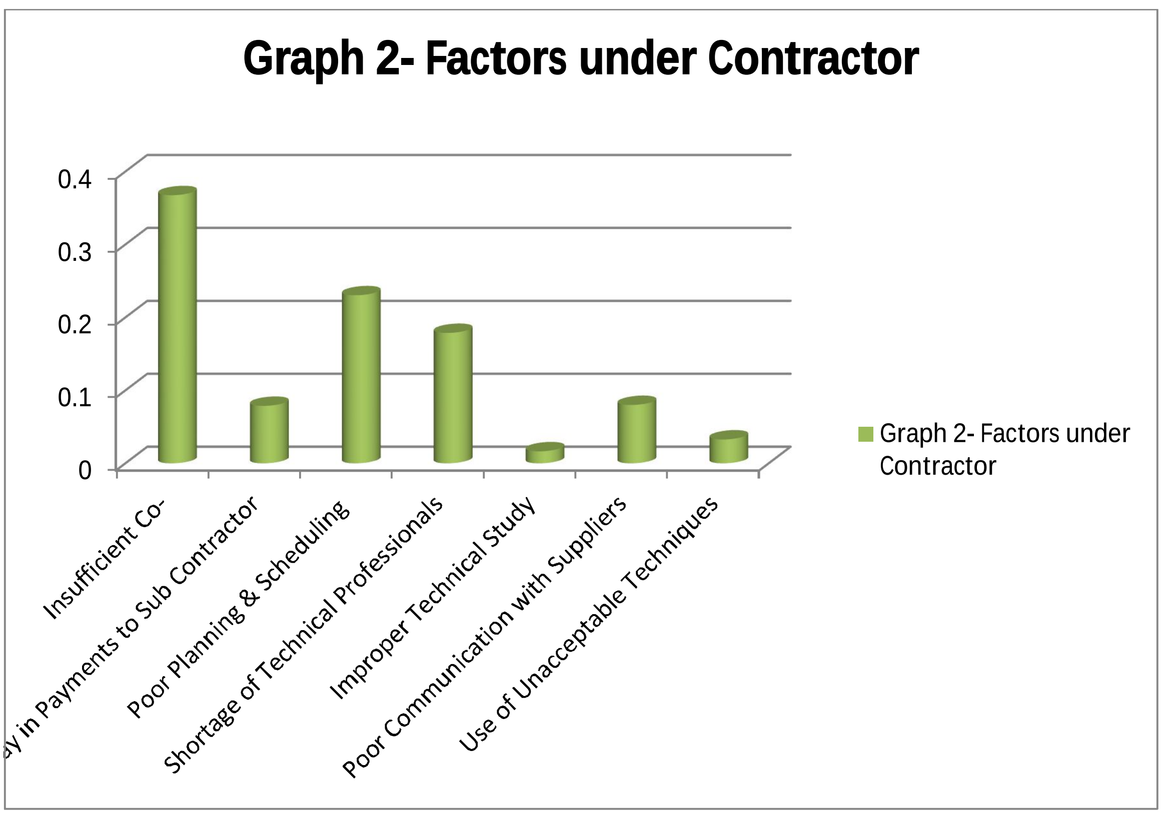
Rank	Sub-Criterions	Local Priorities
1	Shortage of Manpower	0.4232
2	Too many change order	0.4232
3	Delay in contractor's payment	0.3696
4	Insufficient co-ordination	0.3676
5	Shortage of equipments	0.3570
6	Slowness in decision making	0.3496
7	Shortage of material onsite	0.3188
8	Delay in approval by engineer	0.3132
9	Delay in payments of sub contractor	0.3036
10	Delay in material delivery	0.2755
11	Poor skill & experience	0.2305
12	Poor planning & scheduling	0.2304
13	Shortage of technical professionals	0.1788
14	Slow response by engineer	0.1393
15	Over design	0.1115
16	Delay in site preparation	0.0819
17	Poor communication with suppliers	0.0800
18	Unskill staff	0.0786
19	Low productivity by equipments	0.0681
20	Delay in procurement of equipments	0.0670
21	Poor leadership	0.0644
22	Financing during construction	0.0488
23	Regular payments	0.0349
24	Stored damage materials onsite	0.0329
25	Lack of material in market	0.0328
26	Use of unacceptable techniques	0.0327
27	Improper technical study	0.0165

Graph 3.1 Rank-wise Percentage Weightings of Criterions



Above graph shows the Rank wise percentage criterions of all the 27 factors. Now we are separated the graph of factors according to their main categories as shown below


Graph 1- Factors under consultant
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Delay in Approval by Engineer
Slow Response by Engineer
Over Design
Graph 1- Factors under consultant


Graph 2- Factors under Contractor
0.4
0.3
0.2
0.1
0
Insufficient Co-
Poor Planning & Scheduling
Shortage of Technical Professionals
Improper Technical Study
Poor Communication with Suppliers
Use of Unacceptable Techniques
Graph 2- Factors under Contractor

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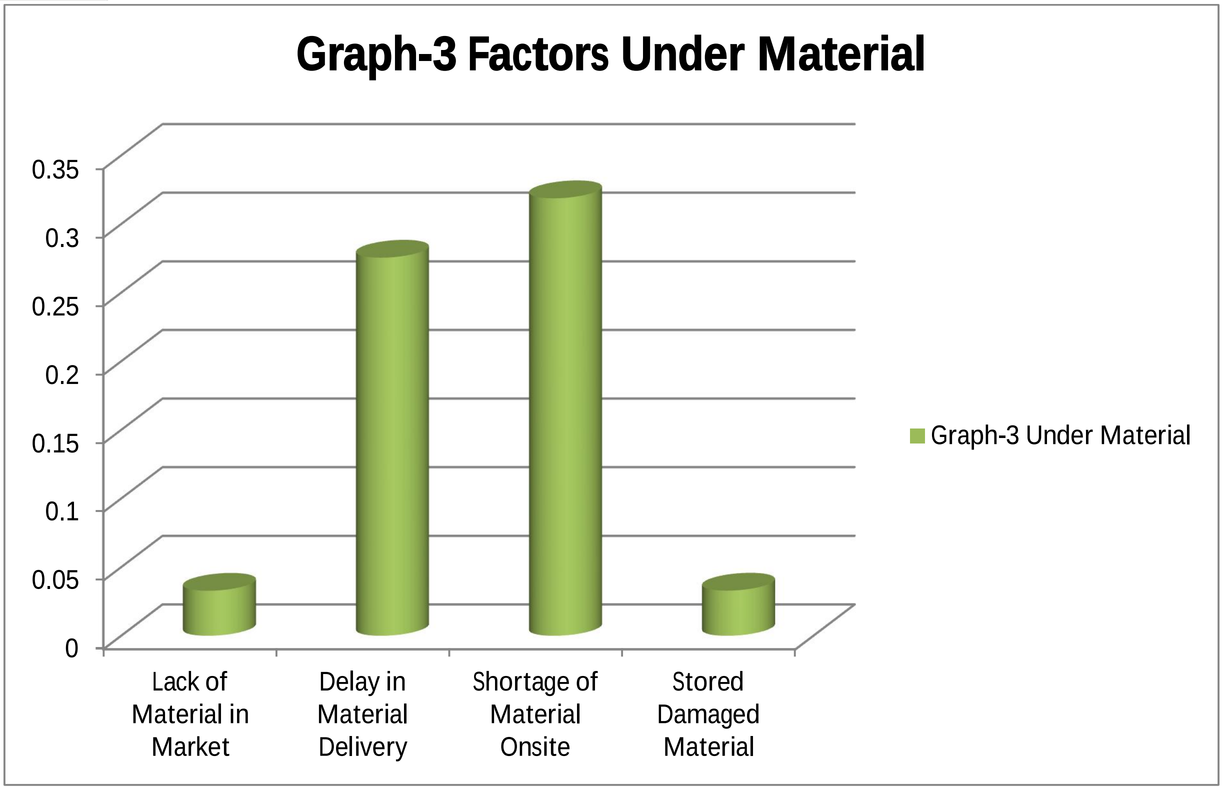

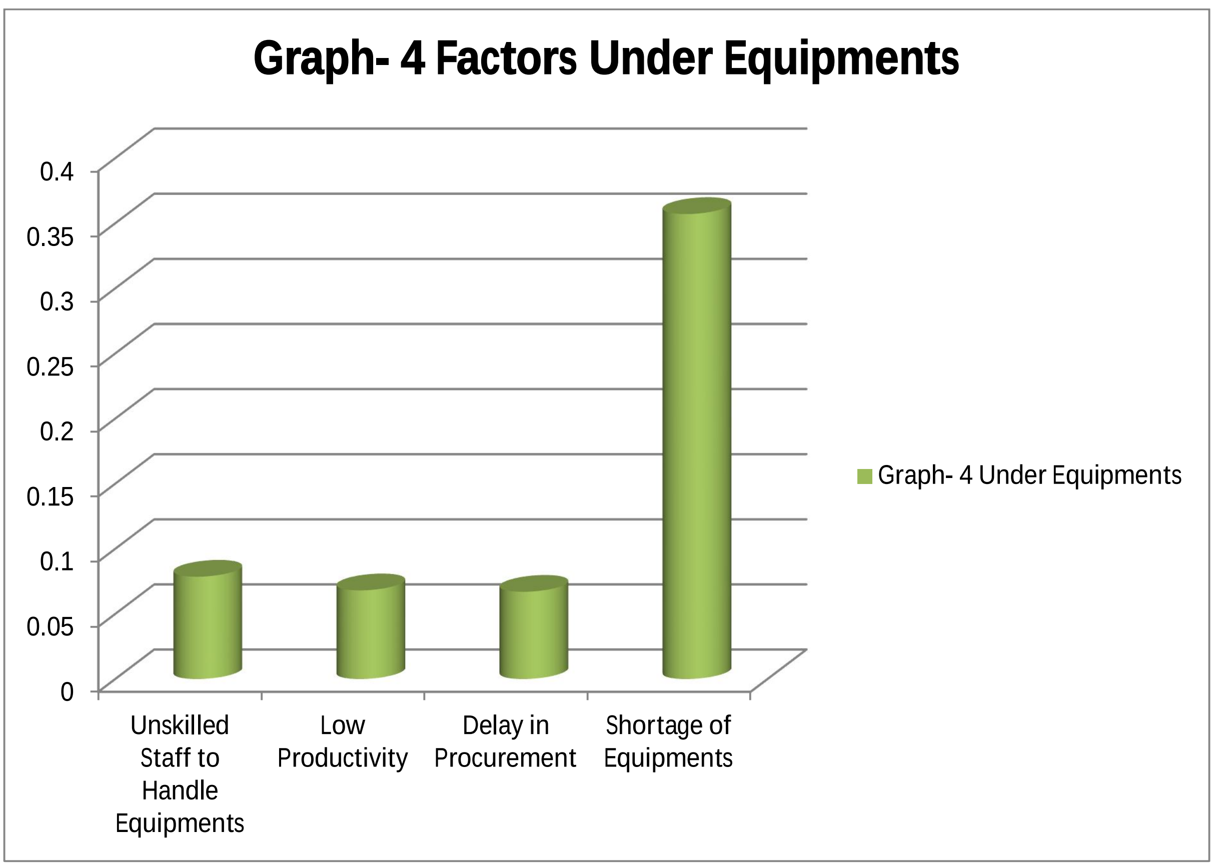

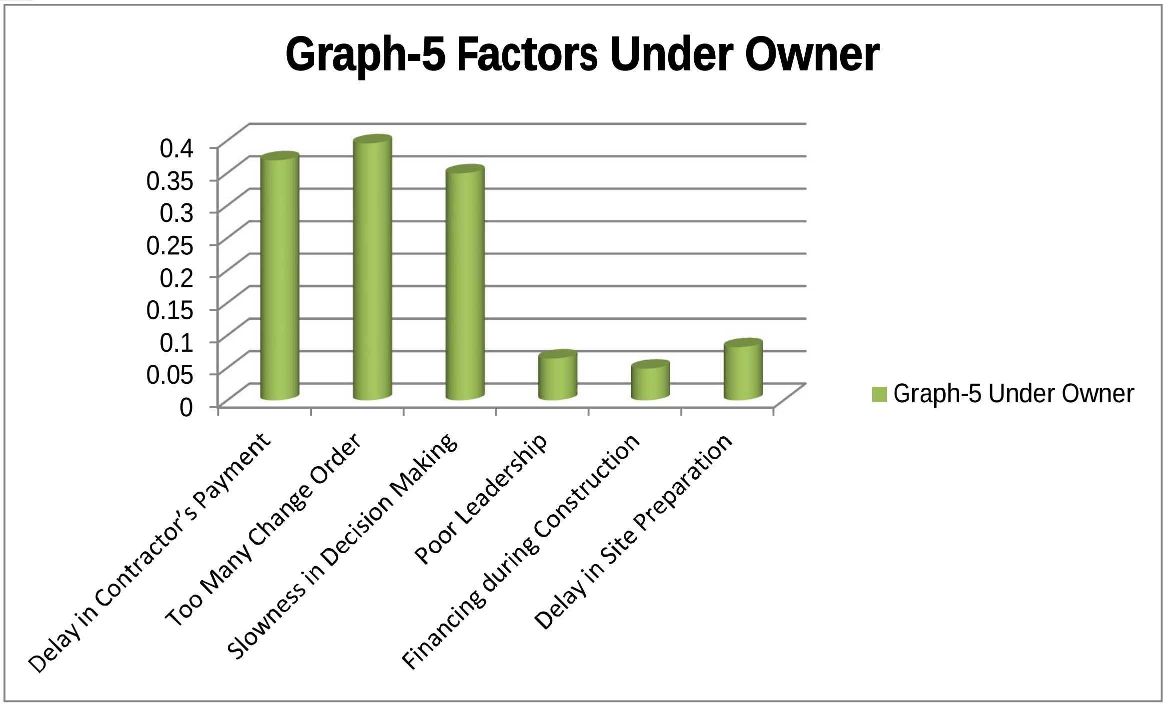

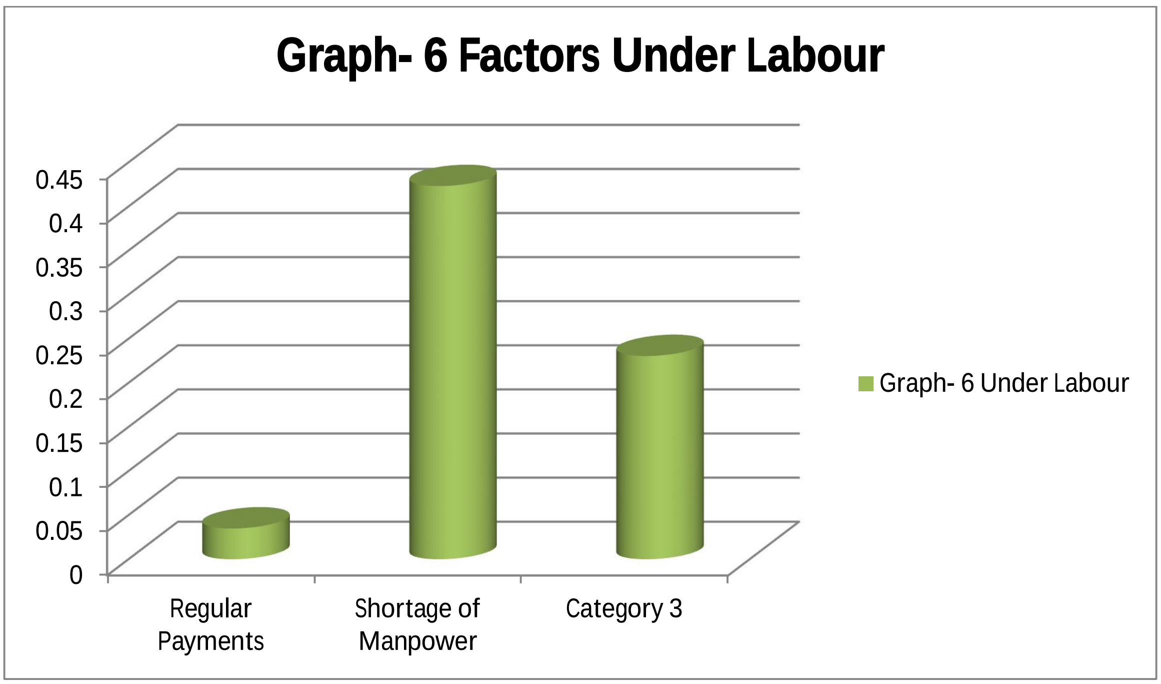

IV. CONCLUDING REMARK

As deliberated in methodology, a vigilant attempt has been made in the preceding chapter to employ Analytical Hierarchy Process to simplify several decision making activities in construction and also to elicit a genuine approach to enhance some of the construction productivity issues in our Indian construction industry. Being prevailed in our motive we have achieved number of results, each of them endowing certain conclusions, concerning to the process of application and accomplishment of our objective. So, in this chapter, a compilation of all such results is carried out and a candid discussion is made to put the lights on various assorted findings of our work. Achieving plentiful affirmative results from the process we are grateful to the originator of AHP Mr T. L. Saaty, for bringing forth such a revolutionary technique for simplification of decision making process. This is what we have achieved from the application of AHP in construction.

V. DISCUSSIONS ON RESULTS

According to Table B, the respondents have ranked 'Shortage of Manpower' as the most influence factor in perspective of Indian construction industry, especially Nashik to be more precise. It's an obvious fact that we can undoubtedly identify the problems regarding this issue. On many construction projects from recent few years the Shortage of Manpower of labours is occurred. Seconly 'Too many change orders' stands to be the next influencing factor. Too many change orders may increase total budget of project.changes throughout a project may be unavoidable, but planning ahead with design and project team can minimize changes along the way. Further, 'Delay in contractor's payment' stands to be the third most influencing factor. Delay in paying construction contractors has impacted negatively on the effectiveness of the contractor and as such affect project delivery schedule. 'Insufficient co-ordination' comes fourth in ranking as it categorised under the contractor's factor. It may causes productivity of work. Co-ordination between each and every person is important for make continuity in work. Fifth comes the 'Shortage of equipments' which will affect the output of labours. Shortage of equipments sometimes may cause stoppage of some particular work which will make delay in construction. . The other all remaining factors are demonstrated & arranged sequential in Graph 1.

VI. CONCLUSION

Above illustrated work proposes diverse applications of AHP in the problems associated with the Indian construction industry, more precise with Nashik. The use of this appealing multi-criterion technique contributes to the rationalisation of entire decision process. The AHP is preferred for its simplicity and transparency in multi-criterion choice situations. Along with the applications in this work, many real world applications have proved that AHP is a valuable tool for dealing with complex issues as it allows the decision makers to decompose the decision problem to its constituent parts.

Pertaining to the work executed here by we can derive plentiful conclusions however the most noteworthy one evolves to be the nature of criterions that truly influence the various properties of decision problem, contrarily some of these criterions are certainly not considered being intangible. Merely the tangible or objective criterions are contemplated being measurable or dimensional. Though these tangible criterions form straightforward data for calculations, the intangible criterions should not be neglected as they are having imperative impact on decision problem. So the solution may be the adaptation of these intangible criterions in the form of category grading which gives a numeric value.

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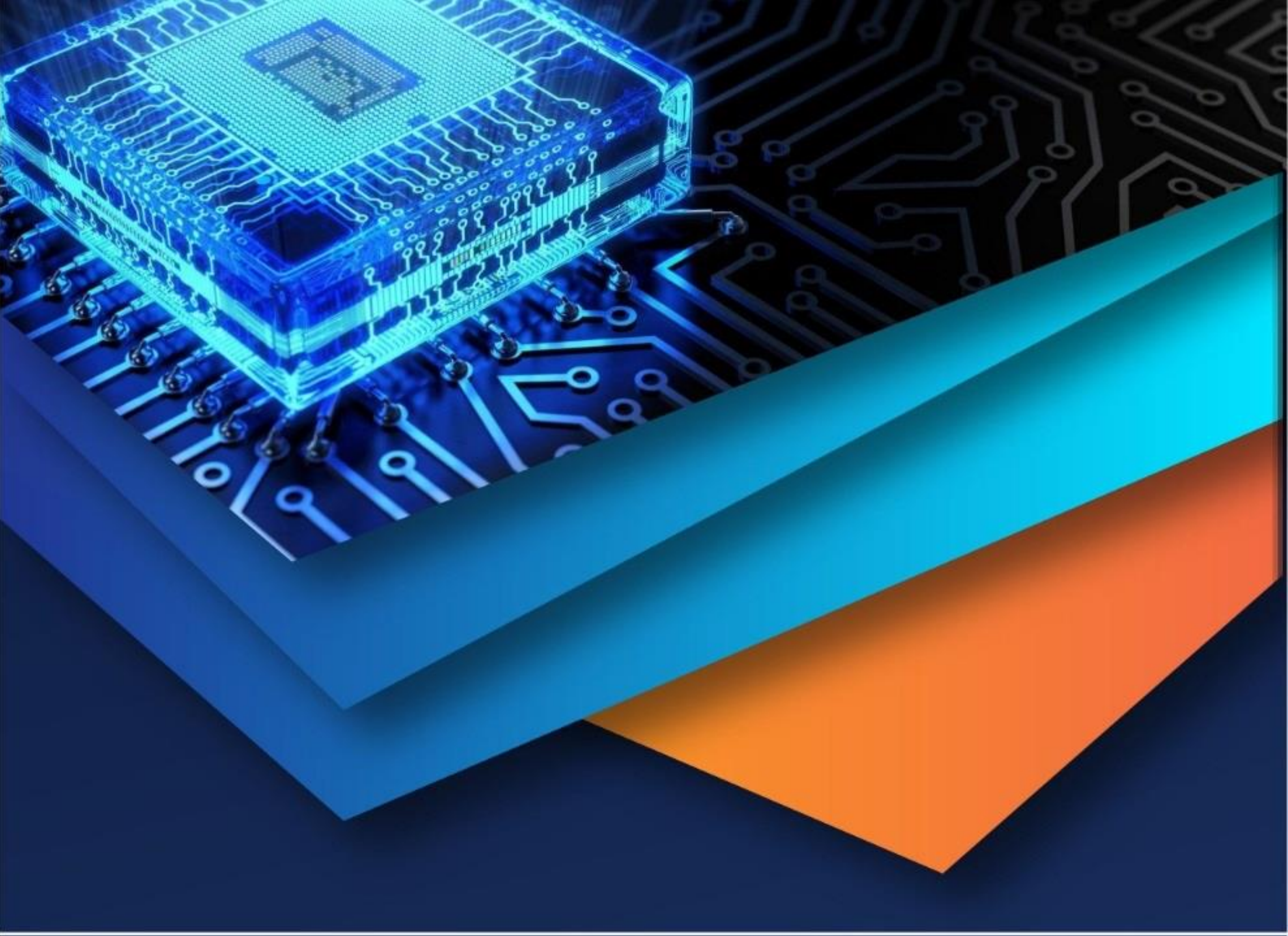

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