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Analytical Hierarchy Process for Project Selection Considering Risks

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***Abstract*: The process of project selection is one of the most significant process which takes place in every firm all over the world. There are many methods which helps in the decision making of this process but there is no standard method for this particular process. This process is recurring one, hence it is necessary to develop a standard method. This paper helps identify a method which helps in the decision-making process. The project selection is a multi-criteria decision-making process. Hence for selection of any project, various criteria should be set based on the requirement. Setting criteria can be confusing and challenging at the same. Most of the researchers in the past have researched that when a project is being selected the criteria chosen is mostly based on the financial aspect. Risk is an unpredictable event; hence more preference should be given to it. Previous studies have shown that in project selection the risk management process is always poor and not many companies opt for risk management at the project selection stage. This has also led to huge loss in the companies due to the wastage of resources which in turn lead the company into a financial constraint. Thus, during the project selection process, risk should be considered as a major criterion. Another goal for this paper is the easy understanding of multi-criteria decision making. Multicriteria decision making can be confusing and tedious. The decision maker should be able to standardize the criteria and make a decision based upon that. There are many methods to carryout multi-criteria decision making. But methods used previously are time consuming and are not accurate. Hence in this paper, analytical hierarchy process is used for the multi-criteria decision-making process. This paper derives analytical hierarchy process for project selection considering risks. Where the process allows the project to be placed in a hierarchy which is mere selection process through a ranking process. The hierarchy is formed in such a clear way that even if the decision maker is not from the field of construction, based on the analytical hierarchy process, the decision can be made. The hierarchy is done on three levels, the overall goal being the first level, criteria being the second level and the alternatives being the final level. The criteria and the alternatives are compared further, and the hierarchy is formed. This comparison is done based on the weights assigned to the criteria and then comparing it with each alternative. Lastly to solidify the method even more, the consistency is also calculated so that the criteria can be used again in further projects.**

***Keywords*: Multi-criteria decision making process, Project selection, Risk criteria.**

1. Introduction

Selection of a project is one of the most important procedures in a construction project. With the projects getting bigger and more complex, the selection of a project is getting complicated. This task for selecting a project is also a recurring process, hence there should be a standard method for it, in order to process it easily in the recurring stages (Archer & Ghasemzadeh 1999). Project selection is basically done to check the viability of the project (Amiri, 2010). The projects are initially just proposals which are then later selected to be developed further. Any new project which is proposed is considered only on the basis of whether or not the project will yield profit. Hence the selection is mostly based on how profitable it is. In the golden days the project selection was done based on past experiences or rationally with uncertainty (Moselhi and Deb, 1993). Their main aim was to earn profit and increase the NPV. Based on the studies in the past the risks were not considered as an individual criterion for project selection. Risk management is very important when it comes to any construction because if the risks are not taken into account, it can cause a huge loss instead of earning the profit. Risk management is very important today as the projects are getting bigger and technologically advanced. Hence along it is getting bigger, there comes a chance of new and unknown risks. One should select a project only after it has been completely analyzed based on risks and prepare risk response actions.

Few researchers have taken up risks as an important factor in project selection, but even in that only quantitative attributes are considered (Dikmen, Birgonul and Ozorhon, 2007). Qualitative attributes are either not considered or assumed to be negligible. This increases the risk of uncertainty. Hence the risks should be carefully considered while selecting a project. The risks considered previously was merely based on finance. The cost and the budget of a project was given the highest priority in a project. But at the same time, they neglected the fact that the project risk of cost is also interdependent on time and quality risks as well (Zhang and Zuo, 2016). While a project selection is done emphasis should be on the risk dependency of the risks to obtain expected yield. Considering the risk dependency another essential factor which needs to be considered that the risks considered should be having various categories and not be generalized as in the past studies the risks are categorized very generally and is not much into detail. Hence the risks should be

attributed one by one depending on the project in order to maximize the Net profit value of the project.

2. Aim and Objectives

The prime aim of this research is to develop a method for the purpose of project selection considering the risks. In order to solve the issues in considering the risks in project selection, the methods used previously are to be compared and a simple method is to be developed. The above aim can be achieved through research of the following objectives:

1. To determine the criteria for the selection of the project considering the risks.
2. To analyze the occurrence and impact of the risks in the project.
3. To compare the past methods to AHP and calculate the risk factor.
4. To identify risks and categorize them using AHP.
5. Compare few projects based on risks using AHP.
6. To develop a better understanding for importance of risks in project selection to increase the interest of investors.

3. AHP

A. Findings

According to (Saaty 1994), the most creative decision to be made is to select factors that lead to that decision. Hence the analytical hierarchy process helps in selecting and narrowing down the factors. After the factors are narrowed down, it is easier to select the project by merely comparing them based on the factors. AHP is the most useful when someone is not fully aware of the project. It helps identify the factors and aspects according to which the project can be selected. AHP also organizes these factors in a hierarchy so that it can be figured that which factor is to be given the first priority. It helps organize and compare the homogenous elements and help the decision maker to solve the issues in each level (Saaty 1994). AHP is a process where it provides a framework wherein it structures and quantifies the elements further to eliminate the factors which are not important. In addition to this the Analytical Hierarchy process also assesses the consistency of the selection of the project so that later for taking a decision in the same aspect can be done without difficulty. Project selection on its own has its flaws, the biggest being the risk management. When a project is selected, the cost of the project is given the highest preference. Though it may be true, but risk is also one of the most important factors which affect the project selection. If the risks are not taken into consideration, then there is a high probability of the failure of the project which can pose as a huge loss for any company taking up the project.

B. Benefit of proper evaluation of project selection considering risk

Usually, in any company before taking up any project, a proper project selection process is done. Most companies already have their own selection process which satisfies their company goals. And most of them focus on how to earn profit with minimal investment. But many companies do not give much importance to risks which are required. Sometimes risks can be either beneficial or a grave damage to the company. Hence there should be a procedure where the risks can be evaluated properly. This helps the company to choose a project where by taking minimal risks, huge profit can be earned.

C. The usage of analytical hierarchy process

AHP is important because if a company decides to take up two or more projects at the same time then the company should be aware of the nature of the project. AHP allows them to judge the project based on a multi-criteria decision-making system. It helps them to assess whether the company is capable of taking up the projects or it might overload their resources. It also helps them to enhance the capability of the company. If the company is not taking up enough projects, then their resources are economically being wasted. AHP also helps to analyze the capability of the company.

D. Assignment of values to the criteria

AHP is a multi-criteria decision-making process which was developed by Saaty 1994. According to the author, AHP allows the decision maker to structure the problem on a multicriteria basis for easy selection of the project. AHP is one of the easiest methods which can be used for project selection. It analyses the various criteria which needs to be taken into account for project selection then arrange it according to a calculative hierarchy. AHP uses principal eigen vectors, values and ratios to prepare a hierarchy. It gives a small amount of inconsistency as the human decision-making ability can be a little inconsistent. The inputs are given as either price or weights. Most preferably weights are assigned to different criteria and based on what decision is to be made the highest weighing criteria is chosen. AHP allows various projects to be categorized based on the weights assigned to the projects. It is done by doing the pair-wise comparison first then finding out the priority vector. AHP consists of different level that is comparison is done in three levels. The foremost level is the criteria to be achieved. The second level consists on the various criteria which are to be compared and the third level is the comparison of alternatives based on various criteria. Hence the name of analytical hierarchy process.

E. Calculation of priority matrix

In this thesis, the project selection is done for projects 1, 2, 3 and 4. Each project is analyzed using AHP with each criterion. Firstly, as the AHP consists of three levels, the first level is to select the best project. The second level is the various criteria based on which the project is selected and then the last level is the alternatives of the projects 1,2,3 and 4. Each criterion is compared with each project and lastly the best project is selected. The first step of AHP is the pair-wise comparison. This can be done in the matrix form which is easier to evaluate. In this process a nominal scale is decided which varies from 1-

9 where 9 being the highest priority.

Table 1
Saaty's scale of relevance

Scale	Numerical Rating	Reciprocal
Extremely Preferred	9	1/9
Very strong to extremely	8	1/8
Very strongly preferred	7	1/7
Strongly to very strongly	6	1/6
Strongly preferred	5	1/5
Moderately to strongly	4	1/4
Moderately preferred	3	1/3
Equally to moderately	2	1/2
Equally preferred	1	1

Usually the priority scale uses only odd numbers as it gives the accurate wholesome value, the even numbers are used for the values in between. Based on this scale the pair-wise comparison is done. The matrix is formed by evaluating a pair of criteria. The criteria taken up for this thesis are C1) Complexity, C2) Risk, C3) Project proceeding in the right direction, C4) Cost rate, 5) Profit. Hence the pair-wise as the name suggests is done with two criteria at a time. Every criterion is compared with each criterion in a pair and based on the scale of 1-9 each criterion is given the priority according to which is more important. For example, when comparing C1 and C3, C1 is more important hence a value of 3 is given to it and when comparing C3 to C1 then the reciprocal value is given to C3 which is 1/3. This depicts that C3 is of 1/3rd importance to C1. Thus, based on this concept each criterion is compared and the values are assigned to it.

Table 2
Pair wise comparison of criteria

	C1	C2	C3	C4	C5
C1	1	0.3	3	0.2	0.2
C2	3	1	7	5	3
C3	0.3	0.14	1	3	0.2
C4	5	0.2	3	1	0.3
C5	5	0.3	5	3	1

This is later converted into a single matrix which is basically the combination of all the pairwise comparisons. This is known as the eigen vector and is named as 'A'. The main aim to form this vector is to obtain the priority vector. Priority vector is a 5X1 matrix which is obtained at the end of evaluation of the eigen vector (5X5 matrix). The evaluation is done by firstly normalizing the vector which means that the sum of each row should equal to 1. This is done simply by diving the element of each row by the sum of the row. This gives the normalized matrix from which the Priority matrix can be calculated. It is calculated by finding the average of each row. Hence when the matrix is evaluated for the criteria C1-C5 then the priority vector obtained is the highest for the risk criteria based on the assumed priority values of pair-wise comparison.

Table 3
Priority matrix of criteria

0.1
0.44
0.25
0.15
0.25

The above result is the priority matrix. A percentage of 44% is obtained for C2 which is the highest among all the criteria. The next step is to find the consistency ratio. This is done as decision making can be very unpredictable and inconsistent. If the consistency ratio is not more than 0.1 then the criteria chosen is consistent. This can be calculated by the ratio of consistency index and random consistency index. The consistency index is obtained by calculating the λ_{max}. this can be done by multiplying the eigen vector matrix with the priority vector matrix. The average of the resulting matrix divided by the priority matrix is the λ_{max} value.

$$= \frac{5.37-5}{5-1}$$

Which here in this case is 5.37. From the formula λ_{maxn}n1, the consistency index can be obtained. The random consistency index is a table given by (Saaty 1994) which is

Table 4
Random Consistency Index

n	1	2	3	4	5	6	7
RI	0	0	0.52	0.88	1.11	1.25	1.35

Hence from the ratio of CI:RI, the consistency ratio is obtained which is 0.08< 0.1 which depicts sufficient consistency. The next step in the analytical hierarchy process is to compare the criteria to each alternative project. Since this thesis is about project selection considering risks, a comparison of risk with each alternative is done. Here the alternatives are:

- P1- Highway Project
- P2- Waste management project
- P3- Construction of a residential building (Multi-storey)
- P4- Refurbishment of an old building

Table 5
Pair-wise comparison of risk with projects

	P1	P2	P3	P4
P1	1	0.3	3	0.2
P2	3	1	5	0.3
P3	0.3	0.2	1	0.2
P4	5	3	5	1

Hence the risk criteria are compared with the projects above and then the eigen matrix for it is formed. The priority matrix is obtained by assigning the weights to each project based on the

scale of 1-9. By assumption, it is seen that that highway and residential projects are far less risky than waste management and refurbishment. As the highway and residential projects are very common projects that are taken up hence the permits can be obtained easily for them whereas in the waste management project, the place of disposal is the main point to be discussed as it can even affect the public and the environment. Similar is the case for refurbishment. The refurbishment of a project requires firstly demolition which might require more permits, then re-designing or altering the previous design requires copyrights. Hence risk is more in the latter than the former. Hence the values are assigned accordingly. After the values are assigned, as usual the matrix is normalized and then the priority matrix is found by the average of each row.

Table 6
Priority matrix of projects based on risk

0.28
0.27
0.07
0.54

After the assumption of the values and attaining the priority matrix, the highest risk was seen in P4 which the refurbishment project. It is a whopping of 54%. Hence based on risk category refurbishment project is the riskiest.

The total project score is hence calculated:

$$\sum_{i=1}^{5} Wi * Si$$

Where, Wi is the weight of the criteria and Si is the weight of the projects based on the risks.

Hence,

Table 7
Project score

W1*S1	0.12
W2*S2	0.11
W3*S3	0.03
W4*S4	0.24

Table 8
Ranking projects

Rank	Project
1	P4
2	P1
3	P2
4	P3

4. Summary

Based on the findings above, it is concluded that Analytical hierarchy process poses to be an advantageous method which simplifies the project selection process. It also summarizes the fact how important is risk while selecting a project. It also discusses the fact that when risk is treated as one of the major criteria other than the financial aspect, then there is a higher possibility of earning profit. This is because they would be aware of the fact there is this much risk in this project. The weight of the risk for each project during the project selection process is calculated using AHP. The analytical hierarchy process is further explained by elaborating how the weights are assigned which is based upon a scale. And the weight assignment is done by comparing the criteria in a pair-wise manner. After the priority matrix is derived by pairwise comparison then the consistency is measured. If the consistency is lesser than 10% then it is sufficiently consistent. Lastly the criteria are compared with each project and then the hierarchy is formed. When the hierarchy is formed the projects can be ranked and according to the ranking, the project selection process can be proceeded. Based on the above resulting ranking, the safest project that can be selected based on the risk aspect is P3 which is a residential project.

5. Discussions

The main aim of this thesis is to understand why risk is an important while selecting a project and how it can be easily done using the AHP. Hence with evidence above the first thing to do any project selection process is to identify the criteria based on which the project selection is to be done. These criteria depend on each project. But previously, the criteria were merely based on funding and profit. The main criteria which are taken into account is usually monetized and has a quantitative value but there are certain criteria such as the risk itself which cannot be quantified. It can only be identified, assessed and mitigated based on the risk itself. Hence it is observed that risk is an essential part of any project and has to be given more importance that it is already given. In regard to this, risk can also be sub-divided into several categories. Hence risk category can be researched further to finely evaluate the project selection procedure. If the risks are considered properly and researched further, then a standard method for the project selection can be obtained by obtaining clear and well-defined criteria which are non-quantifiable but is also is as significant as any other criteria such as funding. As in the case of the method used which is the analytical hierarchy process s compared to the traditional method of linear programming or cost-based criteria method is much easier and makes it simple for the decision maker, be it the decision maker is aware of the topic or not, by using analytical hierarchy process. This is because in analytical hierarchy each criterion is evaluated separately with each criterion using a pairwise comparison and also giving a multi-criteria approach to the decision maker. After defining the criteria, it can easily compare to alternatives based on any

project and its requirements to calculate which criteria has the highest weightage. When the highest weightage is found then it is easy to form a hierarchy of which project can be selected and rank them accordingly. This is very helpful for any company which needs to do project selection as it will help identify the economic potential of the company as well illustrates a way to use that potential to the fullest. As certain companies do not realize its full potential and end up wasting their resources which can be put to use and further elevate their position in the market. Hence, there is scope for further research in this topic. This is because if the common risks are identified between projects on a global level then the weights can be assigned accordingly, and hence proper standardized method can be developed which is consistent over the globe. Though analytical hierarchy process is clear and easy. The risk categorization can be done more in detail and assumption of weights could be standardized as well. Hence whenever there is a requirement for project selection, there is a standard and well-refined method to do so. And selecting project considering risks using analytical hierarchy process can prove to be an outstanding method which can be standardized upon further research.

6. Conclusion

The project selection being a tedious process is broken into criteria to make the selection easier based on the criteria. But based on the above research, it is seen that the criteria selected for the purpose project selection mainly focuses only on financial aspect of the project. This poses as a threat to any company which choses criteria only based on financial constraints, as risk is a huge part for any project's success or failure. The project will result in a failure if the risks are not managed beforehand. Hence the risk management should be done in the project selection stage itself. This requires risk to be a major criterion in the project selection process which has been shown in this paper.

A. Contribution of research to knowledge

This paper comprehensively identifies why project selection is important and also why risk should be considered as a major criterion for the selection of the project. By doing the literature review, it is observed that risk is an uncertain event. Hence it has a two-way probability, it can either occur or it might not occur. It can either also be beneficial or a complete failure. It depends on the requirements of the particular project. There are very few companies who are willing to take any risk in a project. But there are companies who do not consider risk at the starting stages of construction. This can pose to be a grave loss for the company. This is because if the company is not prepared for the risk then there will be extra overhead costs and also time delay which might also lead to the failure of the project. Hence the risk management should be done at the project selection process itself. This allows the company to prepare for the risk beforehand. Risk should be considered as a major criterion so as to manage the risks later if it occurs. Project selection being a multi-criteria decision-making process, various criteria should be standardized and one of the major criteria should be risk consideration. For that analytical hierarchy process is used in this paper. According to literature review analytical hierarchy process is one of the easiest methods of project selection.

B. Limitations

This paper depicts the project selection process considering risks. This process can be achieved by analytical hierarchy process. But there is a limitation where the analytical hierarchy process is done for only for four types of projects. Hence this work can be considered only for those particular projects. Another limitation of this paper is that when the analytical hierarchy process is carried out the risk is considered only as a single criterion where risk can be divided into various sub-criteria.

C. Recommendations for further research

According to this paper, Analytical hierarchy process is one of the easiest methods for project selection, but it has not been proved to be a standardized method. Hence there is scope for the method to be researched further so that the method can be improved and standardize it later. Another recommendation which can be given is considering more types of projects and not limiting to just one type. Risk in itself is a huge topic which can be divided into various sub-criteria, hence analytical hierarchy process can be done for each sub-criterion based on various alternatives of the projects.

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