# Research on the Importance Data Generation of Target System Based on Complex Network

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**Abstract.** Using the relevant theoretical knowledge of complex networks, each fire strike target is described in a networked manner through different dimensions, and according to the interaction relationship between each node, the performance and network weighted assignment of each target node are performed to intuitively reflect the system role of each node. Through the weighted synthesis of different performance importance and network importance evaluation, the importance data of each target node is obtained. Through the solution of the importance of the target system in different scenarios, extensive collection of relevant data can generate a target importance database, and a comprehensive analysis of the importance data can provide a basis and basis for the selection of strike targets.

**Keywords:** complex network · importance · data generation · target system

## 1 Introduction

With the continuous increase of the scale of the combined unit and the continuous improvement of the ability to independently carry out complex combat tasks, the ability of the unit equipment system is the key to the improvement of the unit's combat effectiveness. Different nodes have different important roles in the target system, supporting the The effectiveness of the entire target system is played. Here, the support and contribution of different target nodes to the target system is called the system node importance of the target [11][12].Through the effective evaluation of the importance of different nodes, it can provide strong information support for equipment support and fire strikes. In order to be able to evaluate the importance of the target node more comprehensively and accurately [2]. On the basis of considering the importance of node performance, this paper uses complex network theory to study it from the perspective of system operation, so as to more accurately find out the key node targets in the enemy's target system, and do a good job of evaluating firepower strikes.

The establishment of a target system importance database can provide data support for the rapid selection of targets, and the generation of importance data based on complex network-related foundations can comprehensively reflect the importance of targets. The node importance of the target system mainly includes two aspects: network importance

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and importance [1][5][7]. Among them, the network importance mainly considers four aspects of the target node's accusation relationship importance, location relationship importance, fire support importance and security support relationship importance. The performance importance mainly considers the importance of threat, the importance of survivability, the importance of repairability and the importance of reconnaissance. By modeling the complex network of the combat system, the node importance of the target is obtained, and then the target list is generated.

The process mainly includes target characteristic analysis, target node processing, establishing connection relationships assigning edge weighting values solving node values determining strike target ranking, selecting strike targets and generating strike targets ist.

## 2 Evaluation of Node Importance of Target System

### 2.1 Related Definitions

For the synthetic detachment, we abstract each weapon as a network node, and there is a complex network $G = \{S, L, \omega\}$, whose equipment system is a complex network composed of undirected weight, directed weight and directed weight, in which $S_i$ is a set of nodes, $L_{ij}$ is a set of edges, and $\omega_{ij}$ is the weight in the weighted network.

For the complex architecture network, the following definitions are required:

Definition 1: Node degree $D_i$: used to reflect the number of nodes directly connected to nodes. Generally, the more points directly or indirectly connected with the point, the closer the point is to other nodes in the general architecture network.

$$D_i = \sum\nolimits_{j=1}^{n} c_{ij}; \quad c_{ij} = \begin{cases} 1 & i,\ j \text{ adjacent} \\ 0 & i,\ j \text{ not adjacent} \end{cases} \tag{1}$$

For weighted networks:

$$D_i' = \sum\nolimits_{j=1}^{n} c_{ij}\omega_{ij}; \quad c_{ij} = \begin{cases} 1 & i,\ j \text{ adjacent} \\ 0 & i,\ j \text{ not adjacent} \end{cases} \tag{2}$$

Definition 2: Node betweenness $J_n$: refers to the shortest path number $J_n$ from node $S_i$ to node $S_j$ in the network through node $S_n$, which can better reflect the influence of nodes on the network, and reflects the importance of nodes from the overall point of view.

$$J_n = \sum\nolimits_{i \neq j \neq n} \frac{d_{ij}^n}{d_{ij}} \tag{3}$$

Where: $d_{ij}$ is the number of shortest paths from node $S_i$ to node $S_j$; $d_{ij}^n$ is the shortest path from node $S_i$ to node $S_j$ through node $S_n$.

Definition 3: Node Distance $C_{ij}$: It represents the sum of the number of edges of the shortest path from node $S_i$ to node $S_j$ in the general system network. Then the farthest distance from any node $S_i$ to the node $S_j$ in the network is the radius $R$ of the network.

$$R = \max\{C_{ij}\} \tag{4}$$

For a directed weighted network, the distance between nodes should consider the weight between nodes [6], which is expressed by $C_{ij}^{'}$.

$$C_{ij}^{'} = \frac{\omega_{ix_1} + \omega_{x_1x_2} + \cdots\cdots + \omega_{x_{y-1}x_y} + \omega_{x_yj}}{\omega_{ix_1}\omega_{x_1x_2}\cdots\cdots\omega_{x_{y-1}x_y}\omega_{x_yj}} \tag{5}$$

Definition 4: Node Proximity $P_i$: It can effectively reflect the relative position relationship between nodes. It refers to the reciprocal of the sum of the shortest distances that can reach node $S_i$ in network $G$.

$$P_i = \frac{1}{\sum_{i\neq j}^{n} C_{ij}^{'}} \tag{6}$$

Definition 5: Node Efficiency A: It reflects the difficulty of information arrival of nodes in the network, and it can effectively reflect the role played by nodes in network transmission [4]. The greater the efficiency value of a node, the greater the role of the node in network information transmission:

$$E_i = \frac{1}{C_{ij}} \tag{7}$$

Where $C_{ij}$ is the distance from node $S_i$ to node $S_j$, and $\frac{1}{C_{ij}}$ is the transmission efficiency from node $S_i$ to node $S_j$.

Definition 6: $n$ -order neighboring node: for any node $i$ in a complex network, its first-order neighboring node is a node with a distance of 1 from the node, which is marked as $\tau^{(1)}(i)$, and then analogized to the $i$ -order neighboring node of node $n$, which is marked as $\tau^{(n)}(i)$.

The degree of node contribution usually shows an exponential decay trend with the increase of node distance [3], so for node $S_i$, the node importance evaluation function of an evaluation attribute is:

$$E_i^n = \sum\nolimits_{n=[0,n]} \gamma^n \sum\nolimits_{i\in\tau^{(n)}(i)} \sigma_i \tag{8}$$

Definition 7. Network Global Efficiency $E_G$: It represents the average value of information transmission difficulty between nodes in the network, and is used to reflect the coupling of the whole network. If the overall network efficiency is high, the information transmission of the whole network is high-speed and effective. Expressed as:

$$E_G = \frac{1}{N(N-1)} \sum\nolimits_{I\neq j\in G} \frac{1}{C_{ij}} \tag{9}$$

## 2.2 Description of System Network

### 2.2.1 Spatial Structure Network

Spatial network mainly reflects the spatial position relationship of equipment, which is an undirected weighted network, and its weight relationship is mainly related to the main combat tasks of the unit in which the equipment participates. When the detachment adopts the inverted triangle attack formation, the positional relationship between the first two points of the inverted triangle is more important than that of the back vertex.

On the one hand, the importance of nodes in the spatial structure network is related to the degree value of nodes locally, which is expressed by the average degree distribution of nodes.

$$E_{IK}^{1} = \frac{D_{i}^{'}}{D^{-2}_{\prime}} \tag{10}$$

On the other hand, it is related to the distance between nodes globally, which is expressed by the proximity of nodes. The proximity of nodes can effectively reflect the spatial distance relationship between nodes, which is the reciprocal of the sum of the distances from node $S_i$ to other nodes in the network $G$.

$$E_{IK}^{2} = \frac{1}{\sum_{i \neq j}^{n} C_{ij}^{'}} \tag{11}$$

Therefore, we can get the node importance of the spatial network:

$$E_{IK} = E_{IK}^{1} E_{IK}^{2} \tag{12}$$

### 2.2.2 Command and Control Network

In the synthetic unit, the command-and-control relationship mainly occurs between different levels, so the command and control network is connected with a directed and weighted level, and the contribution degree of $n$ -level neighbor node comprehensively measures the importance of this node in the whole network. In the network, the importance of each accusing node should fully reflect the influence and contribution of node $S_i$ to neighboring nodes, and also reflect the influence and contribution of node $S_i$ to nonadjacent nodes. The importance of a node is closely related to its command ability, task correlation and spatial distance. Here, we use the degree value, edge weight, node betweenness and node efficiency to evaluate the importance of a node, so that it can better adapt to other command networks outside the synthetic unit, and has better evaluation applicability.

1) Node local importance

In the weighted network of command and control, the local importance of nodes is related to the number of nodes directly connected to nodes and the weight of connected edges. In addition, the local importance of nodes is closely related to the number of paths between nodes [8]. Therefore, we can construct the evaluation matrix with the average degree of nodes and the intermediate number of nodes to determine the local importance of nodes without cascade.

$$E_{IZ}^{'}(i) = \varphi \frac{D_{i}^{'}}{\overline{D}_{i}^{\prime 2}} + \phi \frac{d_{ij}^{l}}{\sum_{s \in [1,n]} d_{is}^{l}};\ \varphi + \phi = 1 \tag{13}$$

For the synthetic detachment, its command and control network is a directed weighted network, because its command authority has a very obvious cascade relationship, and the cascade relationship will greatly weaken the accusation effect with the increase of hierarchy. Therefore, the command ability of a node is closely related to the command level of the node. For example, if the node $S_1$ is a battalion command vehicle and the $S_{1-1}$ vehicle is a company commander vehicle, then the importance of the node $v_1$ and the importance of the node $S_{1-1}$ will be a cascade exponential relationship.

$$\begin{cases} E_{IZ}^{\prime 0} = \gamma^0 E_{IZ}^{\prime 0} \\ E_{IZ}^{\prime 1} = \gamma^1 E_{IZ}^{\prime 0} \\ \quad \cdots\cdots \\ E_{IZ}^{\prime n} = \gamma^n E_{IZ}^{\prime 0} \end{cases} \tag{14}$$

The above relationship can better reflect the importance relationship between nodes and neighboring nodes in the cascaded relational network. Where: $\gamma^p$ is the cascade coefficient, and the influence ability of command and control decreases with the increase of cascade command and control relationship $p$. Therefore, the local importance CC of the node is $s$:

$$E_{IZ}^{o}(i) = \gamma^p \left( \varphi \frac{D_i^{'}}{\overline{D}_i^{\prime 2}} + \phi \frac{d_{ij}^{l}}{\sum_{s\in[1,n]} d_{is}^{l}} \right)$$
$$\begin{cases} \varphi + \phi = 1 \\ \;p \in N_+ \end{cases} \tag{15}$$

2) Global importance of network

For complex networks, the centrality of network global efficiency [10] represents the influence of network nodes on the global network, which is an important measure of the global coupling of complex networks. It can better reflect the influence of different nodes' edge changes on the global efficiency of the network, and can improve the evaluation level of command relationships among different levels. In a complex network, $E_G$ represents the global efficiency of the network. At this time, if any edge $\pi$ in the network is removed, the global efficiency of the network will change, and its change rate will be recorded as $E_G^{\Delta(\pi)}$, and there are

$$E_G^{\Delta(\pi)} = \frac{E_G - E_G(\pi)}{E_G} \tag{16}$$

In a complex network, two nodes are connected at both ends of a connecting edge. For a weighted network, the centrality of network efficiency, that is, the importance degree $E_{IZ}^{*}$ of network nodes, is as follows:

$$E_{IZ}^{*}(i) = \omega_{(\pi)} \sum\nolimits_{i\in k} E_G^{\Delta(\pi)} \tag{17}$$

Where: $s$ represents the weight of connected edge $\pi$, and this method can improve its better estimation method for the importance of weighted network nodes. At the same time, the importance of nodes can be estimated by calculating the rate of change of the global efficiency of the network by removing the connection edge, which can effectively explain the situation of loss of connection between nodes, equipment function damage and so on, and has good adaptability.

Therefore, the comprehensive importance of nodes in the command and control network is as follows:

$$E_{IZ}(i) = E_{IZ}^{*}(i) \times E_{IZ}^{o}(i) \tag{18}$$

### 2.2.3 Fire Support Network

The fire support relationship is mainly reflected in the performance parameters and fire support relationship of the target node itself. In the network relationship, only the network influence of the node itself is considered, that is, the influence of the performance of the node itself is excluded. In the network system, the fire support relationship of nodes is mainly related to the distance between nodes, and the farther the distance is, the weaker or relatively weaker the support effect is. Therefore, the efficiency between nodes can be used to represent the fire support relationship and describe the difficulty of reaching the target node.

$$E_{IH} = \frac{1}{C_{ij}} \tag{19}$$

### 2.2.4 Safeguarding Support Network

In the guarantee support network, the information transmission between nodes can be represented by the connection between nodes. The transmission of information is first expressed as the information transmission and support function of nodes to adjacent nodes. In the system networkof $G$, the degree of a node represents the node. It is neighbors with each node, and at the same time reflects its own importance contribution in the role relationship of related nodes.

$$E_{IC}^{1} = \sum\nolimits_{i \neq j \in G} \frac{c_{ij} D_i E_j}{\omega_{ij} \times \overline{D}_i^2} \tag{20}$$

In the whole information transmission network $G$, the node $S_i$ not only contributes to the neighboring nodes, but also affects the whole network system. In order to fully reflect the information transmission influence of nodes in the global network, here we combine the node efficiency $E_i$ to reflect the influence of node $S_i$ on the information transmission of the global network.

$$E_{IC} = E_i \sum\nolimits_{i \neq j \in G} \frac{c_{ij} D_j E_j}{\omega_{ij} \times \overline{D}_i^2} \tag{21}$$

## 2.3 Description of Attribute Importance of System Nodes

The attributes of the equipment nodes in the synthetic detachment are different with different equipments, and the attributes of each equipment node are qualitative evaluation indicators, which can be scored by experts through expert evaluation method, and the weight of each evaluation expert score obtained by IGAHP method. [9] Finally, the evaluation value of equipment node attribute importance is obtained.

Assuming that a total of $x$ experts in related fields are invited to score $y$ indicators respectively, each expert will give a judgment vector, among which the index vectors given by expert $a$ and expert $b$ are:

$$W_a = (w_{a1}, w_{a2}, \cdots w_{an})^T$$
$$W_b = (w_{b1}, w_{b2}, \cdots w_{bn})^T \tag{22}$$

The index weight vector given by two experts can be determined by the degree of compatibility $C(a, b)$.

$$C(a, b) = \frac{\sum_{i=1}^{n} w_{ai} \times w_{bi}}{\sqrt{\left(\sum_{i=1}^{n} w_{ai}^2\right) \times \left(\sum_{i=1}^{n} w_{bi}^2\right)}} = C(b, a) \tag{23}$$

Through the analysis of the compatibility of expert evaluation indicators, wes can get the difference of expert evaluation. When the two experts' evaluation is completely consistent, there are $C(a, b) = 1$ and $C(a, b) \in [0, 1]$. The smaller the value of $C(a, b)$, the greater the difference of expert judgment. From this, the weight of the $p$ expert can be found as follows:

$$\omega_p = \begin{cases} \frac{1}{x}, C(p, q) = 1 \\ \frac{\sum_{q=1}^{x} C(p,q)}{\sum_{p=1}^{x} \sum_{q=1}^{x} C(p,q)} \end{cases} \tag{24}$$

According to the evaluation index value $W_x$ given by experts and the weight $\omega_p$ given by experts, the evaluation values of the attribute importance of equipment nodes can be obtained respectively, which are expressed by $E_{S1}, E_{S2}, E_{S3}, E_{S4}, E_{S5}$ respectively.

## 2.4 Generation of Comprehensive Importance Data of Target System Nodes

According to the above description of equipment network importance and analysis of equipment attribute importance, the comprehensive importance of equipment node $S_i$ in complex network is defined as:

$$\xi_i^{'} = \psi_{11} E_{IK} + \psi_{12} E_{IZ} + \psi_{13} E_{IT} + \psi_{14} E_{IC} + \sum_{k=1}^{4} \psi_{2k} E_{Sk} \tag{25}$$

After normalizing $\xi_i^{'}$, the comprehensive importance $\xi_i$ is obtained.

### 2.5 Target Selection

The implementation of a specific strike on a target usually takes into account our combat objectives and mission requirements, and at the same time needs to comprehensively consider the distribution of the target and the system capabilities of both parties. By analyzing the importance of the system nodes of the target, the effect of the target in the enemy's combat system can be judged. According to the importance value of the target node, the importance of the target is sorted and the strike target is selected to generate a strike target list.

The target list mainly includes basic information such as target number, target system node importance, target name, target characteristics, and target level. Through the relevant information of the target list, it provides data support for weapon target matching and enhances the accuracy of weapon target matching.

The target number, the node importance of the target system, and the target name can be obtained from the solution results of the model. According to the obtained importance of the target node, combined with the performance importance of the target node, the characteristics of the target are analyzed. In order to meet the needs of combat plan generation, the target level in the target list is mainly divided into emergency targets, important targets and general targets.

## 3 Example Analysis

### 3.1 Background Introduction

The 1st Battalion of the 1st Combat Brigade of the 4th Infantry Division of the Blue side was formed into the 1st Company of the 1st Battalion, and the 1st Battalion of the 1st Heavy Combat Brigade of the 4th Infantry Division of the Blue side was formed as the main attack group. At present, after the first stage of combat operations, the red team has broken through the enemy's frontier positions and continued to expand the victory. With the coordinated support of the friendly and neighboring echelons, the blue team has launched a counterattack against the red team. At this time, the enemy formed a rear triangle formation and arranged a battle formation to carry out counter-attack operations against me.

### 3.2 Target Architecture

Here, some targets of the combined enemy detachment are unified as follows. The battalion has 3 companies and 1 reconnaissance platoon of the battalion headquarters company. Each platoon has 4 combat equipment, which is equivalent to 4 ordinary target nodes; each company has 3 platoons. 1 company finger equipment (equivalent to command and control nodes), 12 combat equipment; 1 battalion command equipment. According to the battalion tactical arrangement, each target node has different spatial location and attack direction. For the convenience of expression and distinction, we use $S_{L-P}^{Y}$ to represent the equipment in the assault group, where $Y = \{1, 2, 3, 4, 5\}$ represents 5 battalions in the synthetic brigade; $L = \{1, 2, 3\}$ stands for assault company, installation company and fire company in synthetic battalion respectively; $P = \{1, 2, 3\}$, representing the

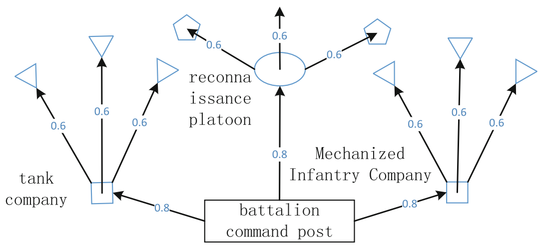


**Fig. 1.** The structure of the accusation network

1st, 2nd and 3rd rows in the company, respectively. The reconnaissance platoon in the synthetic battalion is denoted by $S_Z^Y$. Then the 1st platoon equipment of the 1st Battalion Assault Company is denoted as $S_{1-1}^1$. Set the No.1 equipment of each company as the command equipment, that is, $S^1$ represents the battalion command equipment, $S_1^1$, $S_2^1$ and $S_3^1$ represent the command equipment of 1–3 company $S_Z^1$ represents the command equipment of 1 battalion reconnaissance platoon, and the rest are combat equipment.

The system network abstracted by each target node of the enemy reflects the positional relationship between each node. For the sake of simplicity, we take the tank company and the reconnaissance platoon of the battalion headquarters company in the enemy's combined detachment as an example to demonstrate and verify the relevant data. According to the positional relationship of each enemy's target nodes, combined with the node system importance evaluation index system, the enemy's accusation network, fire support network and security support network are described and calculated respectively, and the network importance of the target node is obtained.

In the enemy's target system, the command and communication capability of the command and control equipment can be expressed by the communication strength. When the target is damaged, its communication capability is generally damaged to a large extent, showing the characteristics of a step function. According to the change of the communication capability of the command and control target nodes, the simplified structure of the command and control network is shown in Fig. 1.

In the enemy's target system, the connection between nodes is directly related to the formation and combat position of the unit. The position relationship network of target nodes is an undirected weighted network, which mainly reflects the relative position relationship of each target node. At the same time, the combat tasks undertaken by the nodes also have a certain influence on the importance of the target nodes. From this, the simplified structural relationship of the positional network of the enemy target system can be obtained as shown in Fig. 2.

In the entire target system, there is a certain protection support relationship between each target node, especially in the weapon platform that can provide fire support for target nodes such as accusation and reconnaissance. At the same time, there is also a certain firepower support relationship between each firepower node, and the firepower support relationship is generally constrained by the distance between the target nodes. In the target node, the equipment in an established platoon can be considered as a firepower node comprehensively, indicating the firepower support relationship of the platoon to other target nodes. The fire support relationship above the platoon level is represented by

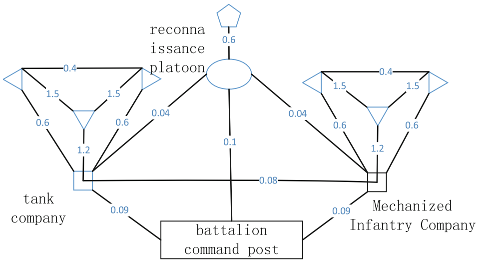


**Fig. 2.** Location relationship network structure diagram

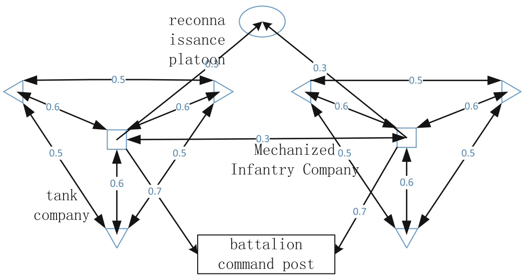


**Fig. 3.** Fire Support Network Structure Diagram

the relationship between the current level or the relationship between the current level and the higher-level command and control nodes, as shown in Fig. 3.

As the basic combat unit, the combined unit has a relatively small combat area. Therefore, 100 m is used as the basic unit value here, and the reciprocal of the distance between each target node is used as the edge connection weight between the two nodes. The distance between each equipment node of an organizational platoon is often less than 100 m. Here, the equipment of the platoon is considered as a whole, and it is simplified as a platoon target node. The distance between the command vehicles of each company can reflect the distance relationship between the companies.

In the course of operations, we believe that sustainment support relationships usually occur between specific nodal connection relationships. Taking the information assurance support relationship as an example, for command and control nodes at a higher level or between companies, the support relationship only exists between command and control nodes or interacts only through command and control nodes. Other weapons and equipment do not exist or there is a weak information support support relationship. In the reconnaissance target node, its information support support function usually provides support for other nodes in the form of information distribution through the superior command and control node. The structure of the support support network is shown in Fig. 4.

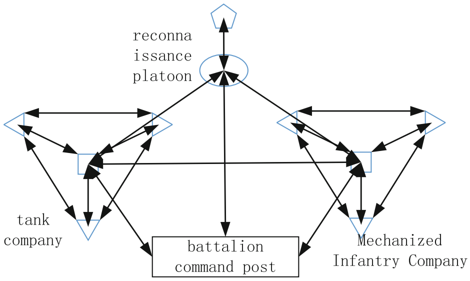


**Fig. 4.** Assurance Support Network Structure Diagram

**Table 1.** Index Weight

| Parameter | $\psi_{11}$ | $\psi_{12}$ | $\psi_{13}$ | $\psi_{14}$ |
|---|---|---|---|---|
| Numerical value | 0.21 | 0.29 | 0.13 | 0.15 |
| Parameter | $\psi_{21}$ | $\psi_{22}$ | $\psi_{23}$ | $\psi_{24}$ |
| Numerical value | 0.05 | 0.09 | 0.04 | 0.04 |

**Table 2.** Target system node importance data

| Numbering | $E_{IK}$ | $E_{IZ}$ | $E_{IT}$ | $E_{IC}$ | $E_{S1}$ | $E_{S2}$ | $E_{S3}$ | $E_{S4}$ | $E$ |
|---|---|---|---|---|---|---|---|---|---|
| $S^1$ | 0.194 | 0.343 | 0.623 | 0.327 | 0.70 | 0.90 | 0.57 | 0.85 | 0.4430 |
| $S_1^1$ | 0.173 | 0.315 | 0.623 | 0.307 | 0.68 | 0.85 | 0.63 | 0.85 | 0.4244 |
| $S_{1-1}^1$ | 0.203 | 0.175 | 0.347 | 0.167 | 0.85 | 0.90 | 0.75 | 0.65 | 0.3430 |
| $S_{1-2}^1$ | 0.198 | 0.127 | 0.323 | 0.125 | 0.85 | 0.87 | 0.75 | 0.60 | 0.3140 |
| $S_3^1$ | 0.173 | 0.315 | 0.623 | 0.307 | 0.68 | 0.85 | 0.63 | 0.85 | 0.4240 |
| $S_{3-2}^1$ | 0.203 | 0.172 | 0.347 | 0.167 | 0.85 | 0.90 | 0.75 | 0.65 | 0.3422 |
| $S_Z^1$ | 0.173 | 0.315 | 0.623 | 0.307 | 0.68 | 0.90 | 0.63 | 0.95 | 0.4329 |
| $S_{Z-1}^1$ | 0.203 | 0.175 | 0.153 | 0.167 | 0.85 | 0.90 | 0.75 | 0.65 | 0.3178 |

### 3.3 System Node Importance Data Generation

According to the evaluation index value $W_x$ given by experts and the weight $\omega_p$ given by experts, the evaluation index weight calculated by IGAHP method is shown in Table 1.

According to Eq. 10, Eq. 16, Eq. 21, and Eq. 25, Calculate the importance of each target node in the network system in four dimensions. At the same time, according to the relevant scores of experts, the performance importance of the corresponding target node can be calculated. According to the given weight relationship of each importance degree, the comprehensive importance degree evaluation result of each target node is obtained. Here, according to the above calculation method, the importance of some target nodes of the 1 battalion, tank company, machine infantry company and reconnaissance platoon of the battalion headquarters company in the enemy target system is given in Table 3–2. The importance of other target nodes is shown in Table 2. Give as needed.

## 4 Conclusions

Using the relevant theory of complex network can effectively build the enemy's target system network, so as to calculate the system importance data of each target node, and generate the target importance database. According to the large amount of data collected, it can provide data support and support for the selection of strike targets, and can effectively test the reliability of models and algorithms. The validity and reliability of the method are verified by the simulation calculation of an example.

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