APPLICATION OF ANALYTICAL HIERARCHY PROCESS IN CONSTRUCTION INDUSTRY

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ABSTRACT

In today's corporate and mercantile world many times it may happen to face a situation in which there may create a perplexity to take the most appropriate decision from the available solutions.in many fields like ranking, profit optimization ,resource allocation, priority fixation, sequential operation and many more, confusing situations are always created and number of times it is difficult for a personnel to take an appropriate decision. Usually, we make decisions on the platforms of experience and logic which is nothing but a presumption to be precise. However, we cannot assure the preciseness of our decision. On the contrary, if the implemented judgements consequently prove to be incorrect then sometimes the impairment is unaffordable. Hence, we entail to bring about a process which can assemble a platform for a correct decision, to boost the productivity and profitability in construction industry.to simplify the critical situations by analyzing the parameters affecting the selection, the 'Analytical hierarchy process' is utilized.

The work consists of meticulous considerations of all subjective and objective parameters concerning our decision problem in both phases. Here we have also tried to elaborate the adaptive exercise of AHP in small as well as large construction projects, as both cases vary from each other in numerous aspects.

Finally, we may conclude that the use of AHP in construction execution will surely be a fruitful approach. On the practical side, the AHP based applications in this work have proven to be a convenient and user-friendly tool for the multi-criterion group decision making process in the construction industry. Here by we particularly proposed the use of simplified methodology for relatively complex decision possesses an inherent ability to unveil the facet knowledge of the competent and experienced users.

Keywords: **AHP**, **Decision making**, **Construction**, **Projects**, **Parameters**

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 1970's and has been extensively studied and refined since then.it has particular application in group decision making and prioritization and is used around the world in a wide variety of decision situations, in fields such as government, business, industry and education.

Rather than prescribing a correct decision, the AHP helps decision makers find the one that best suits their goal and their understanding of the problem.it provide a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. The AHP converts those evaluations to numerical values that can be Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another in pairs, with respect to their impact on an element above them in the hierarchy.in making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgements about the element's relative meaning and importance.it is the essence of the AHP that human judgements ,and not just the underlying information, can be used in performing the evaluations.

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. This capability distinguishes the AHP from other decision-making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternative's relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of actions.

AHP was developed to assist in the making of decisions that are characterized by a great number of interrelated and often contending factors.to make such decisions, the relative importance of the factors involved must be properly assessed to enable trade-offs among them. 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 objective factors allows for the incorporation into the decision-making process of subjective judgements and user intuition by producing a common formal and numeric basis for solution

Often project managers are faced with decision environments and problems in projects that are complex. The elements of the problems are numerous, and the interrelationships among the elements are extremely complicated. Relationships between elements are extremely complicated. Relationships between elements of a problem may be highly nonlinear. Changes in the elements may not be related by simple proportionality. Furthermore, human value and judgement systems are integral elements of project problems. Therefore, the ability to make sound decisions is very important to the success of a project and is achievable with the use of AHP.

Decision-making can be considered as the choice, on some basis or criterion, of one alternative among a set of alternatives. A decision may need to be taken based on multiple criterions rather than a single criterion. This requires the assessment of various criterion and the evaluation of alternatives based on each criterion and then aggregation of these evaluations to achieve the relative ranking of the alternatives with respect to the problem. The problem is further compounded when there are several or more experts whose opinions need to be incorporated in the decision-making.it is lack of adequate quantitative information which leads to dependence on the intuition, experience and judgement of knowledgeable persons called experts.

OBJECTIVES

1)To study the fundamentals of Analytical Hierarchy process and its applications

2)Application of AHP in various complex activities of residential construction project by Considering all tangible and intangible factors provides a comparative statement.

3)To study and identify various factors affecting construction productivity in Indian Context.

LITERATURE REVIEW

Decision making in a complex situation in construction industry is a burning topic from ancient era, however, bit serenity has arrived after the evolution of AHP technique over other decision-making methods. Since then, the AHP technique has been tried to be exploited in various facets by several researchers around the globe, concluding that scope of its application in various sectors is yet more to be harnessed. Let's scrutinize some of the imperative works in the field of AHP by some of the proficient researchers.

LITERATURE SUMMARY

From the range of comprehensive facts elicited in the above works we are pleased to learn the various fundamentals of AHP and its applications. further, we observed that numerous researchers are carried overseas by various professionals, but a very scarce work is performed with a respect to Indian construction industry. We cannot disregard the fact that the attributes of construction industry and its various sensitive features vary from nation to nation, state to state, place to place and project to project. hence, to work out the applicability and derive likewise improvements in various construction activities which need skill to deal with complex decision making, in context with Indian construction industry, more precisely with context of construction scenario in Nashik

METHODOLOGY

For a long period of time people have been concerned with the measurement of both physical and psychological events. By physical we mean the realm of what is fashionably known as the tangibles as it relates to some kind of objective reality discovered by an individual conducting the measurement. By contrast, the psychological is the realm of the intangibles as it relates to subjective ideas and beliefs of an individual emerged from the world of experience. The question is whether there is coherent theory that can deal with both these worlds of reality without compromising either. Fortunately, the answer happens to be, The AHP is a method that can be used to establish measures in both the physical and social domains I.e. Tangibles and intangibles. So, in correlation with both these domains, this work has brought forth the application of AHP for the process of selection and evaluation on both small- and large-scale residential construction projects considering subjective and objective factors.

Analytical Hierarchy process (AHP)

The Analytical Hierarchy Process (AHP) is a multi-attribute decision-aiding method developed by Saaty. It aims at quantifying relative priorities for a given set of alternatives on a ratio Scale, based on the judgements of the decision-maker, and stresses the importance of the intuitive judgements of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process. Since a decision-maker bases judgements on knowledge and experience, then makes decisions accordingly, the AHP approach agrees well with the behavior of a decision-maker. The strength of this approach is that it organizes tangible and intangible factors in a systematic way, and provides a structured yet relatively simple solution to the decision-making problems, In addition, by breaking a problem down in a logical fashion from the large, descending in gradual steps, to the smaller and smaller, one is able to connect, through simple paired comparison judgements, the small to the large.

AHP PROCESS

Saaty proposed the following steps for applying AHP

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 (criterion on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.

3.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. The pair-wise comparisons are done in terms of which element dominates the other.

4. There are (n-1) judgements required to develop the set of matrices in step

Reciprocals are automatically assigned in each pairwise comparison.

5.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.

6.Having made all the pairwise comparisons, the consistency is determined by using

Eigen value E to calculate the consistency index, CI as follows:

$$CI=(E-N)\ (N-1)$$

Where n is the matrix size

Judgement consistency can be checked by taking the consistency ratio (CR) of CJ with the appropriate value. If the CR is acceptable, if it does not exceed 0.10. if it is more, the judgement matrix is inconsistent. To obtain a consistent matrix, judgements should be reviewed and improved.

7.Steps 3 to 6 performed for all levels in the hierarchy.

For pairwise comparison between the two pairs, the importance of one component over another is indicated by acceptance level rating. For this the number scale is utilized which is placed between the two components of pairwise comparison.

The rating is to be given on the side of the component which is more favored or accepted. The acceptance level ratings and meaning of each rating is given below.

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

Relative measurement scale

AHP has been applied in a wide variety of applications-multi objective decision-making being just one. A look at the three primary functions of AHP, structuring complexity, measurement, and synthesis helps in understanding why AHP is such a general methodology with such a wide variety of applications.

DATA COLLECTION AND ANALYSIS

1)Location of the plot-

The surrounding area of the residential plot is very important. It affects the price and the beauty of the plot. Plot Should be taken in the area provided with a lot of services and in a sustainable environment free from all kinds of pollutions. Efforts should be made to buy it near to the main road. Because such plots are more valuable as compared to the plots situated away from the main road.

2)Shape of the plot

The geometry of the plot for any kind of construction is very important which can affect the appearance of structure. The shape of the plot should be such that the construction can be easily made with cost low as possible, and in the future, you can further expand it. A plot with more routes will be considered a good one.

3)Civic Services

The plot for a residential building should be taken in an area provided with many numbers of amenities. Such as electricity, Telephone, Fax, Internet, Gas, School, Colleges, University etc. and the most important is the good and fast transport system. So that communication becomes faster and quicker.

4)Surface soil

Soil on site should not be of made-up type as far as possible. The buildings constructed over such soils normally undergo differential settlement and sometimes become the cause of collapse. Cracks in buildings in such conditions are quite common.

5)Dominance by the Adjoining structures-

The selected Site should be large enough, both to ensure the building abundant light and air to prevent any over dominance by the neighboring buildings.

With respect to above factors following are the details for all the three sites

Factors	**Site A**	**Site B**	**Site C**
Location of site	-1.5 km from Nimani Panchavati -Less developed area -Moderate transport	-0.5 km from Nimani Panchavati -Developed area -Good Transport	-2 km from Nimani Panchavati
Shape of plot	-21m x 20m -Nearly Square	-21m x 20m -Nearly Rectangle	-19m x 33m
Civic Services	Moderately Available	Densely available	scarcely available
Surface of site	Artificially filled surface	Natural soil surface	Natural surface with hard rock platform
Dominating structures	Closed from one side	Closed from three sides	Open from all sides

Depending upon all the above factors it will become easier to use AHP for the site selection process. The above five factors become the criterion of the AHP hierarchy, which will be as below.

With reference to the above table and hierarchy the calculations can be done as below.

For pairwise comparison the following rating may be referred

1-Equal importance

3-Moderate importance

5-Essential or strong importance

7-Very strong importance

9-Extreme importance

Comparison between alternatives

Pairwise comparison for location of site

Site A to Site B

Site B to Site C

Site A to Site C

Pairwise comparison matrix for location of site

Site	A	B	C
A	1	1/3	2
B	3	1	3
C	1/2	1/3	1
Total	4.5	1.67	6

Synthesized matrix for location of site

Site	A	B	C	Eigen Vector
A	0.22	0.2	0.33	0.25
B	0.67	0.6	0.5	0.59
C	0.11	0.2	0.17	0.16

Consistency Index=CI=(E-n)/(n-1)

CI=0.0225

Random Index = 0.58

Consistency ratio = 0.038<0.1

Hence the judgements are acceptable

Pairwise comparison for Shape of Site

Site A to Site B

Site B to Site C

Site A to Site C

Pairwise comparison matrix for Shape of Site

Site	A	B	C
A	1	3	5
B	1/3	1	2
C	1/5	1/2	1
Total	1.53	4.5	8

Synthesized matrix for shape of site

Site	A	B	C	Eigen Vector
A	0.653	0.67	0.625	0.649
B	0.215	0.22	0.25	0.342
C	0.130	0.11	0.125	0.121

Eigen Value=3.1

Random Index=0.58

Consistency ratio=CR=0.05/0.58

0.086<0.1Hence the judgements are acceptable

Pairwise Comparision for Civic services available on site

Site A to Site B

Site B to Site C

Site A to Site C

Pairwise comparison matrix for Civic services available on site

Site	A	B	C
A	1	1/3	3.
B	3	1	7
C	1/3	1/7	1
Total	4.33	1.472	11

Synthesized matrix for Civic services available on site

Site	A	B	C	Eigen Vector
A	0.23	0.224	0.272	0.242
B	0.692	0.679	0.636	0.669
C	0.076	0.097	0.09	0.087

Eigen Value=E=3.0006

Consistency Index=CI=(E-n)/(n-1)

CI=0.0003

Random Index=0.58

Consistency Index=CR=0.0003/0.58

=0.0005<0.1

Hence the judgements are acceptable

Pairwise comparison for the surface of the plot

Site A to Site B

Site B to Site C

Site A to Site C

Pairwise comparison matrix for surface of site

Site	A	B	C
A	1	1/5	1/7
B	5	1	1/3
C	7	3	1
Total	13	4.2	1.476

Synthesized matrix for surface of site

Site	A	B	C	Eigen Vector
A	0.076	0.047	0.096	0.073
B	0.384	0.238	0.275	0.282
C	0.538	0.714	0.677	0.643

Eigen Value=E=3.059

Consistency Index=CI=(E-N)/(N-1)

CI=0.0295

Random Index=0.58

Consistency Ratio=0.0508<0.1

Hence the Judgments are acceptable

Pairwise Comparison Matrix for Dominating Structures

Eigen Value=E=3.059

Consistency Index=CI=(E-N)/(N-1)

CI=0.0295

Random Index=0.58

Consistency Ratio=0.0508<0.1

Hence the Judgments are acceptable

Individual priority weightings of sites with respect to criterions

Criterions	Site A	Site B	Site C
Location of site	0.25	0.59	0.16
Shape of plot	0.649	0.342	0.121
Civic services	0.242	0.669	0.087
Surface of site	0.073	0.282	0.643
Dominating structures	0.536	0.079	0.383

Comparison between alternatives

For making the comparisons between the above five criterions, the questionnaire survey was conducted of the for Random sequencing the criterions based on their importance over each other from which the relative scores for criterions are worked out

Relative score for criterions

Respondents	Location	Shape	Civic Services	Surface soil	Dominating structures
Number	Score	Score	Score	Score	Score
1	5	3	2	4	1
2	4	1	5	3	2
3	4	3	5	2	1
4	4	2	3	5	1
5	3	1	4	5	2
6	5	1	3	4	2
7	4	2	1	5	3
Total score	29	13	23	28	12

Pairwise comparisons for Five criterions

Criterion 1 to Criterion 2

Criterion 1 to Criterion 3

Criterion 1 to Criterion 4

Criterion 1 to Criterion 5

Criterion 2 to Criterion 3

Criterion 2 to Criterion 4

Criterion 2 to Criterion 5

Criterion 3 to Criterion 4

Criterion 3 to Criterion 5

Criterion 4 to Criterion 5

Pairwise comparison matrix for five criterions

Criterion	C1	C2	C3	C4	C5
C1	1	7	3	2	9
C2	1/7	1	1/5	1/7	2
C3	1/3	5	1	1/3	5
C4	1/2	7	3	1	7
C5	1/9	1/2	1/5	1/7	1
Total	2.087	20.5	7.4	3.615	24

Synthesized matrix for five criterions

Criterions	C1	C×2	C3	C4	C5	Eigen Vector
C1	0.479	0.341	0.405	0.553	0.375	0.43
C2	0.068	0.048	0.027	0.039	0.083	0.057
C3	0.158	0.243	0.135	0.091	0.208	0.167
C4	0.239	0.341	0.405	0.276	0.291	0.310
C5	0.053	0.024	0.027	0.039	0.041	0.036

Eigen value=E=5.165

Consistency Index=CI=0.0412

Random Index=1.12

Consistency ratio=CR=0.036<0.1

Hence the Judgments are acceptable

Overall Priorities of sites

Overall Priority of site A

(0.430×0.250) +(0.053×0.649 +(0.053×0.242) +(0.310×0.073) +(0.036×0.536) = 0.224

Overall Priority of Site B

(0.430×0.590) +(0.053×0.342) +(0.167×0.669) +(0.310×0.282) +(0.036×0.079) = 0.473

Overall priority of Site C

(0.430×0.160) +(0.053×0.121) +(0.167×0.087) +(0.310×0.643) +(0.036×0.383) = 0.302

Comment on above analysis

So, from the above AHP analysis for the selection of site, the available alternative were A, B and C from which the site B proved to be dominating over the remaining two sites

Results and discussions

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 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 complex decision-making problems come in decision making process.

From the available number of options of sites, we divulged that Site B will be more beneficial in all expressions as it has demonstrated its prominence in a blend of tangible and intangible factors. We derived the eigen vectors which indicate the priority of alternatives, hence also called as priority weightings for every individual criterion.

Comparative statements for AHP selections

The actual selection made by the site owner=Site A (Weight= 0.224)

The selection suggested by AHP analysis = Site (weight = 0.473)

According to the weights calculated for both the sites, Site B gains approximately twice that of Site A, which if followed will prove to be beneficial.

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 Appeling multi-criterion technique contributes to the rationalization of entire decision process. The AHP is preferred for its simplicity and transparency in multi-criterion choice situations. Along with the applications this week, many real-world applications have proved the AHP is a valuable tool for dealing with complex issues as it allows the decision makers to decompose 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 criteria are 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.

Illuminating certain other derivations of this work we are convinced about the following conclusions.

1. Pairwise comparison technique forms to be an incredible one, having ability to translate variety of judgements in a numeric and calculative form by means of which we can proceed with AHP solution for decision problem. In logical proportion to these judgements, we can arrive at the concluding selection or decision which proves to be worthy in all expressions

2. Consistency ratio is a noteworthy way to certify the logical proportioning of the judgements entered in the form of pairwise comparison matrix. Its Value surpassing 0.1 indicates the inconsistency in judgements which should be modified in compatibility with proportionate comparisons, which assist in arriving the precise AHP solution.

3. Here, we decomposed the certain selection activities of construction process into a three level AHP hierarchy, first level being a decision problem, second level accommodate the selection criterions and third one is the level in which the candidate alternatives are evaluated. Here, we acknowledged that, process was considerable enough to accommodate diverse nature of criteria and further all were homogeneously promoted for decision making solution.

4. Employing AHP as a consistent evaluation methodology in both phases of work, we arrived at an assurance to an immense extent about the proficiency of the solution model to achieve simultaneously time, cost, quality and productivity specifications of client as well as contractor.

5. The AHP proved to provide the objective mathematics needed to process the subjective and personal preferences of individuals or groups for decision making. It is well suited to decisions in which the criterions are qualitative and have a large subjective component, thus requiring judgements. The only requirement is to verify the judgements by calculating consistency.

6. Thinking in financial terms regarding the range of factors influencing labor productivity, the fact is enough convincing that for mega-project's employing large labor forces on work, the cost for fulfillment of all factors is not much higher as we observed in cost analysis, however the returns after fulfillment of all factors will be worth refundable in terms of productivity.

7. AHP based applications in this work have proven to Be a convenient and user-friendly tool for multi-criterion group decision making process in construction industry. Here by we particularly proposed the usage of simplified methodology for relatively complex decision processes, compelling its user for orderly and meticulous thinking, as AHP possesses an inherent ability to unveil the facet knowledge of the component and experienced users.

References

1.Saaty (2011), AN innovative orders of magnitude approach to AHP based multi criteria decision prioritizing divergent intangible human acts. European journal of operations research volume 214

2.kabir and Hasin, multiple criteria inventory classification using fuzzy analytic hierarchy process. International journal of industrial engineering applications 2011

3.Saaty (1987), The analytical hierarchy process-what it is and how it is used, Pergamon journals.

4.Ishizaka (2011), the main developments in the analytical hierarchy process. Science direct journal volume 38

5. Palcic (2009), Analytical hierarchy process as a tool for selecting and evaluating projects. International journal of simulation modelling.

6.willam (2017), The state of the art of integrations and applications of the analytical hierarchy process, European journal of operations research.

7.Zeshui and Cuiping (1997), A consistency improving method in the analytical hierarchy process, European journal of operations research.

8.hafeez and malik (1999), Determining key capabilities of a firm using analytical hierarchy process, international journal of operations research.

9.Wong and Heng (2006), application of the analytic hierarchy process in multi-criteria analysis of the selection o intelligent buildings, ScienceDirect journal volume 43

10.khalek (2018), identify and prioritize the major influencing causes of automated concrete mixing system for mega construction projects using analytic hierarchy process. Alexandra engineering journal, volume 57

11.Saaty (1980). The analytical hierarchy processes. McGrow hill, New- York

12.Harmouda and Shabaan (2015), Enhancing Labour productivity within construction industry through analytical hierarchy process, universal journal of management.

13.Ingle and Pammer (2020), Evaluation labor productivity in construction firms by analytical hierarchy process, international research journal of engineering and technology, volume 07

14.Mistri and Patel (2019), Analysis of causes effects and impacts of skills shortage for sustainable construction through analytic hierarchy process, international journal for technology innovation through analytical hierarchy process.

15.Shelar and Mishra (2022), sub-watershed prioritization of Koyna River basin in India, using multi criteria analytical hierarchical process, remote sensing and GIS techniques, science direct journal, volume 128

16.Panchal and Shrivastava (2021), Landslide hazard assessment using analytic hierarchy process, Ain shams engineering journal.

17.milosevic and Selimi (2016), AHP multi-criteria method for sustainable development in construction.

18.schmoldt et.al (2001). The analytical hierarchy process in natural and environmental decision making.

19.Mahdi and Alrashid (2016), Decision support system for selecting the proper project delivery method using analytical hierarchy process, international journal of project management.

20.Saaty (1980), The analytical hierarchy processors publications.

21.Kuzman and Sengani (2013), comparison of passive house construction types using analytical hierarchy process, energy and buildings volume 64

22.Zehedi (1986), The analytic hierarchy process-A survey of the method.

and its applications.

23.Foteinopoulos and Stavropoulos (2019), Block based Analytical Hierarchy process applied for the evaluation of construction sector additive manufacturing, ScienceDirect journal

24.Li and Cao (2023), Exploring the effect of different waste polypropylene matrix composites on service performance of modified asphalt using analytic hierarchy process, journal of science direct, volume 405

25.Mariia and Bogaerts (2016), Multi criteria decision making for sustainable wall paints and coatings using analytical hierarchy process, science direct journal

26.Russo and Camano (2015), Criteria in AHP, science direct

27.Mamun and Sohail (2019), Assessment of surface water quality using fuzzy analytic hierarchy process, science direct journal.

28.Rajkumar and Rishi (2015), A comprehensive water quality index based on analytical hierarchy process, Elsevier

29.Yanjie and Lee (2023), evaluation of wastewater management and energy saving for sustainable green building through analytic hierarchy process and artificial neural network model, science direct journal, volume 318

30.Panchal and Shrivastava (2021), Landslide hazard assessment using analytic hierarchy process, science direct journal

31.Sharma and Bae (2008), Analytical hierarchy process to assess and optimize distribution network, journal of ScienceDirect, volume-207