Applying the Analytical Hierarichy Process and Weighted Sum Model for Small Project Selection in Iraq

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Abstract. The assessment and selection of small projects are usually carried out using commercial, official, environmental and marketing data before the investment decision is made. Small projects are among the most important sources of job opportunities and revenue in many nations. The contribution of small enterprises the provision of work has been a controversial issue around the world, it is therefore important to clarify how best to choose between projects. This paper shows an example from Karbala governorate, which demonstrates project prioritization through two project selection methods. A questionnaire was completed and scores were computed for prioritizing potential projects.

The first category used an analytical hierarchy process (AHP) model for investment selection when comparing a number of options (alternatives) with respect to specific criteria, then investment with the highest weight was used to select small projects in this field for second stage transference. The second category used a weighted sum model (WSM) for top small project selection, which operated by obtaining all small project scores, and declaring that with the highest project to score to be the best small project. After combining the data and research procedure, we found that the best option from among small projects in Karbala was an industrial dairy factory.

1. Introduction

Modern business dealings are challenging events, that demand financial and operational acuity, an understanding of quality and ideally, consideration for the environment. In such circumstances, a straightforward and shrewd strategy for itemized and differential financial investigation of an assessment framework, regardless of practical or local market restrictions, can be exceptionally valuable in identifying the best projects.

Small projects are an important source of income and employment in numerous nations. The contribution of small organizations to the creation of new jobs has been an issue for discussion the world over and often, similar segments and components are involved. However, there are sometimes differences in scope and time period (life cycle of the project).

This study seeks to identify a method to pick the best project specifications, in terms of their various points of interest and ability to accomplish explicit objectives. The selection problems involved are often complex because they require documents and analysis relative to many factors (both tangible and intangible) and many researchers have used fuzzy AHP or Fuzzy TOPSIS to present a procedure for the problems of project selection. However, fuzzy methods need a body of data accumulated over several years to give accurate results, but our experience in this study suggests that the lack of data was among the biggest difficulties encountered. For this reason the researchers decided to use models that give accurate results without the need for cumulative data.

2. Small Projects

A small venture can be characterized as a discrete business project, utilizing a few individuals to generate an item or administrative project within short timetables and using relatively few assets. Such projects not usually involve itemized action plans. The task administrators and group are engaged with the undertaking, they discuss and clarify expectations. Despite a general lack of accord on the definition of small ventures, most investigations that have characterized have described those whose scope is characterized by small scale and flexibility, such as:
Generally, operate with straightforward modest procedure and constrained formal documentation [1].
- Short duration.
- Involve relatively few staff [2].
- Act within a restricted territory.
- Low capital outlay.
- Most necessities are accessible locally
- Often the objective is to generate a specific benefit, contingent upon needs.
- High creativity and productivity levels, notwithstanding minimal managerial expenses [1].

3. Analytic Hierarchal Process (AHP)

The analytic hierarchical process (AHP) approach is an efficient multi-criterion assessment technique where people are empowered to construct multi-part issues within a progressive system for assessing quantitative and subjective components. The AHP determines the means by which participants decide the overall significance of various options in a multi-criteria basic leadership condition. It allows managers to decide the different variables with their loads, which indicates their significance and the chain of importance relevant to the choice [3].

The AHP was created by Saaty, who established a reliable method for changing pairwise correlations into figures speaking to the overall needs of each criterion, as shown in Table 1.

| Importance | Description                                |
|------------|--------------------------------------------|
| 1          | Equivalent significance                     |
| 3          | Modest significance of one over another     |
| 5          | Strong or essential significance            |
| 7          | Very strong or demonstrated importance      |
| 9          | Extreme significance                        |
| 2, 4, 6, 8 | Intermediary values                         |

3.1 Building the Hierarchy

To build the hierarchy requires transformation of transforming the judgement problem into a hierarchical model, with the objective at the apex of the pyramid and decision alternates at the lower level. In the building step, we see that the benefit of the hierarchal analysis is connected with the number of issues concerned in decision-making. Figure 1 illustrates.
3.2 Constructing the Pairwise Appraisals Matrix

The components of a specific stage are compared with respect to a certain element at the higher step stage. Decisions are devised for contrasting, utilizing estimation scales of 1–9. The comparisons number depending on the number of items to be compared, as in the following Equation (1):

\[
\text{The number of comparisons} = \frac{n(n-1)}{2}
\]

Where \( n \) is the number of criteria [4].

3.3 Calculating Priorities for Criteria with Relevance to the Goal

A normalization matrix is built for irregular data elimination, on the basis of equation (2). The resultant matrix accumulates elements in each column in the pairwise appraisal matrix. Each column’s elements must divide by the summation of the column to produce the normalized scores. Each column’s summation must be equal to 1.

Assuming that \( e_{ij} \) describes the element \((i, j)\) of appraisal matrix:

\[
N_{ij} = \frac{e_{ij}}{\sum e_{ij}}
\]

Where \( N_{ij} \) is the normalized pairwise comparison matrix of criteria \( i \) with criteria \( j \) [5]. The overall priority weights for criterion are obtained by averaging the values made in each row, based on Equation (2), and this indicates the relative significance of the criteria with respect to the objective. The sum of all priority vectors for criteria must equal 1.

\[
O_c = \frac{\sum_{j=1}^{n} N_{ij}}{n}
\]

Where \( O_c \) refers to the overall priority weights of criteria [6].

3.4 Calculating Alternatives Priority with Reference to Each Criterion

All scores are calculated for each criterion in the normalizing matrix as a result of calculating each alternative’s row averages in the matrix. The criteria won’t have the same significance. Therefore, this step in the analytical hierarchy process will develop each criterion’s relative precedence (weight). This weighting is described as relative because the achieved criterion precedencies are measured with respect to other criteria.

3.5 Consistency Checking

Before using the resultant totalities from the normalized appraisal matrix, and the preferences specified in the original, pairwise appraisal matrix must be checked for consistency. This is determined by Equation (4),

\[
C. I. = \frac{\lambda_{\text{max}} - n}{(n-1)}
\]

\( n \) : is the comparing elements number [7].

\( \lambda_{\text{max}} \): eigenvalue, found by summation of each elements produces of all priority vector \( (O_c) \) and the pairwise comparison matrix \( (e_{ij}) \) column summation as in the below equation [8].
\[ \lambda_{\text{max}} = \sum_{j=1}^{n} \left[ \sum_{i=1}^{n} e_{ij} \theta_{ij} \right] / g_{2924} / g_{2920} / g_{2880} / g_{2869} \]  

(5)

4. The Weighted Summation Method (WSM) [8]

The weighted summation method (WSM) is a methodology widely used in selection problems, specifically in particular dimension problems. When there are M alternates and N criteria, then viable alternate is the one which satisfies the following equation:

\[ W_{\text{WSM}} = \text{Max} \sum_{j=1}^{N} e_{ij} w_{j} \text{ for } i = 1, 2, 3, \ldots, N \]  

(6)

- \( W_{\text{WSM}} \) is the best alternative’s WSM scores.
- \( N \): decisions criteria number.
- \( e_{ij} \): real value of  \( i \)th alternate in terms of the \( j \)th criteria.
- \( w_{j} \): importance weightiness for \( j \)th of criteria [9].

The whole value of each alternative equals products summation. The execution of the WSM requires the assessments of each option on 0–100 limited measures for all criteria, whereby the higher score expresses the best performance with the conforming criterions. The technique is compliant for quantitative documents, such as budgets and effectiveness figures, that are automatically planned for 0–100 local scales, and when no quantitative information can be obtained the decision-makers must rate the options’ performances with an arithmetical scale directly.

The immediate ratings frequently use values between zero (the poorest potential option) and one hundred (the most viable possible option). This model complexity begins when applied to multiple-extent decision making problems. In merging different dimensions, and dissimilar units, the additives value statement is violated. It has been utilized with dissimilar implementations such as robots [10].

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**Figure 2.** FAST diagram for implementing the small projects in a research environment [11].
5. First Stage for Small Project Selection
This step comprises investment valuation and selection. The investments must be arranged in descending order relative to specific limitations, and are identified as feasible to be implemented in the working environment where the society needs them and to examine their current limitations (such as taxes imposed and the readiness of the environment for such investments, appropriateness to the community and the social requirement. A mathematical model is applied, to choose the top investment weight. All data and information applied at this stage are obtained from the Investment Authority of Karbala Governorate. The following must be determined at this point:

1. The size of investment.
2. Types of investment offered.
3. Selection of environment within which investments may be implemented.
4. Set investment objectives.
5. Identify each alternative: Ai, Where the number of Ai=m.
6. Identify each restriction (criteria): Rj, Where the number of Rj=n.
7. Significance for restriction (criteria) i in respect to the other criteria j, (Sij)
8. Significance for alternative i respecting to the other alternate j based on each criterion (w ij). If i=j then Sij=1.

Finally, we have the weights of alternatives and this permits the choice of best investment, that being the option having the highest weight for achieving governorate's strategic planning goals. After taking the decision, begin the investor’s role is to choose the best small project.

5.1 Identification of Alternatives for Investment
Karbala governorate has many significant and possible investments. In this study, four creative investments (alternatives) are chosen with regard to the governorate’s requirements and resources:

1- Agricultural investment: Many fields can classified under this category, such as the cultivation of rare dates that can be sold locally and abroad. Also, projects that use glasshouses to generate seasonal products (vegetables and fruits ) through the year .
2- Industrial investment: Options include plastic industries (agricultural tools, pots and dolls) where there is a probability of providing raw materials easily; where equipment can easily be found in the local market and operation does not require great specialist proficiency. Also the food industry (canned foods and dairies) as a result of Karbala province being a flourishing area, the paper industry and manufacturing of building materials.
3- Services investment; Including marketing projects, internet companies , transport , health centers and schools.
4- Commercial investment: For example, the marketing of building equipment, electronics, building up poultry fields and others.

5.2 Investment Criteria Identification
Many criteria should be calculated to formulate the problem, as follows:

1- The governorate needs the offered project: this criterion expresses the extent to which the society overseen by the governorate needs such projects. This information is obtained from the annual strategic plan.
2- Availability of funds required for establishing the project: this criterion requires the required funds for establishing and operating any project must be available from the commercial investor’s budget.
3- Period length needed for instituting the project: this criterion dictates that the project establishment period must be calculated. Shorter duration means a project has greater feasibility, and will start to achieve the incomes sooner after construction, due to earlier operation.
4- Provision of job opportunities by the project: this criterion focuses on people working numbers from the governorate involved in the project. Larger projects are more feasible under this criterion since they are better able to absorb unemployment.
5- Infrastructure and raw materials: this criterion explores the availability of raw materials required to operate the project in the same governorate or nearby, and the local capacity to provide crucial infrastructure (electricity, water, communication lines, transportation, fuel, etc.).

6- Knowledge availability, procedure and work skills: for this criterion a full knowledge of the proposed project must be available including work techniques, machinery, production processes and raw materials. How to deliver products if the project is productive, and in the case of projects requiring professional services, how to provide those services.

7- Marketing ability: this criterion focuses on entering the market easily and marketing the products generated by the project. The marketing stage is one of the most crucial work stages in any project.

8- Project risks: this criterion considers the prospective risks which may appear as a failure in the project, for example high levels of competition, environmental threat or decreasing incomes (e.g. through damage to raw materials due to particular environmental exposure, or short product lifespans which may cause major loss if the products cannot be marketed).

9- Capacity of project for growth and sustainability: this criterion encompasses the extent to which the project should be able to offer its products/services continuously to the local market, where this criterion depends on all the preceding criteria.

10- Return on investment and expected incomes: under this criterion the project should be able to achieve an adequate and acceptable profit percentage, otherwise it is not feasible.

These criteria were proposed by the researcher when comparing fifteen criteria from a research study published the National Investment Authority entitled *How to Choose Your Project*, along with other references of project selection and these ten common criterions.

5.3 Select the Size of Investment and Input Data

The investment size specified for small investments has ranged 25,000,000 million – 250,000,000 million Iraqi dinars (1 $ = 1200 Iraqi dinars). These numbers has been assessed with respect to projects of small size implemented in the governorate, which are shown in Table 2 with the selected investments.

The problem is formulated as follows:
1. Number of alternatives (Ai), i=4
2. Number of Criteria (Cj), j=10

| Criteria                                      | Symbol | Alternatives  | Symbol |
|-----------------------------------------------|--------|---------------|--------|
| The governorate’s need for proposed project   | C1     | Agriculture   | A1     |
| The availabilities of funds required for      | C2     | Industrial    | A2     |
| establishing the project                      |        | Investment    |        |
| Duration for establishing a project           | C3     | Service       | A3     |
| Provision of job opportunities by the project | C4     | Commercial    | A4     |
| Raw materials and requirements                | C5     |               |        |
| Knowledge availability, procedure and work    | C6     |               |        |
| skills                                        |        |               |        |
| Marketing ability                             | C7     |               |        |
| Project risks                                 | C8     |               |        |
| Capacity of project for growth and sustainability | C9     |               |        |
3. The significance of each criterion $i$ with respect to other criterion $j$, $(e_{ij})$, is presented in Table 3. All criterion significance numbers applied in importance tables were collected by an employee, supervisor in Karbala Investment Authority, for the granting of investment licenses.

| Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|----------|----|----|----|----|----|----|----|----|----|-----|
| C1       | 1  | 1/2| 3  | 3  | 1  | 7  | 1  | 1  | 3  | 1   |
| C2       | 1/2| 1  | 5  | 3  | 3  | 3  | 2  | 1/3| 1/2|     |
| C3       | 1  | 1  | 5  | 1/2| 1  | 1  | 1/3| 5  | 1   |
| C4       | 1  | 1/5| 1/3| 1/3| 1/2| 1/3| 1/5|    |     |
| C5       | 1  | 1  | 2  | 5  | 3  | 3  | 1  |    |     |
| C6       | 1  | 1  | 2  | 1/2| 1  | 1/7|    |    |     |
| C7       | 1  | 1  | 1  | 1  | 1  | 1/3|    |    |     |
| C8       | 1  | 1  | 1/2| 1/2|    |    |    |    |     |
| C9       | 1  | 1  | 1/3|    |    |    |    |    |     |
| C10      |    |    |    |    |    |    |    |    |    | 1   |

The areas shadowed Table 3 signify horizontal significance equal to the inverse of the vertical significance $(e_{ij} = 1/e_{ji})$. 


6. Applying AHP Model

Implementation of the first stage (investment selection) was conducted by applying the analytical hierarchy process with Expert Choice software to generate results, as in the following steps:

6.1 Building up the Hierarchy

The problem was organized in a progressive system structure. The problem levels were clearly presented as a top down list showing objective, criteria and alternatives, as Figure 6 illustrates.

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Figure 5. Alternatives' importance with respect to the other alternatives for each criterion

Figure 6. AHP Hierarchy
6.2 Building the Pair-wise Evaluation Matrix

The criteria significance from Table 2 was applied with Expert Choice 11 software as shown in Figure 7.

![Figure 7. Priority of all Criteria](image)

Dark numbers on a precedence cell imply that the vertical paradigm could really compare to the even rule (1,2,3..., 9), and red numbers on the precedence cell imply that the level measure could easily compare to the vertical basis (1,1/2,1/3..., 1/9). The priority for each criterion with respect to the goal depending on preceding AHP steps is shown in Figure 8.

![Figure 8. Priorities of criteria with respect to the goal](image)

Table 4. Importance Results Summarization of Alternates for Each Criterion

|                   | Agricultural Investment | Industrial Investment | Serving Investment | Commercial Investment |
|-------------------|-------------------------|-----------------------|--------------------|-----------------------|
|                   | (I1)                    | (I2)                  | (I3)               | (I4)                  |
| Priority          |                         |                       |                    |                       |
Table 4 shows that each investment has differs from the others in terms of criterion significance, whereby the job opportunities weight that may be provided by the project criteria C4 = 0.262 in agricultural investment while in industrialist investment C4=0.562, C4=0.101 in service investment and C4=0.112 in commercial investment. This will assist investment selection if the governorate’s highest goal is to offer job opportunities.

6.3 Determining the Overall Rate
The overall rate can be obtaining by determining each alternative’s value and selecting that which has the maximum value. Investment ranking results, showing industrial investment to be the Karbala governorate’ priority and which needs local governorate support for its small projects, are shown in Figure 9.
7. Second Stage of Small Project Selection
When the best investment, which achieves a certain objective, is selected, the alternative small projects with this investment type will be suggested with respect to the size of investment and whether the small project is required and could achieved the specified goal.

The investor selects the project which he desires to be executed in light of his technical and financial capabilities and providing the investment terms, he then proffers it to the authority involved. The relevant project scores are submitted by the investors and confirmed in order of their importance. All submitted projects may be supported by executing authority if they have sufficient resources. The criteria must be selected (specifically the size of the investment, technical and financial capabilities of the investor), that are required for comparison to elect the best small project using the WSM method.

Implementing the proposed model will involve project identification, identification of the projects that are needed by local governorate to implement an annual strategy and determination of the requirements and estimated cost of these projects.

7.1 Identify Small Project Alternatives and Criteria
In this study, when the alternatives’ values results were ranked, the industrial options appeared to show top value. Hence, we will take the small projects alternates in an industry field for implementation in the city and calculate its scores to find the best small project for investor that have the maximum scores within the definite criterions.

The industrial field has a wide scope and its projects are numerous. At this stage five of the small industrial projects (Pi) are selected and studied from the investors and submitted to the Industrial Bank (Karbala branch) for loans. The projects, whose scores will be determined below, are the projects with a greater rate of return and a lesser retrieval period than the other feasibility study. Table 5 shows the suggested small projects and comparisons of criteria required to apply the second stage, where the criterion weights are taken from the investment selection stage.

| Criteria                                           | Symbol | Alternatives       | Symbol |
|----------------------------------------------------|--------|--------------------|--------|
| The governorate needs the proposed project         | C1     | Dates factory      | P1     |
| The availabilities of funds requiring for establishing the project | C2     | Water filling factory | P2     |
| Duration required to establish project             | C3     | Dairy factory      | P3     |
| Provision of job opportunities by the project      | C4     | Block factory      | P4     |
Raw materials and requirements
Knowledge availability, procedure and works skills
Marketing ability
Project risks
Capacity of project for growth and sustainability
Return on investment and expected incomes

7.2 Applying the WSM
The small projects’ data were gained from their feasibility studies and through expert assessment. Table 6 shows their ratios and weights.

| Alternatives | C1  | C2  | C3  | C4  | C5  | C6  | C7  | C8  | C9  | C10 |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| P1           | 0.27| 0.21| 0.21| 0.17| 0.22| 0.20| 0.23| 0.05| 0.18| 0.26|
| P2           | 0.27| 0.13| 0.14| 0.13| 0.20| 0.20| 0.22| 0.23| 0.07| 0.12|
| P3           | 0.18| 0.42| 0.43| 0.27| 0.21| 0.20| 0.20| 0.34| 0.27| 0.28|
| P4           | 0.18| 0.13| 0.07| 0.33| 0.20| 0.20| 0.17| 0.11| 0.18| 0.19|
| P5           | 0.09| 0.13| 0.14| 0.10| 0.16| 0.20| 0.18| 0.27| 0.29| 0.15|

Microsoft Excel 2010 was used for score calculation by application of the WSM.

| Alternatives               | Score  |
|----------------------------|--------|
| Dates factory (P1)         | 0.6485 |
| Water filling factory (P2) | 0.5901 |
| Dairy factory (P3)         | 0.9650 |
| Block factory (P4)         | 0.6191 |
Table 7 shows the highest scoring option was the dairy factory (P3), which means it is the best small project for implementation and it has the priority in terms of achieving a specified goal.

8. Results & Discussion
Small project selection is an essential step to ensure achievement of a project goal, and through studying criteria and related importance it is possible to select the more feasible from all options available. The AHP and WSM methods aid small project selection where qualitative and quantitative data can be involved in the prioritisation process, and help to make an evaluation procedure that aids investors to take the right decision with the least resources.

In this study, the first stage of investment selection when applying the AHP model provided the criteria’s importance for each alternative and allowed interested parties to understand each criterion’s importance to this investment. The second stage showed the Karbala governorate need for the dairy factory because it had the highest scores in terms of the weights accorded to its criteria, and the date factory has the second grade in terms of the governorate’s need. Applying the WSM gave us an expeditious method by which to determine alternative scores in cases lacking data.

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