Evaluating Implementation of Electric Power Generation Projects in Iraq

Ameer A. Nadhum¹, a *, Kadhim R. Erzaij¹, b

¹Civil Engineering Department, University of Baghdad, Baghdad- Iraq
a.nathum1001@coeng.uobaghdad.edu.iq, b kadhim1969@yahoo.com

Abstract. Iraq has witnessed development in many fields and the electricity production sector is one of the most important of these fields. This is attributed to the State's philosophy in supporting this sector through the development of economic development projects to serve and raise the level of the Iraqi individual. Electricity production in Iraq is affected by many variables such as load growth, economic and financial conditions, planning, etc. All these led to a disparity in the production of electric power to cover the demand for energy. The paper deals with the electricity generation sector overview in Iraq, Analysis of the effects of variables on the implementation of power generation projects in Iraq, and Creating a mathematical model. The results enable decision-makers to prioritize the implementation of power generation projects in Iraq.

Keywords: Electrical power planning, Implementation of power generation projects, Multi-linear regression.

1. Introduction

The electricity sector is a vital sector that plays an important role in the economic development of many countries that have faced wars such as Iraq [1]. The implementation of power plant projects in Iraq is one of the important elements in improving the reality of electric power, which suffers from a deficit in the provision of electric power over the past decades for several political, security and economic reasons. The authors provide an assessment of the factors of implementation of power generation projects in Iraq and consider how to draw policy can determine the priority of project implementation according to these factors. They discuss the requirements of the management of the implementation of these projects, in which the objectives of this policy can be achieved to implementation of projects better.

Electrical power planning has been determined in varying degrees of inclusiveness. Some scientists have given relatively narrow definitions. There are several definitions in this area where energy planning is known, Hiremath et al. (2007) states that “energy planning is limited to having sources and switching devices in groups that ideally meet the energy requirements of various tasks. This can occur at the central or decentralized level” [2]. A process aimed at finding a solution, often at the lowest cost, for a particular centralized or decentralized demand. Later, however, the scope of energy planning was greatly expanded.

Both Rojas-Zerpa and Yusta (2014) and Loken (2007) have debated that energy planning problems are limited to multiple criteria for decision-making, so that a simple and globally optimal planning does not exist [3,4]. However, both views reflect[2]. Energy planning, often by focusing on finding many suitable options for power supply. There are comprehensive definitions of energy planning by other researchers. Summarized under the term integrated energy planning. Bhattacharya (2012), in his paper on off-grid electricity planning, mentioned that “successful implementation… requires careful planning of all phases associated, which goes beyond stripping technology selection or selection decision of
component” [5]. Along the value series and from other stages that he considers important for energy planning for obtaining on best estimates of demand, energy delivery, and appropriate implementation mechanisms Bhattacharyya remarkably highlighted the importance of energy planning analysis to draw valuable lessons for future projects.

Mirakyan and De Guio (2013) display a broader definition in their review of integrated energy planning. It again features the multi-criteria nature of energy planning, its applicability at different units of analysis, and their diffusion across different stages of the value chain for different power stages including generation, transmission, distribution [6]. Söderholm (1999) notes that lifetime costing approaches tend to miss considerations of maximum energy demand, rather than focusing on actual energy provided for a longer period. Most technologies may be economically viable in these cases, despite their high lifetime cost to prevent temporary power outages. In general, he points out that economic standards are of global importance for finding more cost-effective solutions for supplying electricity to developing [7].

Technological factors generally include functionality, reliability, efficiency, safety, and energy quality measured in exergy content. For example, Okello et al. (2014) found several technological advantages to the use of bioenergy technology including reliability, safety, and functionality [8]. Researchers P. A. Trotter, M. C. McManus, and R. Maconachie (2017), a systematic review of the planning and implementation of electricity in sub-Saharan Africa, analyzed decision factors and criteria that ensure economic, social, environmental, technological and political standards [9]. The objective of this study is to identify the factors that most influence the implementation of electric power generation projects in Iraq.

2. Methodology

One of the most important methods used to provide engineering solutions to problems. Many data that includes many variables can be used by analyzing it, and results can be used and entered in many applications. In this paper, a statistical method for prediction will be used by analyzing the factors statistically and creating a mathematical model using the SPSS statistical analysis program through which a strategic plan is developed to implementation of electric power generation projects in Iraq and determine the priority of implementation of these projects.

3. Electricity generation sector overview in Iraq

Most of the existing stations in Iraq were built between 1955 and 1986. Many were damaged during the first Gulf War in 1991 and did not receive adequate rehabilitation or maintenance due to lack of spare parts and the shortage of skills imposed by the economic sanctions for more than 12 years following the Gulf War, with a few small gas stations that operated in 2003. Iraq’s other generating capacity weaknesses include low generating availability, high technical losses, and load factors resulting in an inability to cope with peak daily demand. Most of the existing electric power plants are thermal electric plants that use crude oil backed by gas and fire plants [10].

Types of electrical generation plants in Iraq are thermal power plants, gas power plants, diesel power plants, and hydropower plants. Within the formations of the Ministry of Electricity, there are four public companies for the production of electricity distributed by geographical regions of Iraq, namely: North Production Company, South Production Company, Middle Production Company, and Middle Euphrates Production Company. The total power generation according to the installed capacity of the four companies is more than 27182 MW and the total power generation for the operating units is 22592 MW and the actual production rate is 9758 MW[11]. These stations are composed of 375 generating units, of which 277 units are in operation with a generating capacity ranging from 1.7 to 610 MW Alone. These generating units are distributed according to their eight hydroelectric power plants with a combined design capacity of 1674 MW, eight thermal power plants with a total capacity of 5,985 MW, 33 gas turbine power plants with a total capacity of about 13,414 MW and 12 diesel engine stations with a total capacity of 1,594 MW. The country also imports about 914 MW[11] from neighboring countries and local investment stations. Fig. 1 shows an overview of electricity generation, which relies mostly on fossil fuels, which accounts for more than 86.3 percent of the main electricity sources in the grid [10].
4. Database
The factors that interfere in this context are based on the data collected through the work of a questionnaire in cooperation with decision-makers, experts and specialists in the energy field in the Iraqi Ministry of Electricity as well as university professors after investigating the interviews and making the required adjustments to create the questionnaire and distribute it to specialists and experts and determine the factors affecting the implementation of generation projects Electrical energy in Iraq. These factors are classified by the researcher to implementation of generation projects electrical energy in Iraq that include major factors financial and economic aspect, availability of infrastructure, and planning aspect, and sub-criteria as shown in Table 1.

Table 1. Main criteria affecting the implementation of power plant projects and their sub-criteria.

| Code | Main criteria                  | Code   | Sub-criteria                                |
|------|--------------------------------|--------|---------------------------------------------|
| C1   | Financial and economic aspect  | C1-F1  | Capital cost of project                     |
|      |                                | C1-F2  | Operating and Maintenance Cost              |
|      |                                | C1-F3  | Project duration                            |
|      |                                | C2-F1  | Near the location of the transmission lines |
|      |                                | C2-F2  | Near the site from the discharge source loads |
|      |                                | C2-F3  | Near the site of the source of water to cool the station |
| C2   | Infrastructure availability    |        |                                             |
| C3   | Planning aspect                | C3-F1  | Capacity of the station                     |
|      |                                | C3-F2  | Project area                                |

5. Linear Regression
When there is a linear relationship between the variable factors it is called linear regression. There are two types of linear regression, the first is simply one variable and the second is multiple variables [12]. If more than one independent variable is used, the multivariate linear regression (MLR) is used. Eq. 1 shows the linear model of MLR formula.

\[
y = a + b_1 * X_1 + b_2 * X_2 + b_3 * X_3 + \ldots + b_n * X_n + \text{Error} \tag{1}\n\]

Where
- \(a\): is the intercept
- \(b_1, b_2, b_3\) and \(b_n\): the slopes.
- \(Y\): is the dependent variable
- \(X_1, X_2, X_3\) and \(X_n\): the independent variables [13].
5.1. Create the mathematical model

In this paper, the factors that influence the implementation of electric power generation projects in Iraq will be analyzed to create a mathematical model financial and economic aspect, availability of infrastructure, planning aspect.

5.2. Financial and economic aspect

To determine the financial and economic aspects of energy resources, "Levelized-cost" is generally used. This cost takes into account all the costs of the plant from the capital, operation, and maintenance. The initial cost of construction and his modification cost can be classified at the capital cost. This cost is covered and is amortized over by the energy output expected to be generated during plant life. As for the daily costs associated with operating the electric power plant, it is classified under maintenance and operation costs [14]. Dealing with the variables financial and economic aspect that has the most important impact on the factors of implementation of projects of electric power production, which are appropriate with the formula is as shown in Eq. 2

\[
F_{EA} = C + (F_1 \times I_1) + (F_2 \times I_2) + (F_3 \times I_3)
\]  

(2)

Where:
- FEA: Financial and economic aspect
- C: Constant
- I_1: Plant Capital Cost
- I_2: Operation and Maintenance Cost
- I_3: Project Duration

Through analyzing the questionnaire using the SPSS statistical analysis program and analyzing the parameters, it is shown to us in Table 2. From the analysis of parameters, the equation for the financial and economic aspects as shown in Eq. 3.

\[
F_{EA} = 0.14 + 0.579 I_1 + 0.286 I_2 + 0.125 I_3
\]  

(3)

| Parameter       | Estimate | Std. Error | Lower Bound | Upper Bound |
|-----------------|----------|------------|-------------|-------------|
| Constant (C)    | 0.14     | 0.346      | -0.558      | 0.839       |
| F_1             | 0.579    | 0.098      | 0.381       | 0.776       |
| F_2             | 0.286    | 0.100      | 0.084       | 0.487       |
| F_3             | 0.125    | 0.110      | -0.097      | 0.346       |

This equation Eq. 3 is used to calculate the effect of the financial and economic factor, to use into the calculation of the main equation. Table 3 shows a summary of the mathematical model shown in Eq. 3 and shows the reliability of this equation for its sub-factors with the main factor.

Table 3. Model Summary of dependent variables for financial and economic aspects.

| Model | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------|----------|-------------------|---------------------------|
| 1     | 0.882a| 0.778    | 0.762             | 0.490                     |

a. Predictors: (Constant), Project duration (Project schedule until the station is operational and connected to the network), Operating and Maintenance Cost, the cost of setting up the project

b. Dependent Variable: Financial and economic aspect
6. Availability of Infrastructure

Generation power plant projects are experiencing problems of locating more than other different projects due to the difficulty of linking these plants with power transmission lines because they usually face the problems of land possession with many different owners. These problems may lead to opposition from the local people and may require lengthy procedures to address and eliminate these difficulties and obstacles, which may lead to time delays. As such, it proposes locating the nearest power transmission networks as well as their proximity to the loads discharge centers [15]. The independent variables of the availability of infrastructure that have the most important influence on the factors of implementation of electric energy production projects, which are appropriate with the formula is as shown in Eq. 4.

$$AI = C + (A_1 \times I_1) + (A_2 \times I_2) + (A_3 \times I_3)$$  

(4)

Where:

- $AI$: Availability of infrastructure
- $C$: Constant
- $I_1$: Distance of Project Site from The Transmission Lines
- $I_2$: Distance of Project Site from The Source of Discharge Loads
- $I_3$: Distance of project site from the water source (cool plant)

Through analyzing the questionnaire using the SPSS statistical analysis program and analyzing the parameters, it is shown to us in Table 4.

| Parameter          | Estimate | Std. Error | 95% Confidence Interval      |
|--------------------|----------|------------|-----------------------------|
| Constant (C)       | 0.234    | 0.252      | -0.274 - 0.742              |
| $A_1$              | 0.289    | 0.167      | -0.048 - 0.627              |
| $A_2$              | 0.415    | 0.197      | 0.017 - 0.813               |
| $A_3$              | 0.207    | 0.173      | -0.143 - 0.558              |

From the analysis of parameters, the equation for availability of infrastructure as shown Eq. 5

$$AI = 0.234 + 0.289 I_1 + 0.415 I_2 + 0.207 I_3$$  

(5)

This equation Eq. 5 is used to calculate the effect of Availability of infrastructure, to use into the calculation of the main equation. Table 5 shows a summary of the mathematical model shown in Eq. 5 and shows the reliability of this equation for its sub-factors with the main factor.

Table 5. Model Summary of dependent variables for financial and economic aspects.

| Model | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------|----------|-------------------|----------------------------|
| 1     | 0.914 | 0.836    | 0.824             | 0.404                      |

a. Predictors: (Constant), Near the site of the source of water for the cooling of plant, Near the location of the transmission lines (the presence of a transport network close to the center of the load to connect the plant to the plant's link to the national grid transmitting energy), Near the site from the discharge source loads

b. Dependent Variable: Availability of infrastructure

7. Planning aspect

The planning aspect includes many sub-factors and tasks that fall within the planning process. It is not possible to deal with all aspects and problems of planning in one way. Therefore, studies that combine several factors, stages and different ways to achieve the goals of all aspects of planning are important
[6]. Dealing with the independent variables for Planning aspects that have the most important impact on the factors of implementation of projects of electric power production, which are appropriate with the formula is as shown in Eq. 6.

\[ PA = C + (P_1 \times I_1) + (P_2 \times I_2) \]  

(6)

Where:
PA: Planning aspect
C: Constant
I_1: Plant Capacity
I_2: Project Area

Through analyzing the questionnaire using the SPSS statistical analysis program and analyzing the parameters, it is shown to us in Table 6.

| Parameter       | Estimate | Std. Error | 95% Confidence Interval |
|-----------------|----------|------------|-------------------------|
| Constant (C)    | 1.21     | 0.287      | 0.632 - 1.789           |
| P_1             | 0.392    | 0.082      | 0.226 - 0.557           |
| P_2             | 0.344    | 0.081      | 0.180 - 0.508           |

From the analysis of parameters, the equation for the planning aspect as shown in Eq. 7.

\[ PA = 1.21 + 0.392 \times I_1 + 0.344 \times I_2 \]  

(7)

This equation Eq. 7 is used to calculate the effect of the planning aspect, to use into the calculation of the main equation. Table 7 shows a summary of the mathematical model shown in Eq. 7 and shows the reliability of this equation for its sub-factors with the main factor.

| Model | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------|----------|-------------------|---------------------------|
| 1     | 0.824 | 0.679    | 0.664             | 0.428                     |

Table 7. Model Summary of dependent variables for the planning aspect.

From the results of sub-criteria, were dealing with the independent variables for Factors affecting the implementation of power plant projects that have the most important impact on the factors of implementation of projects of electric power production, which are appropriate with the formula is as shown in Eq. 8.

\[ FAIPPP = (W_1 \times FEA) + (W_2 \times AI) + (W_3 \times PA) \]  

(8)

Where:
FAIPPP: Factors affecting the implementation of power plants projects
FEA: Financial and economic aspect
AI: Availability of infrastructure
PA: Planning aspect

Through the use of the SPSS statistical analysis program for the questionnaire, finding the arithmetic mean, and obtaining the weight of each of the main equation factors so that weights (W) appeared as shown in Table 8.
Table 8. Parameter weight of variables for implementation of power plant projects.

| Parameter | W_1 | W_2 | W_3 |
|-----------|-----|-----|-----|
| Weight    | 0.339 | 0.326 | 0.335 |

From the analysis of parameters, the equation for variables for implementation of power plants projects as shown in Eq. 9:

\[
\text{FAIPPP} = 0.339 \times \text{FEA} + 0.326 \times \text{AI} + 0.335 \times \text{PA}
\]  

This equation, using to calculate the priority of implementing electric power generation projects in Iraq by entering the calculation of the effect of the factors of implementing power generation projects and their weights. This equation is used on the projects proposed to be implemented, showing us the order of priority of implementing these projects according to their importance. Table 9 shows data for a series of electrical power generation projects that were previously implemented according to the Iraqi Ministry of Electricity.

Table 9. Electrical power generation projects that were previously implemented in Iraq.

| Generating Station | Plant Capital Cost $/MW | Operation and Maintenance Cost $/MW | Project Duration Day | DPS from the Transmission Lines km | DPS from The Source of Discharge Loads km | DPS from the water source km | Capacity MW | Project Area m² |
|--------------------|------------------------|-------------------------------------|----------------------|-----------------------------------|------------------------------------------|-----------------------------|-------------|-----------------|
| A                  | 870253                 | 3600                                | 540                  | 2.27                              | 6.34                                     | 4.63                        | 500         | 632192          |
| B                  | 766856                 | 5700                                | 720                  | 11.23                             | 14                                       | 1.42                        | 1250        | 485530          |
| C                  | 915660                 | 5700                                | 540                  | 0.63                              | 8                                        | 0.18                        | 500         | 10000           |
| D                  | 787656                 | 3500                                | 510                  | 1                                 | 3.22                                     | 2.26                        | 292         | 118786          |
| E                  | 767490                 | 5700                                | 540                  | 15                                | 21.15                                    | 10                          | 500         | 63364           |

CLV: Compared with the largest value.
CSV: Compared with the smallest value.

Through the use of Eq. 9, the implementation of electric power generation projects will be arranged according to their importance to factors, and this equation will be applied to several projects previously implemented by the Iraqi Ministry of Electricity as follows in Table 10.

Table 10. Prioritizing the implementation of electric power generation projects in Iraq.

| Station | W_1 | Eq.3: FEA% | W_2 | Eq.5: AI% | W_3 | Eq.7: PA% | Eq.9: FAIPPP% | Ranking |
|---------|-----|------------|-----|-----------|-----|-----------|---------------|---------|
| A       | 0.339 × 82.60693 + 0.326 × 30.13674 + 0.335 × 51.29 = 55.01048 | 2 | 55.01048% |       |       |       |               |         |
| B       | 0.339 × 89.73067 + 0.326 × 14.02423 + 0.335 × 57.1294713 = 54.12897 | 3 | 54.12897% |       |       |       |               |         |
| C       | 0.339 × 96.015 + 0.326 × 66.53775 + 0.335 × 43.3095561 = 68.74909 | 1 | 68.74909% |       |       |       |               |         |
| D       | 0.339 × 76.36148 + 0.326 × 61.58967 + 0.335 × 10.9112585 = 49.62005 | 4 | 49.62005% |       |       |       |               |         |
| E       | 0.339 × 86.64575 + 0.326 × 8.138603 + 0.335 × 23.3536035 = 39.84955 | 5 | 39.84955% |       |       |       |               |         |

The results show that Project (C) ranked first with a score of points 68.74909%, Project (A) ranked second with a score of points 55.01048%, while Project (B) ranked third with a total score 54.12897%, Project (D) ranked fourth with a score of points 49.62005%, finally Project (E) ranked fifth and last...
among the projects 39.84955% that were applied the equation to its data, and in this formula, we get a sequence of projects that must be implemented according to their importance and by the sources of funding and government budgets.

9. Conclusion
After obtaining the results to successfully apply the equations and prioritize the stations for each project, the conclusion can be summarized as follows:

- The MLR multivariate linear regression model provided good results by validating the training data series.
- Through analyzing the questionnaire using the SPSS statistical analysis program and obtaining weights of the main factors (W), we realize that the financial and economic factor is the most influential on the implementation of electricity generation projects in Iraq.
- The mathematical model assists decision-makers in setting a priority implementation of future electric power generation projects in Iraq and strategic plans.
- The mathematical model equation can be developed by applying it to renewable energy plant projects by creating other factors that affect the priority of implementing renewable power plant projects such as solar energy, wind energy and other energies.

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