Research on quality evaluation of municipal engineering project designs with 2-tuple linguistic information

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Abstract

Municipal engineering is an important infrastructure that supports normal production and life of the city. With the development of urbanization, its characteristics of comprehensiveness and complexity emerge increasingly and its importance requires each public work to have a high standard of quality. In this paper, we studied the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. We apply the TWHA and TCWHA operators to the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. Finally an illustrative example has been given to show the developed approach.

Keywords

Multiple attribute decision making; 2-tuple linguistic variables; TWHA operator; TCWHA operator; municipal engineering project design.

1. Introduction

Now our city's new project has become less and less, and the modification or repair and municipal engineering but because of the need of city development is gradually increasing, and the municipal engineering construction environment is complex and changeful. Previously appointed directly by the government of municipal engineering is now also used as a commodity into the market. Construction enterprises through bidding by LAN project profit space is very limited, in the competitive market environment, the construction enterprises to based on the municipal engineering, and to improve enterprise beneficial result, the key is how to effectively guarantee the quality of the premise, to control their own cost[1-2]. The construction of municipal engineering projects and other projects are in many unique. One of, municipal engineering involved in the professional of many types, including roads, bridges, culverts, drainage, lighting, electrical, power, green and many other projects, the need to cross the industry across professional coordination. Secondly, time tight, municipal engineering are a lot of reconstruction engineering, emergency project completed and put into use, the requirements as soon as possible. Third, municipal engineering are mostly old engineering renovation and new construction at the same time, face a lot of demolition, land acquisition or covering problem. Fourth, municipal engineering involves the road widening, not interrupted traffic in construction. Municipal engineering is an important infrastructure that supports normal production and life of the city [3-4]. With the development of urbanization, its characteristics of comprehensiveness and complexity emerge increasingly and its importance requires each public work to have a high standard of quality. However, the reality of the situation is not optimistic. After the completion of many large municipal projects, there are various errors and problems from design to construction. For a long time, people used to focus municipal project management on procurement and construction management and has made some successful experiences, but they ignored the leading role that design places in the construction of municipal, the facts that the design phase of the construction management is the important bond of the entire process of the municipal project management and the quality of design have the decisive influence on the quality of municipal engineering [5-7]. In this paper, we studied the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. We apply the TWHA and

TCWHA operators to the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. Finally an illustrative example has been given to show the developed approach.

2. Preliminaries

Similar to WA and OWA operators[8], weighted harmonic averaging (WHA) operator[9] and ordered weighted harmonic averaging (OWHA) operators[10] are introduced as follows.

Definition 1[9]. Let $WHA: R^{+n} \to R^{+}$, if WHA

$$WHA_{\omega}\left(a_1, a_2, \cdots, a_n\right) = 1 \Big/ \sum_{j=1}^{n} \frac{\omega_j}{a_j} \tag{1}$$

Then WHA is called a weighted harmonic averaging operator, where $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$ is the weight vector of $\left(a_1, a_2, \cdots, a_n\right)$, with $\omega_j \in [0,1]$ and $\sum_{j=1}^{n} \omega_j = 1$, R is the set of all positive real numbers.

In [10], Chen developed the ordered weighted harmonic averaging (OWHA) operator.

Definition 2[10]. An ordered weighted harmonic averaging operator of dimension n is a mapping $OWHA: R^n \to R$ that has an associated vector $w = \left(w_1, w_2, \cdots, w_n\right)^T$ such that $w_j > 0$ and $\sum_{j=1}^{n} w_j = 1$. Furthermore,

$$OWHA_{w}\left(a_1, a_2, \cdots, a_n\right) = 1 \Big/ \sum_{j=1}^{n} \frac{w_j}{a_{\sigma(j)}} \tag{2}$$

where $\left(\sigma(1), \sigma(2), \cdots, \sigma(n)\right)$ is a permutation of $\left(1, 2, \cdots, n\right)$, such that $\alpha_{\sigma(j-1)} \geq \alpha_{\sigma(j)}$ for all $j = 2, \cdots, n$.

In the following, Wei[11] extended the WHA and OWHA operators to accommodate the situations where the input arguments are 2-tuple linguistic assessment information[12-15].

Definition 3[11]. Let $x = \left\{\left(r_1, a_1\right), \left(r_2, a_2\right), \ldots, \left(r_n, a_n\right)\right\}$ be a set of 2-tuples and $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$ be the weighting vector of 2-tuples $\left(r_j, a_j\right)$ $\left(j = 1, 2, \cdots, n\right)$ and $\omega_j \in [0,1]$, $\sum_{j=1}^{n} \omega_j = 1$, The 2-tuple weighted harmonic average is

$$\left(\bar{r}, \bar{a}\right) = TWHA_{\omega}\left(\left(r_1, a_1\right), \left(r_2, a_2\right), \ldots, \left(r_n, a_n\right)\right) = \Delta\left(1 \Big/ \sum_{j=1}^{n} \frac{\omega_j}{\Delta^{-1}\left(r_j, a_j\right)}\right)$$

$$\bar{r} \in S, \bar{a} \in \left[-0.5, 0.5\right) \tag{3}$$

Definition 4[11]. Let $x = \left\{\left(r_1, a_1\right), \left(r_2, a_2\right), \ldots, \left(r_n, a_n\right)\right\}$ be a set of 2-tuples, A 2-tuple ordered weighted harmonic averaging operator of dimension n is a mapping $TOWHA: R^n \to R$ that has an associated vector $w = \left(w_1, w_2, \cdots, w_n\right)^T$ such that $w_j > 0$ and $\sum_{j=1}^{n} w_j = 1$. Furthermore,

$$\left(\tilde{r}, \tilde{a}\right) = \mathrm{TOWHA}_{\mathrm{w}}\left(\left(r_1, a_1\right), \left(r_2, a_2\right), \ldots, \left(r_n, a_n\right)\right)$$

$$=\Delta\left(1\Big/\sum_{j=1}^{n}\frac{w_j}{\Delta^{-1}\left(r_{\sigma(j)},a_{\sigma(j)}\right)}\right),\hat{s}\in S,\hat{a}\in\left[-0.5,0.5\right) \quad (4)$$

where $\left(\sigma(1),\sigma(2),\cdots,\sigma(n)\right)$ is a permutation of $(1,2,\cdots,n)$, such that $\left(r_{\sigma(j-1)},a_{\sigma(j-1)}\right)\geq\left(r_{\sigma(j)},a_{\sigma(j)}\right)$ for all $j=2,\cdots,n$.

However, both the operators consider only one of them. To solve this drawback, in the following Wei[11] proposed the 2-tuple linguistic combined weighted harmonic averaging (T-CWHA) operator.

Definition 5[11]. A 2-tuple linguistic combined weighted harmonic averaging (TCWHA) operator is a mapping $TCWHA: S^n \rightarrow S$, which has an associated weighting vector $w=\left(w_1,w_2,\cdots,w_n\right)^T$ with $w_j\in[0,1]$, $\sum_{j=1}^{n}w_j=1$ such that

$$\left(\hat{r},\hat{a}\right)=\text{TCWHA}_{\omega,w}\left(\left(r_1,a_1\right),\left(r_2,a_2\right),\ldots,\left(r_n,a_n\right)\right)$$

$$=\Delta\left(1\Big/\sum_{j=1}^{n}\frac{w_j}{\Delta^{-1}\left(\hat{r}_{\sigma(j)},\hat{a}_{\sigma(j)}\right)}\right),\hat{s}\in S,\hat{a}\in\left[-0.5,0.5\right) \quad (5)$$

where $\left(\hat{r}_{\sigma(j)},\hat{a}_{\sigma(j)}\right)$ is the j-th largest of the 2-tuples linguistic weighted arguments $\left(\hat{r}_i,\hat{a}_i\right)\left\{\left(\hat{r}_i,\hat{a}_i\right)=\Delta\left(\Delta^{-1}\left(r_i,a_i\right)/n\omega_i\right),i=1,2,\ldots,n\right\}$, $\omega=\left(\omega_1,\omega_2,\cdots,\omega_n\right)^T$ be the weighting vector of 2-tuples $\left(r_i,a_i\right)$ $\left(i=1,2,\cdots,n\right)$ and $\omega_j\in[0,1]$, $\sum_{j=1}^{n}\omega_j=1$, and n is the balancing coefficient..

3. Research on quality evaluation of municipal engineering project design with 2-tuple linguistic information

The following assumptions or notations are used to represent the quality evaluation of municipal engineering project design with 2-tuple linguistic information. Let $A=\left\{A_1,A_2,\cdots,A_m\right\}$ be a discrete set of alternatives, and $G=\left\{G_1,G_2,\cdots,G_n\right\}$ be the set of attributes, $\omega=\left(\omega_1,\omega_2,\cdots,\omega_n\right)$ is the weighting vector of the attributes $G_j\left(j=1,2,\cdots,n\right)$, where $\omega_j\in[0,1]$, $\sum_{j=1}^{n}\omega_j=1$. Let $D=\left\{D_1,D_2,\cdots,D_t\right\}$ be the set of decision makers, and $\nu=\left(\nu_1,\nu_2,\cdots,\nu_t\right)$ be the weight vector of decision makers, where $\nu_k\in[0,1]$, $\sum_{k=1}^{t}\nu_k=1$. Suppose that $\tilde{R}_k=\left(\tilde{r}_{ij}^{(k)}\right)_{m\times n}$ is the decision matrix, where $\tilde{r}_{ij}^{(k)}\in\tilde{S}$ is a preference value, which takes the form of linguistic variables, given by the decision maker $D_k\in D$, for the alternative $A_i\in A$ with respect to the attribute $G_j\in G$.

In the following, we apply the TWHA and TCWHA operators to the quality evaluation problems of municipal engineering project design with 2-tuple linguistic information.

Step 1. Transforming linguistic decision matrix $R_k=\left(r_{ij}^{(k)}\right)_{m\times n}$ into 2-tuple linguistic decision matrix $R_k=\left(r_{ij}^{(k)},0\right)_{m\times n}$.

Step 2. Utilize the decision information given in matrix R_k, and the TWHA operator

$$z_i^{(k)} = \left(r_i^{(k)}, a_i^{(k)}\right) = \text{T-WHA}_{\omega}\left(\left(r_{i1}^{(k)},0\right),\left(r_{i2}^{(k)},0\right),\cdots,\left(r_{in}^{(k)},0\right)\right)$$
$$= \left(1\Big/\sum_{j=1}^{n}\frac{\omega_j}{\Delta^{-1}\left(r_{ij}^{(k)},0\right)}\right), r_i^{(k)} \in S, a_i^{(k)} \in [-0.5,0.5)$$

to derive the individual overall preference value $\tilde{r}_i^{(k)}$ of the alternative A_i.

Step 3. Utilize the TCWHA operator:

$$z_i = \left(r_i, a_i\right) = \text{T-CWHA}_{\omega,\mathrm{w}}\left(\left(r_i^{(1)},a_i^{(1)}\right),\left(r_i^{(2)},a_i^{(2)}\right),\cdots,\left(r_i^{(t)},a_i^{(t)}\right)\right)$$
$$= \Delta\left(1\Big/\sum_{k=1}^{t}\frac{w_j}{\Delta^{-1}\left(\hat{r}_i^{(k)},\hat{a}_i^{(k)}\right)}\right), r_i \in S, a_i \in [-0.5,0.5), i = 1,2,\cdots,m$$

to derive the collective overall preference values $z_i = (r_i, a_i)(i=1,2,\cdots,m)$ of the alternative A_i, where $\left(\hat{r}_i^{\sigma(k)}, \hat{a}_i^{\sigma(k)}\right)$ is the k-th largest of the 2-tuples linguistic weighted arguments $\left(\hat{r}_i^{(k)},\hat{a}_i^{(k)}\right)\left\{\left(\hat{r}_i^{(k)},\hat{a}_i^{(k)}\right) = \Delta\left(\Delta^{-1}\left(r_i^{(k)},a_i^{(k)}\right)\big/t\nu_k\right), k=1,2,\ldots,t\right\}$, $\nu = (\nu_1,\nu_2,\cdots,\nu_n)$ be the weight vector of decision makers, with $\nu_k \in [0,1]$, $\sum_{k=1}^{t}\nu_k = 1$, $w = (w_1, w_2, \cdots, w_t)$ is the associated weighting vector of the TCWHA operator, with $w_k \in [0,1]$, $\sum_{k=1}^{t} w_k = 1$, and t is the balancing coefficient.

Step 4. Rank all the alternatives $A_i(i=1,2,\cdots,m)$ and select the best one(s) in accordance with $z_i(i=1,2,\cdots,m)$. If any alternative has the highest z_i value, then, it is the most important alternative.

4. Numerical example

Municipal public works is the key infrastructure facilities of a city to a healthy, sustainable development, is also a city of civilization construction in two aspects of material and spiritual reflection and guarantee. Quality control and management of municipal engineering now is one of the most important social focus, the main management and local governments at all levels of the administrative departments of construction control points, and at the same time, difficulties of management quality management is also the municipal engineering project. Therefore, the present situation and existing problems of the quality risk management to scientific, objective, comprehensive evaluation of municipal engineering project in China, and for the present situation and problems and puts forward the corresponding quality risk management and control measures, is our country all levels of government project management department of the urgent need to address the problem, and solve the problem of, will play an important role in improving the quality of our municipal engineering project risk management control level. Starting from the connotation of risk management, a detailed analysis of municipal engineering quality risk management content, including the risk type, the construction of municipal engineering risk identification, risk assessment, risk control, construction practice of China Municipal Engineering Project and on the basis of the existing problems, constructs the evaluation risk management of municipal engineering quality model, in order to improve the quality management of municipal engineering project in China, ensure project completion. Suppose an experts group plans to evaluate the entrepreneurship independent innovation ability based on the tacit knowledge. There is a panel with five possible municipal engineering project designs $A_i(i=1,2,3,4,5)$ to select. The expert group selects four attribute to evaluate the five possible municipal engineering project designs: ①G_1 is the strength of the construction enterprise level; ②G_2 is the perform and consistency of the plan; ③G_3 is the major design flaws; ④G_4 is the construction enterprises continued service. The five possible municipal engineering project designs $A_i\left(i=1,2,\cdots,5\right)$ are to be evaluated using the 2-tuple linguistic information by the decision maker under the above four attributes, as listed in the following matrix.

$$R_1 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccc} G_1 & G_2 & G_3 & G_4 \end{array} \\ \begin{pmatrix} VP & G & P & P \\ P & P & EG & EG \\ G & G & VP & G \\ G & EP & P & VP \\ VP & M & P & M \end{pmatrix} \end{array}$$

$$R_2 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccc} G_1 & G_2 & G_3 & G_4 \end{array} \\ \begin{pmatrix} M & VP & P & G \\ P & M & VP & VG \\ G & P & EG & VP \\ EG & G & G & P \\ P & M & M & G \end{pmatrix} \end{array}$$

$$R_3 = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{array} \begin{array}{c} \begin{array}{cccc} G_1 & G_2 & G_3 & G_4 \end{array} \\ \begin{pmatrix} P & VG & M & VP \\ VP & P & P & VP \\ VG & VP & EG & M \\ G & EP & VP & P \\ M & P & P & G \end{pmatrix} \end{array}$$

In the following, we utilize the approach developed for quality evaluation of municipal engineering project design with 2-tuple linguistic information.

Step 1. Transforming linguistic decision matrix $R_k=\left(r_{ij}^{(k)}\right)_{m\times n}$ into 2-tuple linguistic decision matrix $R_k=\left(r_{ij}^{(k)},0\right)_{m\times n}$ as follows

$$R_1=\begin{pmatrix} (VP,0) & (G,0) & (P,0) & (P,0) \\ (P,0) & (P,0) & (EG,0) & (EG,0) \\ (G,0) & (G,0) & (VP,0) & (G,0) \\ (G,0) & (EP,0) & (P,0) & (VP,0) \\ (VP,0) & (M,0) & (P,0) & (M,0) \end{pmatrix}$$

$$R_2 = \begin{pmatrix} (M,0) & (VP,0) & (P,0) & (G,0) \\ (P,0) & (M,0) & (VP,0) & (VG,0) \\ (G,0) & (P,0) & (EG,0) & (VP,0) \\ (EG,0) & (G,0) & (G,0) & (P,0) \\ (P,0) & (M,0) & (M,0) & (G,0) \end{pmatrix}$$

$$R_3 = \begin{pmatrix} (P,0) & (VG,0) & (M,0) & (VP,0) \\ (VP,0) & (P,0) & (P,0) & (VP,0) \\ (VG,0) & (VP,0) & (EG,0) & (M,0) \\ (G,0) & (EP,0) & (VP,0) & (P,0) \\ (M,0) & (P,0) & (P,0) & (G,0) \end{pmatrix}$$

Step 2. Utilize the information given in the $\tilde{R}_k$, and the TWHA operator, we get:

$$z_1^{(1)} = (P,0.23), z_2^{(1)} = (P,0.21), z_3^{(1)} = (VP,0.09)$$
$$z_4^{(1)} = (M,0.15), z_5^{(1)} = (P,-0.31), z_1^{(2)} = (VP,0.45)$$
$$z_2^{(2)} = (P,-0.25), z_3^{(2)} = (G,-0.36), z_4^{(2)} = (P,0.38)$$
$$z_5^{(2)} = (P,-0.04), z_1^{(3)} = (M,0.18), z_2^{(3)} = (P,0.20)$$
$$z_3^{(3)} = (M,-0.24), z_4^{(3)} = (P,0.08), z_5^{(3)} = (M,0.11)$$

Step 3. Utilize the TCWHA operator to derive the values $z_i = (r_i, a_i)$ of the alternative A_i.

$$z_1 = (P,0.43), z_2 = (P,0.14), z_3 = (P,0.26)$$
$$z_4 = (M,-0.21), z_5 = (P,0.09)$$

Step 4. Ranking all the municipal engineering project designs $A_i\,(i = 1,2,\cdots,5)$ in accordance with the $z_i\,(i = 1,2,\cdots,m)$: $A_4 \succ A_1 \succ A_3 \succ A_2 \succ A_5$, and thus the most desirable municipal engineering project designs is A_4.

5. Conclusion

Construction project is the typical type of projects, and it is rather important in today's society. With the development of economics and the enlargement of investment scale of construction projects which are represented by municipal works, the government requires a more normative management function, because of the unsuitable of the traditional management function. The management level should also be improved. Among all the factors, the quality evaluation of municipal engineering project design is the total integration of the implementation process of projects, integrating the human resources, material resources and knowledge. Therefore it is inevitable requirements to better and improve the project quality management of unicipal engineering project design for promoting project management level. In this paper, we studied the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. We apply the TWHA and TCWHA operators to the evaluation problems for quality evaluation of municipal engineering project design with 2-tuple linguistic information. Finally an illustrative example has been given to show the developed approach. In the future study, we shall extend the models proposed to other domains[16-27]..

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