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# CIVIL PROJECT MANAGEMENT IN COST AND DURATION REDUCTION WITH PRIORITIZATION OF SUITABLE CONSTRUCTION WORKSHOP ARRANGEMENT

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## ABSTRACT

*With the increasing advance and development of industry, more facilities and equipment have been made for construction industry and civil works, which as a consequence of these advanced equipment and facilities, the conduction of large and more complicated civil projects is now possible. On the other hand, with the increase of size and complexity of civil projects, the need for safety and reserving the environment and finding ways in order to reduce accidents in construction workshops is felt more than ever. With an accurate and systematic planning for suitably arranging the construction workshops, aside from providing more various factors involved with projects, the operational costs can be reduced while also the environment is preserved. In this project, using the TOPSIS analysis method, we have assessed and prioritized the equipment and facilities placement according to the norms of duration, environment and cost in construction workshops so that the consequent issues are minimized. Based on the analyses, the norms of environment, cost and duration are orderly prioritized and it is necessary for the projects that the workshop is equipped according to these factors to consider the safety, accessibility, project planning, total budget, projects location and duration of work as the main priorities so that workshop equipment be lucrative.*

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KEY WORDS

*Construction safety, Project management, TOPSIS, Workshop equipment*

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## INTRODUCTION

One of the important concepts influencing the quality advantage of civil engineering projects is accompanied with cost reduction in construction workshops and workshop equipment. This concept may have a significant direct or indirect effect on human resources capabilities and also on utilization and effectiveness of the required resources of projects. Because with a decent workshop equipment, a suitable process can be guided and become systematic, however, a bad equipment can result in disturbance, dailiness and wasting the available workshop resources. The purpose of civil workshop placement is to identify, select and determine the temporary and necessary tools and equipment for conducting different constructive operations, determination of size, shape and the dimensions of equipment and finally placing them in the most efficient location inside or near the workshop at the duration of project conduction [1]. In order to present a method for construction workshop placement design, one of the methods can be inspiration from the former presented methods and combining them [2]. Zouein and Tommelein has proposed a method for dynamic placement of construction facilities. They attempted to create a sequence of placement during the life cycle of the project have tried to optimize placement by using linear planning and addressing the cost reduction caused by transportation and moving the facilities and equipment [3]. For the first duration, optimization of constructive operations in terms of safety and the effect of safety on workshop site design were investigated by Anumba and Bishop. In 1989, Farrel and Hover have studied the use of a software for suitable placement of cranes in construction workshops with the purpose of preventing the accidents caused by cranes [4]. Moreover, in 2010, Said and El-Rayes have considered the safety issues in fundamental structures and have pursued the issue of workshop site placement with the two goals of safety risk and cost reduction, and aside from the temporary fixed equipment, the temporary changeable equipment were also considered by them and they have proposed a dynamic placement model. This evaluation model is consisted of four main stages: [1] risk identification, [2] brightness safety optimization, [3] cost safety optimization, and [4] performance evaluation of the model [5]. Hegazy and Elbeltagi have generated a model based on genetic algorithm for site dynamic placement planning. This model using two dimensional reticulated coordinates are able to work with any disordered shape in the site area and each facility occupies a number of reticulated units based on its size and shape. The main advantage of this model to other proposed methods is its ability to work with any form of site and its lack of limit in using circular and square shape for facilities [6]. Sanad et al. [7, 8] have proposed a model in which aside from considering the real distance between facilities for minimizing the trip distance, cost were considered more accurately to the concept of safety. With the expansion and complication of civil engineering projects, the need for safety maintenance and finding ways to reduce incidents in workshops and also improving the generative yield accompanied with the need of conserving the environment is felt more than ever. In this study, using the TOPSIS analytic method, we attepted to evaluate and prioritize the tools and equipment placement based on environmental, duration and cost merits in construction workshops so that the consequent issues are minimized. Thus, identification of the effective factors is conducted using the available sources and the experts' opinions.

## MATERIALS AND METHODS

### Workshop equipment process

Workshop equipment include the activities that are performed before each project conduction [9]. Workshop equipment is of a significant role in the amount of cost, safety and the quality of projects. A decent workshop placement and equipment is enormously effective on the process of project conduction. Thus, considering the effective factors in this area and understanding the priority of these factors can be of a significant contribution to transportation optimization. Moreover, for gaining an understanding of the construction workshop equipment jargons, see [10, 11, and 12].

In each contract, a percentage or an amount of money is paid for workshop equipment. Basically, it is very important to conduct a primitive study on workshop before any executive operation. Generally, the workshop equipment procedure can be divided into different categories as it is shown in **Table- 1** [13 and 14].

**Table 1: Workshop equipment process**

| | |
|---|---|
| 1) Understanding the project and its related matters | 2) Design |
| 3) Provision of executive and preparatory plans for workshop | 4) Preparing the work place |
| 5) Providing the administrative, well-fare and facilities departments | 6) Procurement and provision of necessary materials |
| 7) Implementation and execution | 8) Equipment and machineries |
| 9) Maintenance, safety and health (12) | 10) Human resource provision |
| 11) Transportation provision | 12) Food provision |

Suitable placement in workshops contributes in reduction of pollution and ecological risks and conserving the environment. For instance, air pollution caused by excessive transportation in workshops can be reduced with placement which causes the reduction of transportation and trips inside the workshop. Furthermore, this can help reducing the access routes caused by suitable placement which results in prevention from destructing the natural resources. Generally, a decent and accurate placement of a construction workshop is of great significance as described in **Table- 2**:

**Table 2: the importance of suitable placement in construction workshops**

| | | |
|---|---|---|
| 1) Increasing the management level and quality | 2) Reducing the operational costs in projects | 3) Reducing the projects operation duration |
| 4) Increasing the quality level of workshop product | 5) Increasing safety in workshops | 6) Reducing the trip and transportation in workshops |
| 7) Reducing the ecological risks | 8) Minimum interruption in workshops | 9) Workers and workshops neighbors health and comfort |

### Data collection and analysis

A sample is consisted of a set of individuals that are selected from a population in a way that they represent the population's features and characteristics, and they are shown with "n". A sample must be selected in a way that all individuals in a population have an equal chance to be selected. In order to choose such a sample, considering the statistical population features, different method ca be used. This sampling method is called a probability sampling method which is also known as the random sampling method. Observing the probability and the equal chance principle for each member of the population causes the selected sample to be a population's representative which is of scientific value and the samples characteristics are coherent and compatible with the population's features. Thus, this method is used in this study.

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Statistical population and sample: since the proposed parameters in this study include a vast area of variables in the field of workshop equipment of civil projects, the statistical population should include expertise, skills and different fields of work related to this current. Nearly 20 experts of design, execution, management and research, distinguished by their experience and their field of work related to the purposes of this study.

Sample volume measuring method: in this study, as the concept of generalizing the results to the population is considered, the probability sampling method were utilized and also, in order to determine the sample volume (n) the Cochran formula (1) were used. In this regard, the statistical population consists of 30 individuals, error level is 5% (95% level of confidence), normal distribution from the table under the normal curve with a confidence level of 95% equals to 1.96 and the volumes of p and q from the previous data and information are replaced with an amount of 5%. This number were resulted as 26.64 for the sample of this study, which is very close to the statistical population and so it is counted as logical.

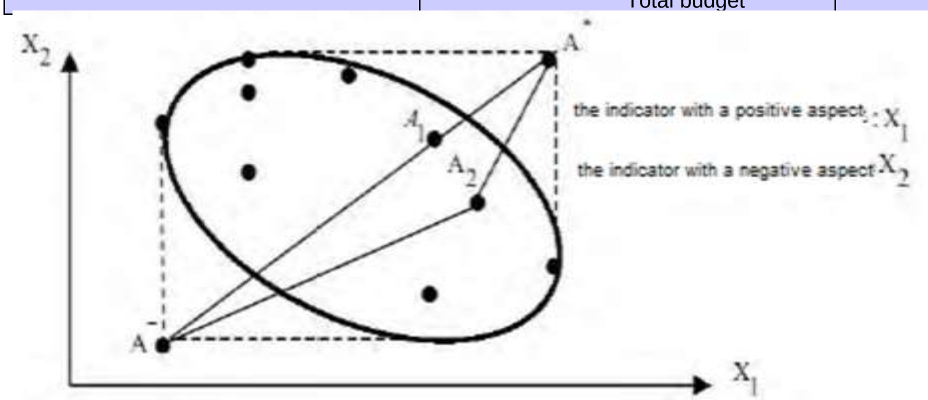
$$n = \frac{Nt^2pq}{Nd^2 + t^2pq} \qquad (1)$$

In the above equation, n: statistical sample volume, N: statistical population volume, t: normal distribution amount, q: the ratio of the lack of feature in the statistical population, p: the ratio of the existence of the feature in the statistical population and $d^2$: the error level.

Data collection: in this study, the available information and evidences and the interview method were used, also the experts' opinion effecting the construction workshop equipment, 3 main factors of cost, duration and environmental conditions and 12 sub-factors were categorized as shown in Table 3.

**Table 3: factors and sub-factors in construction workshop equipment**

| Environmental merit | Cost merit | Duration merit[1] |
|---|---|---|
| Atmospheric conditions | The cost of materials and equipment | Duration of execution |
| Project's location | Employees costs | Duration of work |
| Access routes | Management cost | Project planning |
| Safety | Provision costs | |
| | Total budget | |




ution. This technique was first tors. The principal logic of this ideal solution is a one which which has the least distant from rpour, 1387]. In other words, in he ideal solution gain a higher A- are orderly the positive and ce to the positive ideal solution

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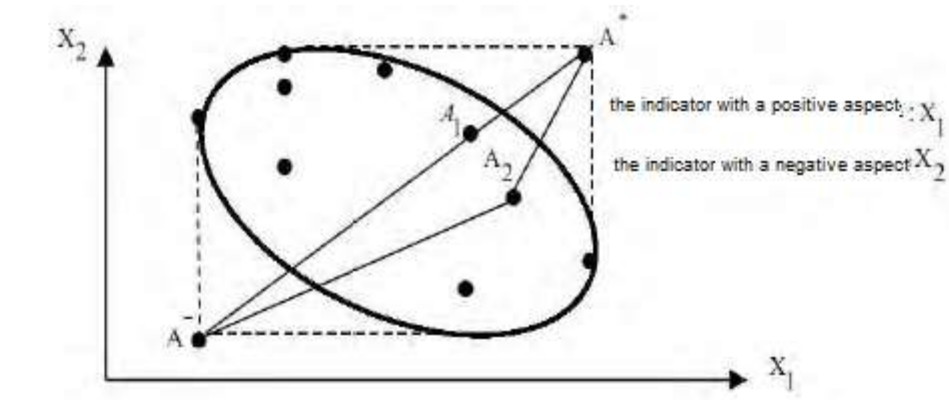


**Fig. 1: the targeted space between two indicators of TOPSIS technique**

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Generally, the TOPSIS technique has 6 phases or steps that each steps of measurement and prioritization in this technique is presented [16].

Step 0 – creating the decision matrix:

In the TOPSIS technique, using n indicators, the m alternatives are evaluated. Thus, according to each merit, each alternative is given a point. These points can be according to quantitative and real or based on qualitative and theoretical values. Either way, an n*m decision matrix should be formed according to equation (2) in a way that $A_i$ of the $i^{th}$alternative, the $X_{ij}$ of the gained numerical value of the $i^{th}$ alternative with the indicator of $j^{th}$alternative. In this matrix, the merit which is of a positive suitability is the profit indicator and the indicator with the negative suitability is the cost indicator.

Step 1) decision matrix normalization:

Similar to other decision making methods with multiple merits, the decision matrix also needs to be normalized. In this regard, the values of the Vector method is used.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccccc} X_1 & X_2 & \cdots & X_j & \cdots & X_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1j} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2j} & \cdots & X_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ X_{i1} & X_{i2} & \cdots & X_{ij} & \cdots & X_{in} \\ \vdots & \vdots & & \vdots & & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mj} & \cdots & X_{mn} \end{bmatrix} \end{array} \qquad (۲)$$

This method as opposed to the simple linear normalizing method isscaled up using the equation bellow:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \qquad (۳)$$

Step 2) formation of the harmonic scaled up matrix:

The next step is the formation of the harmonic scaled up matrix according to the weights of the merits. Thus, it is necessary to primarily calculate the merits weights using a technique such as AHP or Shannon entropy. The weight of each merit is multiplied to its related element. Formation of the harmonic scaled up matrix with the assumption of the W vector as the algorithm's input is determined as the following equations:

$$W = \{w_1, w_2, \dots, w_n\} \approx \text{assumed from DM} \qquad (۴)$$

$$V = N_D * W_{n*n} = \begin{vmatrix} V_{11}, \dots, V_{1j}, \dots, V_{1n} \\ V_{m1}, \dots, V_{mj}, \dots, V_{mn} \end{vmatrix} \qquad (۵)$$

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Here, $N_D$ is a matrix in which its merits' points are scaled up and comparable and $W_{n*n}$ is a Diagonal matrix which only its main diagram elements are not zero.
Step 3) calculation of positive and negative ideals:
Calculation of PIS and NIS is the next step of the procedure. In this step, for each indicator, a positive ideal (A+) and a negative ideal (A-) is measured. For merits that are of positive weight, the positive ideal is the largest value of that merit and the negative ideal is the smallest value of that merit. Also, for the merits with negative weight, the positive ideal is its smallest value and the negative ideal is its smallest value. For the positive ideal alternative (A+) and the negative one (A-) the following is defined:

$$A+=\left\{\left(MaxV_{ij}\,|\,j\in J\right),\left(MinV_{ij}\,|\,j\in J'\right)|\,i=1,2,\ldots,m\right\}=\left\{V_1^+,V_2^+,\ldots,V_j^+\right\} \quad (۶)$$

$$A-=\left\{\left(MinV_{ij}\,|\,j\in J\right),\left(MinV_{ij}\,|\,j\in J'\right)|\,i=1,2,\ldots,m\right\}=\left\{V_1^-,V_2^-,\ldots,V_j^-\right\} \quad (۷)$$

$$J=\left\{j=1,2,\ldots,n\,|\,j\ for\ \text{cost}\right\} \quad (۸)$$

$$J'=\left\{j=1,2,\ldots,n\,|\,j\ for\ \text{cost}\right\} \quad (۹)$$

Step 4) calculation of the distance from positive and negative ideals and calculation of the ideal solution:
In this step, the relative closeness of each alternative with the ideal solution is calculated. The Euclidean distance of each positive and negative ideal is calculated using the following formulas:

$$d_i^+=\sqrt{\sum_{j=1}^{n}(V_{ij}-V_j^+)^2} \qquad for\ i=1,2,\ldots,m \quad (۱۰)$$

$$d_i^-=\sqrt{\sum_{j=1}^{n}(V_{ij}-V_j^-)^2} \qquad for\ i=1,2,\ldots,m \quad (۱۱)$$

Step 5) calculation of the ideal solution or the relative closeness:
In this step, the relative closeness of each alternative with the ideal solution is calculated. For this purpose, the following formula can be utilized:

$$CL_i^*=\frac{d_i^-}{d_i^-+d_i^+} \qquad for\ i=1,2,\ldots,m \quad (۱۲)$$

The CL value is between zero and one. The closer this value is to one, the closer the strategy is to the ideal answer and it would be a better strategy. Also, it is observed that if $A_i$ = A+, then $d^+_i = 0$ and then, $CL^+_i = 1$. And if $A_i$ = A-, then $d^-_i = 0$ and then, $CL^+_i = 0$. Thus, the closer the $A_i$ alternative is to the ideal solution (A+), the closer the value of $CL^+_i$ to one.

**Table 4: Decision matrix (N)**

| | Cost | Duration | Environmental conditions |
|---|---|---|---|
| Sub-merits | Positive | Positive | Positive |
| Project planning | 7.67 | 8.30 | 6 |
| Safety | 7 | 7 | 8 |
| Material and equipment cost | 8.67 | 6.30 | 6.30 |
| Employee's cost | 8 | 5.67 | 5.30 |
| Management cost | 8.30 | 6.30 | 5.30 |
| Provision cost | 8.30 | 5.67 | 5.67 |
| Total budget | 9 | 7.333 | 5.67 |
| Execution duration | 6.67 | 8.67 | 6 |
| Work duration | 7.67 | 9 | 5.67 |
| Atmospheric conditions | 5.67 | 6.30 | 8.30 |
| Project location | 6.67 | 7 | 8 |
| Access route | 7 | 7.30 | 8.30 |

| Weight | 0.333 | 0.333 | 0.333 |
|---|---|---|---|

Step 6) the final step of alternatives ranking:
In the final step, the existing alternatives of the assumed issue can be ranked based on the $CL^{+}_{i}$ descending order.

## Data processing and induction

According to the mentioned steps that are mostly used in engineering issues in this study, the hierarchical analysis and TOPSIS techniques were used for evaluation, analysis and comparing the results. According to the step 0, the decision matrix of this project is presented in **Table- 4**.

Decision matrix normalization according to step 1 is presented for sub-merits A1 to A15 in **Table- 5**.

**Table 5:Scaled up matrix (N1)**

| | C1 | C2 | C3 | | C1 | C2 | C3 | | C1 | C2 | C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.26 | 0.3 | 0.24 | A5 | 0.28 | 0.20 | 0.21 | A9 | 0.26 | 0.32 | 0.225 |
| A2 | 0.24 | 0.25 | 0.32 | A6 | 0.28 | 0.2 | 0.23 | A10 | 0.19 | 0.23 | 0.33 |
| A3 | 0.29 | 0.23 | 0.25 | A7 | 0.3 | 0.26 | 0.22 | A11 | 0.22 | 0.25 | 0.32 |
| A4 | 0.27 | 0.204 | 0.21 | A8 | 0.22 | 0.31 | 0.24 | A12 | 0.24 | 0.26 | 0.33 |

In order to calculate the harmonic scaled up matrix (V), the scaled up matrix (gained from step 2) is multiplied to the square matrix ($w_{n*n}$) which its main diagram elements are the weights of the indicators and its other elements equals zero. Table 6 shows the harmonic scaled up matrix

**Table 6 : The harmonic scaled up matrix (V)**

| | C1 | C2 | C3 | | C1 | C2 | C3 | | C1 | C2 | C3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | 0.035 | 0.077 | 0.07 | A5 | 0.071 | 0.055 | 0.053 | A9 | 0.063 | 0.082 | 0.057 |
| A2 | 0.059 | 0.060 | 0.077 | A6 | 0.071 | 0.053 | 0.056 | A10 | 0.046 | 0.058 | 0.081 |
| A3 | 0.075 | 0.055 | 0.066 | A7 | 0.074 | 0.067 | 0.056 | A11 | 0.058 | 0.066 | 0.077 |
| A4 | 0.069 | 0.052 | 0.056 | A8 | 0.055 | 0.079 | 0.06 | A12 | 0.054 | 0.063 | 0.085 |

In the next stage, according to the third step, the alternatives that are identified as the most and least factors are recognized. In other words, for the positive indicators, the positive ideal is the largest value of v and the negative ideal is the smallest value of v. Also, for negative indicators, the positive ideal is the smallest value of v and the negative ideal is its largest **[Table- 7].**

**Table 7: The positive and negative ideals of each indicator**

| Merit | Positive ideal | Negative ideal |
|---|---|---|
| Cost | 0.078 | 0.049 |
| Duration | 0.083 | 0.053 |
| Environmental condition | 0.085 | 0.054 |

Finally, the fourth, fifth, and the sixth steps were conducted as was described in the previous section and the alternatives ranking is conducted according to **Table- 8** and **Figure- 2**.

**Table 8 : Alternatives ranking**

| Rank | Alternatives | Distance to the positive ideal | Distance to the negative ideal | CL |
|---|---|---|---|---|
| 1 | A1 | 0.027 | 0.034 | 0.557 |
| 2 | A2 | 0.024 | 0.042 | 0.636 |
| 3 | A3 | 0.044 | 0.026 | 0.371 |
| 4 | A4 | 0.053 | 0.023 | 0.302 |

| | | | | |
|---|---|---|---|---|
| 5 | A5 | 0.049 | 0.02 | 0.289 |
| 6 | A6 | 0.046 | 0.025 | 0.352 |
| 7 | A7 | 0.033 | 0.037 | 0.528 |
| 8 | A8 | 0.038 | 0.032 | 0.457 |
| 9 | A9 | 0.036 | 0.034 | 0.485 |
| 10 | A10 | 0.044 | 0.033 | 0.428 |
| 11 | A11 | 0.035 | 0.035 | 0.500 |
| 12 | A12 | 0.026 | 0.037 | 0.587 |

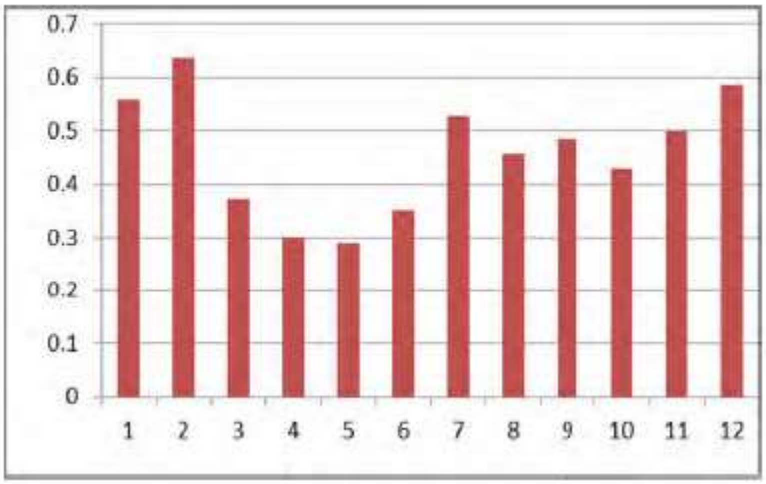


**Fig. 2: Alternatives ranking**

## RESULTS

In this study,a model for ranking of equipment placement in civil project sites were presented. Also, the conducted studies on the discussed issue in this research indicates that using a TOPSIS analytic technique for accessing this model is one the main reasons for innovation in this research. Aside from this purpose, after conducting accurate scientific and experimental studies, the important factors in workshop equipment were listed (Project planning, Safety, Material and equipment cost, Employee's cost, Management cost, Provision cost, Total budget, Execution duration, Work duration, Atmospheric conditions, Project location, and access route). According to the analyses, the environmental merits, cost and duration are orderly prioritized and the civil engineers of the projects that are executed according to these workshop equipment factors should prioritize the factors of safety, access route, project planning, total budget, project location, and work duration as the main factors so that the workshop placement and equipment be beneficial in the project conduct. Other factors that are of lower priorities include the execution duration, atmospheric conditions, employees and management cost.

## CONFLICT OF INTEREST

Authors declare no conflict of interest

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None

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