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Group Decision-Making Method of Entry Policy During a Pandemic

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Abstract: Omicron, the new mutant coronavirus, has spread rapidly globally, attracting close attention from different stakeholders worldwide. The complex and constantly changing epidemic situation has had a new impact on the world. Therefore, this paper focuses on the characteristics of the rapid spread of the COVID-19 variant strain. Generally, epidemic prevention experts conduct preliminary screening as part of the existing epidemic plan database according to the current local situation, after which they sort the alternatives deemed more suitable for the situation. Then the decision-makers identify the most divergent expert group, plan for consultation and adjustments, and finally obtain the plan with the smallest divergence. This article aims to integrate the experts' opinions with the method of minimizing the differences, which can maximize the expert consensus and help organize the schemes that best meet the epidemic situation. The experts' negotiation and iteration of the differences in the initial plan align with the current complex and dynamic epidemic situation and are of great significance to the rapid formulation of plans to achieve effective prevention and control.

Key words: epidemic prevention and control; group decision-making; alternative ranking; control policy

1 Introduction

On November 24, 2021, the novel coronavirus variant, B.1.1.529, was first detected by South African scientists and was later identified as "Omicron" by the World Health Organization on November 26. In a few days, more than ten countries and regions around the world have discovered the new mutant strain, which has spread to most countries in the world within a month. By then, all countries around the world had paid great attention to this novel strain. Prior to this, COVID-19 was investigated by many scholars worldwide[1, 2], involving studies such as novel coronavirus gene sequence[3], treatment[4], post-epidemic economic development[5, 6], and epidemic prediction model research and establishment[7]. However, the rapid development and transmission of the COVID-19 virus have led to little research on the decision-making methods of epidemic prevention and control. Meanwhile, in the early stage of discovering the new virus, there were insufficient data to support the determination of the transmissibility, pathogenicity, risk of secondary infection, and immune evasion of the strain. In addition, enforcing restrictions directly led to economic fluctuations, which affected various industries worldwide. In other words, the degree of control directly affects economic activity. However, for areas where the mutated strain of the new coronavirus has emerged, we can only prevent the spread of the epidemic and enable the world to overcome it as soon as possible by effectively importing and exporting control. In this paper, the main background considered when making policy decisions is how to balance national security and economic growth rate, that is, to ensure the normal activities of citizens and national economic growth to the greatest extent based on the premise of ensuring national security. The strain is constantly mutating, spreading faster, and carrying more viruses and mutated

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amino acids on essential proteins than ever before. The grim international situation has once again proven that the strategy of "lying flat out" employed by some countries encouraging coexistence with the virus is not realistic. Therefore, it is necessary to formulate appropriate policies to ensure public safety and speed up the containment of the epidemic in response to the complex and volatile situation.

When it comes to formulating epidemic prevention and control plans, the group decision-making of experts is always involved. Group decision-making aims to gather the different opinions of multiple experts into a final plan or an acceptable ranking[8]. The first step in group decision-making is to screen the feasible alternatives. As there is often more than one decision-maker, this process requires assembling and processing their inputs and obtaining the optimal final plan through a particular method[9]. There have been many studies conducted by scholars on the method of program ranking[10]. Since Saaty proposed the multiplicative preference relationship[11], many experts have examined preference-based scheme ranking[12, 13]. For example, Tanino defined the group fuzzy preference ranking caused by the difference or diversity of individual opinions in 1984[14]. Since the opinions of decision-makers are not always accurate, scholars use vague language to express the opinions of such decision-makers[15]. In recent years, the method of measuring distance has been applied to various fields[16]. Many scholars have quantified the consensus degree of expert ranking based on distance methods, such as Hamming distance[17, 18] and Euclidean distance[19, 20]. Yet, distance-based methods may sometimes fail to adequately reflect consensus in group decision-making. Hou and Triantaphyllou[21] proposed a pre-metric-based concept to express the different opinions of experts, thus making up for the deficiency of the distance-based identification method. Some complex problems of group decision-making require decision-making based on multiple criteria, and scholars have also conducted in-depth research in this area[22, 23]. Governments often adopt the simple majority principle when formulating epidemic prevention and control policies, resulting in no solid basis for the effectiveness of the plan. Owing to the rapid development of novel, mutant coronavirus strains, it is not feasible to simply copy the prevention and control plan adopted in the last outbreak. At this stage, the focus of epidemic prevention and control is to prevent and control new outbreaks quickly. Moreover, the currently confirmed cases are infected with both the Delta and Omicron strains, thus bringing new difficulties in the formulation of effective prevention and control policies. Therefore, this paper studies the methods for decision-making on epidemic prevention and control and proposes an effective decision-making method that conforms to the characteristics of the spread and mutation of the novel coronavirus.

The remainder of this thesis is arranged into the following sections. Section 2 introduces the group decision-making method used in this paper and provides an overview of the basic concepts used. Section 3 proposes the general process of group decision-making for epidemic prevention and control programs based on the characteristics of the spread of novel coronavirus mutations, which can minimize differences among experts coming from various fields and facilitate quicker decisions that best meet the needs of the epidemic. Section 4 takes the most critical step in controlling the spread of the virus (i.e., the overseas import policy) as an example to realize group decision-making in epidemic prevention and control policies. Section 4 also compares the method proposed in this paper with an existing decision-making method and demonstrates the superiority of the method used in this paper. Finally, Section 5 presents the conclusions of this paper and future research directions.

2 Related Theory

This paper studies the decision-making methods of epidemic prevention and control programs in the case of new outbreaks. This section briefly describes the basic theories and concepts used.

It is supposed that there are m experts $(e_1, e_2, \ldots, e_m)$ participating in the selection of n alternatives $(p_1, p_2, \ldots, p_n)$, where $1 < m < +\infty$ and $1 < n < +\infty$. The definitions are given in the following:

Definition 1 A sequence $(S_i)_{n\times 1}$ is the indifference sequence set[24] of the alternative set A, if and only if $S_i = \{|P_i|+1, |P_i|+2, \ldots, |P_i|+|Q_i|\}$, where $P_i = \{a_j | a_j \in A, a_j \succ a_i\}$ and $Q_i = \{a_k | a_k \in A, a_i \sim a_k\}$. Here, $(P_i)_{n\times 1}$ is called the predominance sequence of the alternation set A with respect to the order relation $\preceq$, if and only if the following is true: $P_i = \{a_j | a_j \in A, a_j \succ a_i\}$. $(Q_i)_{n\times 1}$ is called the indifference sequence of the alternation set A with respect to the order relation $\preceq$, if and only if the following is true: $Q_i = \{a_k | a_k \in A, a_i \sim a_k\}$.

A sequence $(S_i)_{n\times 1}$ also represents the preference map of the corresponding expert.

Definition 2 $\Delta(V^{(1)}, V^{(2)})$ represents the consensus gap[24] between the two preference maps, where $V^{(1)} = (V_i^{(1)})_{n\times 1}$ and $V^{(2)} = (V_i^{(2)})_{n\times 1}$,

$$\Delta(V^{(1)}, V^{(2)}) = \sum_{i=0}^{n} \delta(V^{(1)}, V^{(2)}) = \sum_{i=1}^{n} \max\{0, \min V_i^{(1)} - \max V_i^{(2)}, \min V_i^{(2)} - \max V_i^{(1)}\}.$$

The consensus gap is a pre-measure concept that only satisfies non-negativity and symmetry, and is used to represent the divergence between two expert rating preference maps. $DispM = (S_{ik})_{n\times n}$ is the dispute matrix[25], representing the disagreement of the experts on the proposal, where $DispM = (S_{ik})_{n\times n}$ represents the total consensus of experts if a_i is in the k-th position.

Definition 3 Assuming that $V^{(1)} = (V_i^{(1)})_{n\times 1}$, $V^{(2)} = (V_i^{(2)})_{n\times 1}, \ldots, V^{(m)} = (V_i^{(m)})_{n\times 1}$ are the PMs of the experts, then the experts are considered to have a consensus if and only if $\forall i (V_i^{(1)} \cap V_i^{(2)} \cap \cdots \cap V_i^{(m)} \neq \varnothing)$. Thus, the consensus ranking[24] is represented by (W_i),

$$\begin{pmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{pmatrix} = \begin{pmatrix} V_1^{(1)} \\ V_2^{(1)} \\ \vdots \\ V_n^{(1)} \end{pmatrix} \cap \begin{pmatrix} V_1^{(2)} \\ V_2^{(2)} \\ \vdots \\ V_n^{(2)} \end{pmatrix} \cap \cdots \cap \begin{pmatrix} V_1^{(m)} \\ V_2^{(m)} \\ \vdots \\ V_n^{(m)} \end{pmatrix} = \begin{pmatrix} \bigcap_{k=1}^{m} V_1^{(k)} \\ \bigcap_{k=1}^{m} V_2^{(k)} \\ \vdots \\ \bigcap_{k=1}^{m} V_n^{(k)} \end{pmatrix}.$$

The consensus gap between each pair of PMs represents the differences between the two experts, and the disagreement matrix represents the disagreements among all experts. The disagreement matrix is defined as

$$D = (\Delta_{jk})(m \times m),$$

where $\Delta_{jk} = \Delta(V^{(j)}, V^{(k)})$.

Definition 4 The Consensus Evaluation Sequence (CES)[21] contains the Group Consensus Index (GCI), the Maximum Disagreement Pairs (MDP), the Pairwise Disagreement Index (PDisaI), the Maximum Dispute Alternatives (MDA), and the Maximum Dispute Index (MDispI). The specific evaluation process is shown in Fig. 1.

(1) GCI is the consensus level of quantitative decision-making from the perspective of experts. Its value range is [0, 1], in which the larger the value, the higher the consensus level of experts. In the absence of special instructions, GCI=1 is generally taken,

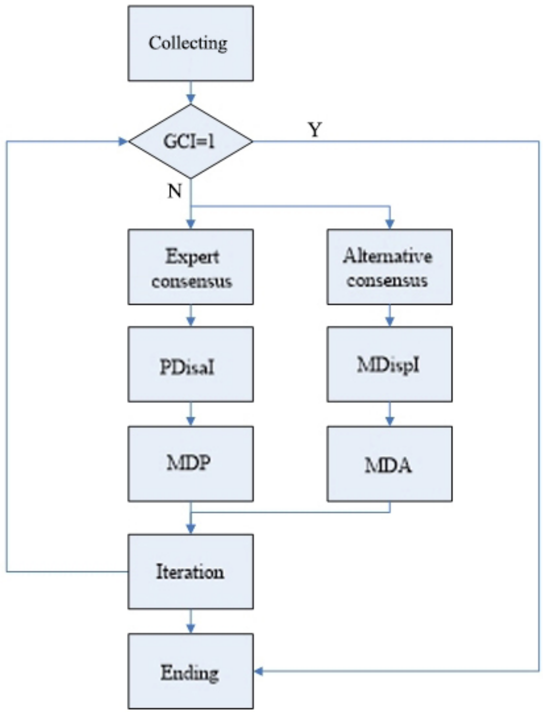

Fig. 1 Evaluation process.

$$\text{GCI} = \frac{2\sum_{i=1}^{m-1}\sum_{j=j+1}^{m} \rho_{ij}}{m(m-1)},$$

$$\rho_{ij} = \begin{cases} 1, & \Delta_{ij} = 0; \\ 0, & \text{others} \end{cases} \tag{1}$$

(2) If the experts do not reach a consensus, the most divergent experts and the most divergent options must be identified.

(a) Disagreement among experts. MDP represents the most divided panel of experts,

$$\text{MDP} = \{(j,k) | \Delta_{jk} = \text{PDisaI}, j < k, \Delta_{jk} < 0\} \tag{2}$$

where

$$\text{PDisaI} = \max_j\{\max_k\{\Delta_{jk} | j < k\}\} \tag{3}$$

(b) Disagreement between plans. MDA represents the most controversial alternative,

$$\text{MDA} = \{i | S_{ik} = \text{MDispI}, S_{ik} > 0\} \tag{4}$$

where

$$\text{MDispI} = \max_i \min_k\{S_{ik}\} \tag{5}$$

3 General Process of Group Decision-Making

Since the outbreak of the COVID-19 virus, the new coronavirus has mutated many times and spread all over the world. No country has shown immunity against it. Judging from the current international epidemic situation, human beings will have to coexist with the new coronavirus for a long time, and epidemic prevention and control will become the norm in most local contexts. However, the viruses at this stage are all mutated strains, which means that the transmission route and speed, the symptoms of the infected person, and the amounts of virus they carry are constantly changing. Humans face many "unknowns" when dealing with outbreaks. In the face of local outbreaks, it is necessary to formulate prevention and control policies in the shortest time and implement them quickly to minimize the difficulty of subsequent epidemic prevention and control. Experts from the epidemic prevention and control team select alternative plans based on the epidemic prevention and control plan database, which is more in line with the local epidemic situation, after which they can undergo the process of group decision-making to select the final plan.

In addition, given that the epidemic affects all aspects of human life, in the process of formulating prevention and control policies, it is necessary to gather the opinions of experts in medical and health, economy, transportation, emergency, social life, and other fields. These experts screen the existing epidemic prevention and control plans based on local real-time situations from which they select the plan that best meets local needs. In this way, group decision-making can adopt the opinions of experts in various fields, break the limitations of personal notions about tackling certain problems, and reduce the error rate in decision-making related to epidemic prevention and control plans.

Based on the characteristics of group decision-making and epidemic prevention and control programs, the following steps can be obtained:

Step 1: Call for proposals. A sound epidemic prevention and control policy involves various aspects, such as management and control policies, nucleic acid testing, and traffic control. Each aspect is decided separately. At present, after nearly two years of accumulating experience with the coronavirus outbreak, many epidemic prevention and control plans have been formed. The first step in determining a good prevention and control plan is to collect plans in various fields and summarize them.

Step 2: Program primary selection. In this step, the experts conduct a preliminary screening of the collected plans, analyze the feasibility of the collected plans, and select an alternative plan that conforms to the local epidemic situation $P_i (i = 1, 2, \ldots, n)$.

Step 3: Form a team of experts. The quality of the expert team determines the effect of the decision-making plan. The epidemic prevention and control policy should not only gather the opinions of medical, healthcare, and related management personnel but also involve experts in other fields, such as economy, transportation, and social security. The experts involved in the decision-making of the current plan are determined according to the decision-making content, denoted as $E_i (i = 1, 2, \ldots, m)$. Each expert prioritizes the options according to their professional knowledge.

Step 4: Form preference maps of experts about the alternatives. First, decision-makers convert the expert preference ranking into a preference map according to Definition 1. Then, they determine the index content contained in the CES and determine the acceptable value range of the GCI.

Step 5: Quantify the dispute and assess whether the experts have reached a consensus. First, a dispute matrix is constructed according to the preference graph, and the dispute index is calculated according to Eq. (3). Second, if PDisaI=0 or GCI is greater than the value determined in Step 4, this indicates that experts have reached a consensus on the ranking of epidemic prevention and control plans, and the solution is based on Definition 3 at this time; otherwise, go to Step 6.

Step 6: Refine the experts' opinions. At this time, experts have yet to reach a consensus on the ranking of epidemic prevention and control plans. Relevant experts are selected according to the dispute index in descending order to modify their preferences regarding the plan via negotiation. If none of these experts are willing to change their rankings, go to Step 7; Otherwise, after obtaining the experts' revised preference order, go to Step 4.

Step 7: Obtain the order of the programs with the least divergence. First, S_{ik} is obtained from Definition 2, which indicates the total recognition gap of experts when P_i ranks k. Then, the distribution model is established and solved,

$$\begin{aligned}
\min \quad & f = \sum_i \sum_k x_{ik} S_{ik} \\
\text{s.t.,} \quad & \sum_{i=1}^{n} x_{ik} = 1, \quad k = 1, 2, \ldots, n, \\
& \sum_{k=1}^{n} x_{ik} = 1, \quad i = 1, 2, \ldots, n, \\
& x_{ik} = 0 \text{ or } 1, \quad i, k = 1, 2, \ldots, n.
\end{aligned}$$

Step 8: Analyze the results. In this step, the consensus results are analyzed, and the selected epidemic prevention and control plan is determined.

4 Decision-Making on Epidemic Prevention at Borders

At this stage, the situation of the COVID-19 epidemic has become more complicated; the coronavirus is mutating rapidly, and the number of confirmed cases infected with the Omicron is increasing rapidly. At the same time, the Delta and Omicron strains are currently coexisting, which makes it more difficult for local governments to formulate prevention and control policies. Since the discovery of Omicron in South Africa, the virus has spread in many countries around the world within a short period of time. Most of the initial cases were imported from abroad; hence, some countries that have eased control have begun to adjust their overseas import policies once again. Many countries have strict controls on overseas imports, while the virus is still spreading rapidly around the world. In the two years of fighting against the pandemic worldwide, from when the mode of transmission remained unknown up to the implementation of many successful anti-pandemic policies, effective prevention and control plans have been established. Judging from the communication status of Omicron, the Chinese policy of "external defense input and internal defense rebound" is widely considered practical and effective. As the initiators of prevention and control policies, it is necessary to "prevent the import and prevent spillover". Therefore, for the control policy, which is an integral part of the prevention policy, it is necessary to consider the two aspects of preventing imports and spillovers when making decisions.

According to the current situation of the local epidemic, different levels of policies are adopted for overseas imports. The government should be able to keep citizens safe while minimizing economic and social activity loss. Thus, the choice of control degree is one of the key decisions concerning the country and the people. Based on this idea, this section takes the entry policy as an example to introduce the application of the group decision-making method in the formulation of a sound epidemic prevention and control policy. The simulation scenario is as follows. During the initial stage of Omicron transmission, there were imported cases and locally confirmed cases in the country. However, there was no large-scale transmission, only several suspected cases and close contacts of confirmed cases in the local area.

Step 1: Call for proposals. The first step in formulating COVID-19 prevention and control plans is to solicit plans from all parties involved, including effective plans based on existing epidemic prevention and control experience and new views from experts from all parties. Based on the existing prevention and control experience and the opinions of experts, we collect 30 plans for the formulation of entry control policies.

Step 2: Select the program to be implemented. Here, epidemic prevention and control experts conduct a preliminary screening of the collected plans according to the current local epidemic situation. Then, they obtain five alternatives that are more in line with the characteristics of this round of epidemic situations. The five alternatives are recorded as $\{P_1, P_2, P_3, P_4, P_5\}$, the details of which are as follows:

P_1: All visitors will be banned from entering the country and all tourist activities and gatherings will be stopped.

P_2: Travelers from countries with confirmed Omicron cases shall be prohibited from entering, and the areas where the confirmed cases are active are closed and managed. Meanwhile, other areas will operate as usual.

P_3: All inbound personnel undergoes 21-day centralized quarantine and two nucleic acid tests. The places where the epidemic occurred and other related places and areas shall be closed and managed at different levels. Those residing in other areas will be restricted from going out.

P_4: All inbound personnel, regardless of nationality and whether they have completed the whole course of the new crown vaccine, must be isolated for 14 days. They must have a negative nucleic acid test result at the end of this period. A 4-week special epidemic prevention measure will be implemented nationwide, and gatherings of more than six people shall be prohibited.

P_5: Entry personnel must have a negative nucleic acid test result 48 hours before departure. After entering the country from a country on the red list (i.e., those with more than 50 confirmed cases in Omicron), the hotel will be quarantined for ten days. Other regions will formulate their respective local control policies according to local conditions.

Step 3: Form a team of experts. The urgently needed policy is the control policy, which must consider medical and health, transportation, economy, citizen psychology, and other aspects. The policy must also select experts from different fields to form an expert team according to the current situation. At this time, three groups of prevention and control experts (E_1, E_2, and E_3) in the field of medical and health, and one group of experts (E_4) in the field of transportation, one group of experts (E_5) in the field of economy and another group of experts (E_6) in the field of public psychology shall be selected. These groups of experts, denoted as E_1, E_2, E_3, E_4, E_5, and E_6, respectively, shall make decisions about entry policies in the epicenter of an outbreak.

Six expert groups in each field will rank five alternatives based on expertise and experience, with specific preferences as follows:

$$E_1 : P_4 \sim P_5 \succ P_2 \succ P_3 \succ P_1,$$
$$E_2 : P_5 \succ P_4 \succ P_2 \sim P_3 \succ P_1,$$
$$E_3 : P_4 \succ P_3 \succ P_5 \succ P_1 \sim P_2,$$
$$E_4 : P_4 \succ P_3 \succ P_2 \succ P_1 \succ P_5,$$
$$E_5 : P_3 \succ P_4 \succ P_2 \sim P_5 \succ P_1,$$
$$E_6 : P_3 \succ P_4 \succ P_5 \succ P_1 \sim P_2.$$

Step 4: Form preference maps of experts about the alternatives. According to Definition 1, the expert preference is transformed into a preference graph, and the results are shown in Fig. 2.

It is determined that the acceptable GCI value is $5/6$, that is, GCI $> 5/6$ indicates that the experts have reached a consensus.

Step 5: Quantify the dispute and judge whether the experts have reached a consensus. Dispute matrix D_0 is obtained according to Definition 2,

$$D_0 = (\Delta_{ij})_{6\times 6} = \begin{pmatrix} 0 & 0 & 4 & 6 & 4 & 5 \\ 0 & 0 & 4 & 7 & 4 & 4 \\ 4 & 4 & 0 & 3 & 2 & 2 \\ 6 & 7 & 3 & 0 & 4 & 5 \\ 4 & 4 & 2 & 4 & 0 & 0 \\ 5 & 4 & 2 & 5 & 0 & 0 \end{pmatrix}.$$

The GCI is calculated according to Eq. (1),

$$\text{GCI} = \frac{2}{15} < \frac{5}{6}.$$

At this time, the expert group has not yet reached a consensus. According to Definition 4, the consensus sequence is given by

$$\text{CES} = [\text{GCI} = \frac{2}{15},\ \text{MDP} = \{(2,4)\},\ \text{PDisaI} = 7,$$
$$\text{MDA} = \{(3,5)\},\ \text{MDispI} = 5].$$

Therefore, it can be seen that the two expert groups with the greatest differences are E_2 and E_4, and the most controversial alternatives are P_3 and P_5.

Step 6: Refine the expert opinion.

The expert groups E_2 and E_4 have the largest differences of opinion, followed by (E_1, E_4) and (E_1, E_6). After consultation, when experts E_4 and E_6 are willing to change their preferences, the changed preferences can be expressed as

$$E_4 : P_4 \succ P_5 \succ P_2 \sim P_3 \succ P_1,$$
$$E_6 : P_4 \succ P_5 \succ P_3 \succ P_1 \sim P_2.$$

According to Definition 1, the modified preference maps of experts are shown in Fig. 3.

The dispute matrix D_1 is thus constructed according to Definition 2,

$$D_1 = (\Delta_{ij})_{6\times 6} = \begin{pmatrix} 0 & 0 & 4 & 0 & 4 & 2 \\ 0 & 0 & 4 & 2 & 4 & 2 \\ 4 & 4 & 0 & 2 & 2 & 2 \\ 0 & 2 & 2 & 0 & 4 & 0 \\ 4 & 4 & 2 & 4 & 0 & 4 \\ 2 & 2 & 2 & 0 & 4 & 0 \end{pmatrix}.$$

The GCI at this time is calculated according to Eq. (1),

$$\text{CGI} = \frac{3}{15} = \frac{1}{5} < \frac{5}{6}.$$

	$V^{(1)}$	$V^{(2)}$	$V^{(3)}$	$V^{(4)}$	$V^{(5)}$	$V^{(6)}$
P_1	$\{5\}$	$\{5\}$	$\{4,5\}$	$\{4\}$	$\{5\}$	$\{4,5\}$
P_2	$\{3\}$	$\{3,4\}$	$\{4,5\}$	$\{3\}$	$\{3,4\}$	$\{4,5\}$
P_3	$\{4\}$	$\{3,4\}$	$\{2\}$	$\{2\}$	$\{1\}$	$\{1\}$
P_4	$\{1,2\}$	$\{2\}$	$\{1\}$	$\{1\}$	$\{2\}$	$\{2\}$
P_5	$\{1,2\}$	$\{1\}$	$\{3\}$	$\{5\}$	$\{3,4\}$	$\{3\}$

Fig. 2 Initial PMs.

	$V^{(1)}$	$V^{(2)}$	$V^{(3)}$	$V^{(4)}$	$V^{(5)}$	$V^{(6)}$
P_1	$\{5\}$	$\{5\}$	$\{4,5\}$	$\{5\}$	$\{5\}$	$\{4,5\}$
P_2	$\{3\}$	$\{3,4\}$	$\{4,5\}$	$\{3,4\}$	$\{3,4\}$	$\{4,5\}$
P_3	$\{4\}$	$\{3,4\}$	$\{2\}$	$\{3,4\}$	$\{1\}$	$\{3\}$
P_4	$\{1,2\}$	$\{2\}$	$\{1\}$	$\{1\}$	$\{2\}$	$\{1\}$
P_5	$\{1,2\}$	$\{1\}$	$\{3\}$	$\{2\}$	$\{3,4\}$	$\{2\}$

Fig. 3 Revised PMs.

At this time, experts have not yet reached a consensus, and the CES calculated using Eqs. (2)–(5) is given by

$$\text{CES} = [\text{GCI} = \frac{1}{5},\ \text{MDP} = \{(1,3), (1,5), (2,3), (2,5), (4,6), (4,6)\},\ \text{PDisaI} = 4,\ \text{MDA} = \{3\},\ \text{MDispI} = 4].$$

Therefore, it can be concluded that there are six pairs of expert groups with the most disputes, namely (E_1, E_3), (E_1, E_5), (E_2, E_3), (E_2, E_5), (E_4, E_5), and (E_5, E_6). P_3 is the most controversial. The dispute matrix M is calculated as follows:

$$M = (S_{ik})_{5\times 5} = \begin{pmatrix} 22 & 16 & 10 & 4 & 0 \\ 14 & 8 & 2 & 1 & 5 \\ 10 & 6 & 4 & 6 & 12 \\ 2 & 3 & 9 & 15 & 21 \\ 6 & 3 & 5 & 10 & 16 \end{pmatrix}.$$

After this iteration, other divergent experts will be reluctant to modify their preferences.

Step 7: Obtain the order of the programs with the least divergence. After the negotiation iteration, the expert group has yet to reach a consensus on the ranking of alternatives. At this time, we minimize differences by constructing the following allocation model,

$$\begin{aligned} \min \quad & y = \sum_{i=1}^{5}\sum_{k=1}^{5} x_{ik} S_{ik}, \\ \text{s.t.,} \quad & \sum_{i=1}^{5} x_{ik} = 1, \quad k = 1,2,3,4,5, \\ & \sum_{k=1}^{5} x_{ik} = 1, \quad i = 1,2,3,4,5, \\ & x_{ik} = 0 \text{ or } 1, \quad i,k = 1,2,3,4,5. \end{aligned}$$

The order of the solutions with the smallest divergence is as follows:

$$P_4 \succ P_5 \succ P_3 \succ P_2 \succ P_1.$$

Step 8: Analyze the results. In the results, the expert group had the lowest preference among all alternatives, indicating that it was reasonable to choose P_4 as the entry plan in cases wherein there is a sudden spread of mutant strains in cities under the new situation of COVID-19. This policy indicates that all inbound personnel, regardless of nationality and whether they have completed the whole course of the new coronavirus vaccine, must be isolated for 14 days. Their nucleic acid test result must also be negative before the end of this period. Moreover, a 4-week special epidemic prevention measure is implemented nationwide, and gatherings of more than six people are prohibited.

In addition, we solved the above decision problem using the Kendall scores method[26] and compared the results with those obtained in this paper.

The first step is to perform the initial processing of the original preferences, which are represented by vectors. The vector format is given by $A = (a_1, a_2, \ldots, a_n)$, where a_i is the rank assigned to alternative i. For example, $A = (5, 3, 4, 1.5, 1.5)$ means that alternative a is in fifth place, alternative b is in third place, alternative c is in fourth place, and alternatives d and e are in first and second places, respectively. According to the initial preference, the vectors of schemes are expressed as follows:

$A_1 = (5, 3, 4, 1.5, 1.5)$, $A_2 = (5, 3.5, 3.5, 2, 1)$, $A_3 = (4.5, 4.5, 2, 1, 3)$, $A_4 = (4, 3, 2, 1, 5)$, $A_5 = (5, 3.5, 1, 2, 3.5)$, and $A_6 = (4.5, 4.5, 1, 2, 3)$.

Then, we calculate the distance matrix, according to $d_{KS} = \frac{1}{2}\sum_i \sum_j |a_{ij} - b_{ij}|$, the KS distance is as follows:

$$(d_{KS})_{5\times 5} = \begin{pmatrix} 11 & 8 & 5 & 2 & 1 \\ 8 & 5 & 2 & 2 & 5 \\ \frac{15}{4} & \frac{11}{4} & \frac{15}{4} & \frac{21}{4} & \frac{33}{4} \\ \frac{7}{4} & \frac{5}{4} & \frac{17}{4} & \frac{29}{4} & \frac{41}{4} \\ \frac{11}{2} & 4 & \frac{7}{2} & \frac{9}{2} & \frac{13}{2} \end{pmatrix}.$$

The distance is minimized using the Hungarian method, and the specific objective function and constraints are as follows:

$$\begin{aligned} \min \quad & z = \sum_{i=1}^{5}\sum_{k=1}^{5} x_{ik} d_{KS}, \\ \text{s.t.,} \quad & \sum_{i=1}^{5} x_{ik} = 1, \quad k = 1,2,3,4,5, \\ & \sum_{k=1}^{5} x_{ik} = 1, \quad i = 1,2,3,4,5, \\ & x_{ik} = 0 \text{ or } 1, \quad i,k = 1,2,3,4,5. \end{aligned}$$

The final consensus ranking is as follows:

$$P_4 \succ P_3 \succ P_5 \succ P_2 \succ P_1.$$

First of all, the KS method expresses differences by distance, and the decision-makers have only one chance to express their opinions, so there is no step in which they can update their opinions based on the situation after the decision. As a result, although the scheme with the least controversy can be obtained quickly, it does not apply to the decision-making project with significant uncertainty, such as the epidemic prevention policy. At this stage, the COVID-19 situation is changing rapidly, and the spread of variants remains uncertain. There is a general law of virus mutation: the transmission becomes stronger and toxicity becomes weaker. The current stage is mainly based on the transmission of the Delta and Omicron strains. Unfortunately, only Omicron follows this rule, while Delta does not seem to follow this mutation law; that is, its transmission and toxicity are higher than the original strain. There are currently confirmed Delta and Omicron cases. The situation is complex and severe, and the virus is constantly mutating. Thus, the future situation cannot be accurately predicted. Related to this problem, the decision-making method used in this paper can collect the opinions of experts in multiple fields and provide opportunities for consultation among these experts. Doing so can help the government cope with the changing COVID-19 environment and reduce decision-making errors. As demonstrated by the results, the method proposed in this paper is feasible.

Second, the results revealed that the two methods had changed the ranking positions of P_3 and P_5. The most important difference between the two schemes is whether to have the nucleic acid before or after the entry. Among them, P_3 can only enter if the nucleic acid test is negative, and P_5 has no requirements for the nucleic acid status of the entry personnel. The method used in this paper moves P_3 forward after consultations with experts from different fields, which is in line with the current international environment of Omicron. In addition, from the practice and research accumulated in the past two years, it can be seen that a key to curbing the spread of the mutated virus is to cut off from the source, that is, to determine the health status of those entering the country. This proves that the study in this paper is meaningful for the prevention and control of outbreaks.

In conclusion, the method proposed in this paper is more suitable for decision-making regarding the formulation of COVID-19 prevention and control programs.

5 Conclusion and Prospect

The rapid mutation of the novel coronavirus and the emergence of strains that do not follow the rules of virus mutation have resulted in the complex and severe COVID-19 situation. To solve problems of precise epidemic prevention and control, this paper proposes a decision-making method for determining plans, which gathers the opinions of experts in various fields. The proposed method identifies the experts with the most remarkable differences and the most controversial schemes according to their preferences. Through the process involving consultation and modification of experts' opinions, the prevention and control plan with the slightest differences and the most consistency with the current epidemic is obtained. This study draws two conclusions. First, the method proposed in this paper can not only quickly determine the epidemic prevention and control plan to ensure urban security and stability of the urban economy and medical system but also optimize the expert group's opinions, thus laying a foundation for the follow-up work of epidemic prevention and control. Second, the entry policy is directly related to the importation of the virus, so strict detection and quarantine of people entering from abroad is a pivotal link to containing the spread of the virus.

However, there is still room for improvement in the research conducted in this work. On the one hand, this study's consensus sequence includes three aspects that must be improved, along with the further optimization of the consensus model. On the other hand, to improve the accuracy and scientificity of decision-making, the current decision-making model has changed to large-scale group decision-making. Future studies must therefore focus on the decision-making methods of epidemic prevention and control in the large-scale context to further improve the accuracy of the proposed method.

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