Research on a decision-making method for aging transformation alternatives in old communities based on large-scale group decision-making

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Abstract. With serious aging, the aging transformation of older communities is important. To meet the needs of a larger number of residents, large-scale group decision-making (LSGDM) can be used to find the most appropriate transformation alternative. This paper aims to construct an LSGDM model based on trust propagation and conflict detection and elimination. The model takes into account the social relationships of community residents. Additionally, it can detect conflicts of opinions of decision-makers in the alternative selection and eliminate them. The model is simple and easy to implement, and it can be easily applied in real life. This LSGDM model can be feasibly applied to practical scenarios. Thus, the model applies to the aging transformation of old communities. The research results can also be used as a reference for similar decisions.

Keywords: Large-scale group decision-making; Old communities; aging transformation; Alternative selection; Trust propagation.

1 Introduction

With serious aging, the value of the aging transformation of old communities has become more prominent. As a project related to people's livelihood, the renovation of public space in old communities aims to meet the interests of community owners[1].

The selection of aging transformation alternatives for older communities is a group decision-making issue. The complex backgrounds of decision-makers, their lack of professionalism and their diverse wishes are important constraints affecting the decision. Various places have successively launched consultation and discussion platforms such as a 'residents' meeting room'. It is hoped that such platforms can achieve the purpose of resolving contradictions and promoting consensus. Although the platforms above have obtained certain results, they are time-consuming and labour-intensive, and it is difficult to achieve a comprehensive consideration. This paper aims to establish a large-scale group decision-making (LSGDM) model that is suitable for the selection of aging transformation alternatives based on the characteristics above. This model can maximise the personal interests of community residents.

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LSGDM refers to the selection of the best option from several alternatives based on the preferences of a large number of decision-makers. In general, when the number of decision-makers involved in the decision is greater than or equal to 20, the decision is called a large-scale group decision[2]. Usually, LSGDM is a complex scenario with a large number of decision-makers and many opinions on decisions. Therefore, research on consensus models and methods is constantly being updated. In traditional LSGDM, the decision-makers are experts with a professional knowledge background[3,4]. They all have fixed evaluation indicators, and this method is generally widely used in large projects. In daily life, there are increasingly more scenarios where LSGDM is applied. But for the general public, the inherent decision-making framework does not apply. An LSGDM model applicable to the public can be constructed[5]. At the same time, decision-makers are easily influenced by other decision-makers, especially those with close social ties. Scholars have applied the social relationships among decision-makers to study group decision-making[6-10].

This paper aims to establish an LSGDM model based on trust propagation and conflict elimination. It will be applied to the selection of community aging transformation alternatives. It can obtain reasonable group decision results, and it also provides a reference for research on similar decision-making problems.

2 Analysis of decision-making mechanisms

2.1 Decision-making research ideas

The choice of an aging transformation alternative involves the interests of all community residents. The number of residents, who are decision-makers, is large, and they have many opinions. To address residents' ideas, this paper aims to develop an LSGDM model based on trust propagation and conflict detection and elimination for the selection of aging transformation alternatives in old communities.

The LSGDM model constructed in this paper consists of three main parts: trust network construction and improvement, decision conflict detection and elimination, and alternative selection. These parts are shown in Figure 1.

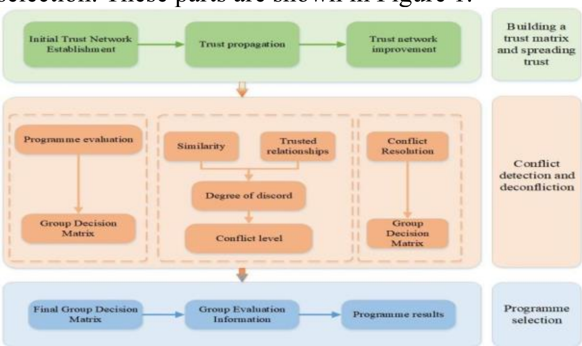

Fig. 1. Large-scale group decision-making model

2.2 Model construction

2.2.1 Construction and improvement of trust networks

The decision-makers in the community aging transformation decision-making process are not independent of each other. There is a complex network of social relationships between them. Decision-makers with strong social ties trust each other and share information about their preferences and willingness to make choices. In contrast, socially distant decision-makers lack trust and are isolated from each other. They may even have antagonistic social relationships, which can lead to conflicting decisions. Therefore, there is a need to categorise the social networks and trust relationships between decision-makers.

First, an initial trust matrix is built. In this process, the assessment values of mutual trust $t_{i,j}$ between decision-makers are obtained. At the same time, decision-makers are classified. Subsequently, trust propagation is performed for missing trust relationships in incomplete social networks. The trust matrix is eventually refined.

(1) Trust network construction

First, the initial trust matrix is created to assess the social relationships and trust between decision-makers. The values $t_{i,j}$ of the trust of each decision-maker e_i in other decision-makers are shown in Table 1.

Table 1. Annotation table of symbols related to the trust value

Symbols	Numerical values	Meaning
Trust value $t_{i,j}$	$T_{i,j}=1$	e_i fully trusts e_j
	$T_{i,j}=0$	e_i does not trust e_j at all
	$0 \le t_{i,j} \le 1$	indicates that the value of trust of e_i in e_j is within a certain range

There are a large number of decision-makers in the LSGDM problem of community aging transformation. Decision-makers are often unable to make an accurate assessment of the trust value of unfamiliar decision-makers.

An initial matrix A can be applied to represent incomplete social relationships in a social network. Each decision-maker provides information on the trust assessment of only the decision-makers whom they know. This is shown in matrix (1).

$$A=\begin{pmatrix} 1 & t_{1,2} & t_{1,3} \\ - & 1 & - \\ t_{3,1} & - & 1 \end{pmatrix} \tag{1}$$

(2) Trust propagation and the improvement of trust networks

In social networks, information is transferable. Thus, trust can be propagated through one or more intermediaries. In this paper, the unknown trust between decision-makers is calculated using a method related to tandem trust propagation and parallel trust propagation[11]. A complete trust matrix is thus obtained.

1) Serial trust propagation.

If there is only one propagation chain between decision-makers e_A and e_B, this is tandem trust propagation. Then, the formula is as follows:

$$t'_{A,B} = (t_{A,i1} \times t_{i1,i2} \times \cdots \times t_{id-1,B}) \times \frac{D_d}{D_{\max}} \tag{2}$$

where $t_{A,i1}$ represents the value of direct trust between decision-makers e_A and e_1. D_d represents the path length of the target node. D_{max} is the longest path in the social network.

2) Parallel trust propagation

If there are multiple propagation chains between decision-makers e_A and e_B, this is parallel trust propagation. We classify decision-makers into three categories based on their tolerance for risk: risk-averse, neutral and risk-taking.

Based on trust propagation, indirect trust relationships between decision-makers in community aging transformation can be obtained, yielding a complete trust matrix B.

2.2.2 Decision conflict elimination

The decision-makers in community aging transformations are the residents of the community. Decision-makers usually evaluate the options differently in large group decision-making situations. These different evaluations create conflicts between decision-makers. Moreover, when decision-makers are in social networks, their relationships can exacerbate or mitigate the differences in information previously obtained from assessments. Therefore, conflicts must be detected and eliminated before the choice of option is made.

(1) Decision conflict detection

First, a decision-maker needs to evaluate the alternatives. When the decision-maker evaluates the alternatives, an intuitionistic fuzzy set is used to represent them. This set is an appropriate representation of the degree of uncertainty of the decision-maker regarding the information to be evaluated.

Let X be a non-empty set; then, the intuitionistic fuzzy set A regarding X can be expressed as follows:

$$A = \{< x, \mu_A(x), \nu_A(x) > | \, x \in X\} \tag{3}$$

We denote the set of decision-makers' evaluation information for alternatives as the vector $D_i = \{d_1, d_2, ..., d_n\}$.

$$D_i = \{\langle \mu_1^i, \nu_1^i \rangle, \langle \mu_2^i, \nu_2^i \rangle, \cdots, \langle \mu_n^i, \nu_n^i \rangle\}, (1 \le i \le m) \tag{4}$$

Based on the evaluation information of all decision-makers, the following group decision matrix (D) is obtained.

We define the similarity of preference for evaluation information between a pair of decision-makers e_i and e_j as the degree of similarity δ, as shown in formula (5):

$$\delta_{ij} = 1 - \frac{1}{2n}\sum_{k=1}^{n}(|\mu_k^i - \mu_k^j| + |\nu_k^i - \nu_k^j|) \tag{5}$$

Furthermore, when decision-makers are in a social network, the social relationship between them can exacerbate or mitigate the differences in the calculated evaluation information. That is, when there is a certain assessment discrepancy between decision-makers e_i and e_j, e_i is more likely to conflict with e_j if e_i does not trust e_j. Therefore, the degree of discord cij between the two decision-makers e_i and e_j is defined as follows:

$$c_{ij} = \delta_{ij} \times (1 - t_{ij}) \tag{6}$$

A reasonable threshold θ (0 < θ < 1) is set to determine whether there is a conflict between two decision-makers. Set the matrix C_θ to make the judgement. Based on C_θ, a conflict network can be constructed. There are directed edges in the network from e_i to e_j. And then we can calculate the in-degree and out-degree.

(2) Decision conflict elimination

When we detect a conflict among decision-makers in community aging transformation, it needs to be eliminated.

We define the degree of conflict Ω for decision-makers as follows:

$$\Omega_i = \frac{I_i + O_i}{2m} \tag{7}$$

Parameter ρ is introduced to describe the degree of consensus among community residents in a social network under conflict, and it is defined as the conflict density in a group. Therefore, to identify the decision-maker e_k with the highest degree of conflict, where Ωk=max $\{\Omega_1, \Omega_2, \ldots, \Omega_m\}$, this decision-maker's evaluation information on alternatives should be revised under the guidance of the moderator.

The revised assessment information for e_k can be expressed as follows:

$$D'_k = \left\{ \langle \mu_1^{i'}, v_1^{i'} \rangle, \langle \mu_2^{i'}, v_2^{i'} \rangle, \cdots, \langle \mu_n^{i'}, v_n^{i'} \rangle \right\}, (1 \le i \le m) \tag{8}$$

2.2.3 Group decision option selection

Alternative selection refers to deciding on the most suitable alternative from the existing alternatives. Based on the final degree of conflict obtained by the process above, the final group decision matrix can be obtained. Subsequently, decision-maker weights are calculated, and the assessment information for alternative X_i is aggregated into a group assessment. Finally, the scores of the alternatives can be obtained, and these scores are ranked to obtain the final choice.

Based on the trust propagation and conflict elimination process, the final swarm decision matrix is expressed as follows:

$$D = (D_1^T, D_2^T, \cdots, D_m^T) = \begin{pmatrix} \langle \mu_1^{1'}, v_1^{1'} \rangle & \cdots & \langle \mu_1^{m'}, v_1^{m'} \rangle \\ \vdots & \ddots & \vdots \\ \langle \mu_n^{1'}, v_n^{1'} \rangle & \cdots & \langle \mu_n^{m'}, v_n^{m'} \rangle \end{pmatrix} \tag{9}$$

According to section 2.2.2, the degree of conflict of each decision-maker can be calculated with the degree of conflict $\Omega = \{\Omega_1, \Omega_2, ..., \Omega_m\}$. Additionally, based on their degree of conflict Ω_i, we can get the weights of the decision-makers ω.

Based on the decision-maker weights calculated above, we aggregate the evaluation information of alternative X_i into a group evaluation:

$$\hat{D}_i = IFWA_\omega(D_i^{1'}, \cdots, D_i^{m'}) = (1 - \prod_{j=1}^{m}(1-\mu_i^{j'})^{\omega_j}, \prod_{j=1}^{m} v_i^{j'\omega_j}) \quad (10)$$

Where Di =<μ_i, v_i> denotes the group evaluation of alternative X_i. Using the score function for intuitionistic fuzzy sets, we obtain the scores for the alternatives:

$$s_i = \mu_i - v_i \quad (11)$$

Finally, the scores of the alternatives can be obtained, and these scores are ranked to obtain the final choice.

3 Model application

3.1 Large-scale group decision-making scenarios

A community completed in 2000 was chosen as a case study for this paper. With the passage of time, the community now has a majority of middle-aged and elderly people. Furthermore, many children of the elderly residents have moved away; thus, there are a large number of empty nesters in the community.

The owners' committee of the community decided to carry out an aging transformation of the community to create an "age-friendly community". In this way, the living happiness of the elderly residents can be improved, and their children can be more at ease.

The owners' committee of the community presented three options to choose from: a community health care centre (X_1), a senior citizens' canteen (X_2) and a community senior citizens' activity centre (X_3). And the owners' committee of the community intended to choose one of the programmes for priority construction. Twenty households were randomly selected in the community, and one member from each household was chosen as the decision-maker to conduct an opinion survey on the three alternatives.

The four groups of decision-makers selected include young people living with elderly residents, young people who do not live with elderly residents, empty nesters, and elderly people living with their children.

3.2 Large-scale swarm decision-making application process

3.2.1 Trust network construction and improvement

First, the relationships between the 20 residents are represented by a network diagram. At the same time, the category of these decision-makers is displayed in terms of the association relationships between them.

The trust relationships among decision-makers are the foundation of LSGDM processes. We need to score the values of trust between residents. The initial trust matrix is obtained by scoring the trust values of the 20 residents with reference to the rating scale above. Through the relationships between residents and the process of trust propagation, the missing values of indirect trust between them can be obtained. On this basis, we can obtain the complete trust value among the residents and finally obtain the complete trust matrix. The complete trust matrix is the basis for subsequent conflict elimination.

3.2.2 Decision conflict elimination

(1) First, 20 residents were asked to evaluate the alternatives, and intuitionistic fuzzy sets were used to represent each resident's evaluation of each alternative. We can get the values of the assessments of the three alternatives made by the 20 decision-makers in the community, and it shows that there are differences in the results of the residents' evaluations of the alternatives. For the same type of residents, the differences between the assessment scores of the alternatives are small, while for different types of residents, the differences between the assessment scores of the alternatives are large.

(2) The degree of similarity δ between decision-makers and the degree of discord c are derived.

We calculated the degree of similarity and dissonance for 20 decision-makers. The calculation shows that the degree of similarity between decision-makers belonging to the same category is high, and the degree of dissonance is low. Additionally, the similarity between different types of decision-makers is low, and the degree of dissonance is high.

As this decision event involves 20 decision-makers, there are 380 valid values of dissonance, with a degree of dissonance c_{ij} ranging from 0 to 0.82. Relatively low degrees of dissonance among decision-makers have less impact on the decision-making process. In this example, we consider keeping one-half of conflicting information, and we follow the supermajority rule. In calculating the degree of dissonance between individual decision-makers, we conclude that there are 189 decision-makers with a degree of dissonance of no less than 0.38, which is close to one half. Therefore, we choose 0.38 as the value of the threshold θ in the numerical example. On this basis, conflict network C_θ can be obtained.

Based on the direction of trust between residents, by calculating their in-degree and out-degree, the degree of conflict Ω can be obtained. It can be calculated that e_3, e_6, e_{19} and e_{20} have relatively high levels of conflict, while e_5, e_9, e_{13}, and e_{17} have relatively low levels of conflict. The next step is the elimination of conflicts.

(3) Assuming that the threshold value Φ of conflict density is 0.3, the conflict density ρ obtained from the degree of conflict above is 0.3475; thus, $\rho>\Phi$. This shows that the overall degree of conflict among residents is relatively large and needs to be eliminated. The assessment information for decision makers with high levels of conflict should be revised under the guidance of the facilitator.

After modification, a new degree of conflict can be obtained:

$\Omega'=\{0.35, 0.35, 0.225, 0.325, 0.2, 0.2, 0.375, 0.375, 0.25, 0.225, 0.35, 0.35, 0.3, 0.375, 0.325, 0.325, 0.25, 0.375, 0.25, 0.225\}$.

The value of the modified collision density ρ is 0.3, which is equal to the threshold. Thus, the subsequent scheme selection process can be performed.

3.2.3 Group decision option selection

From the degree of conflict of residents, the weight value ω for each resident in the choice of options can be derived. Based on the weight value, the group evaluation value of each alternative can be obtained:

$$d_1 = \langle 0.55, 0.34 \rangle,\ d_2 = \langle 0.51, 0.38 \rangle,\ d_3 = \langle 0.56, 0.31 \rangle$$

The final alternative is scored as follows:

$$s_1 = 0.20,\ s_2 = 0.13,\ s_3 = 0.25$$

The results of the alternatives are ordered as follows: $s_3 > s_1 > s_2$.Therefore, the establishment of a community elderly activity centre X_3 is the final choice for this LSGDM problem.

3.2.4 Comparison of methods

The validity of this paper's methodology has been verified through comparative analysis with two other types of decision-making methods (as shown in Table 2).

The first approach is an LSGDM approach that considers trust risk in social networks. The second approach is an LSGDM approach based on this paper's conflict elimination but without considering social and trust relationships.

Table 2. Comparison of the results of this method with those of other methods

Methods	Programme prioritisation
Method 1	$X_3>X_1>X_2$
Method 2	$X_1>X_3>X_2$
Method of this paper	$X_3>X_1>X_2$

Comparing the method of this paper with method 1, the order $X_3>X_1>X_2$ is the same, indicating that the model established in this paper is feasible. In this paper, we analyse the social relationships of decision-makers and take into account the trust relationships between them when making decisions on solutions to obtain more accurate decisions. Comparing the method of this paper with method 2, the order of X_1 and X_3 is different. The main reason is that method 2 does not consider social relationships. In the actual decision-making process, the mutual trust relationships between decision-makers will have a greater impact on the results.

In summary, the approach proposed in this paper is feasible. Therefore, the proposed method is applied to the selection of community aging transformation alternatives, demonstrating the effectiveness and practicality of the solution.

4 Conclusion

The selection of aging transformation alternatives for old communities involves a large number of residents, whose opinions are complex and diverse, making it difficult to make quick decisions. This paper uses the LSGDM method to solve this problem. The main findings are as follows: (1) An LSGDM model based on trust propagation and conflict elimination is constructed for the aging transformation of old communities. Finally, a suitable alternative can be selected. (2) The effectiveness of the method in a real-world problem is demonstrated. After a series of calculations, the model can derive the weight of each decision-maker in the decision-making process and the overall score of the decision-maker for each option. Ultimately, the alternative with the highest score, that is, establishing a community elderly activity centre first, can be obtained. This result shows that elderly residents have a greater demand for activities, and future research on aging-appropriate transformation can be further conducted from this perspective.

This paper establishes an LSGDM model based on trust propagation and conflict elimination to solve the alternative selection problem of aging transformation in old communities. It can improve solution efficiency, take into account the interests of most residents, and satisfy the rights of community residents as community subjects. The research results can provide a reference for similar decisions. Notably, this paper considers only their degree of association and trust when analysing the social relations of community residents. Next, we will examine in more depth the impact of residents' and social connections on decision-making consensus. Furthermore, the number of data collected in this paper is not large enough, and the scope is not comprehensive enough. This problem needs to be addressed in future research.

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