A Technical Study of Sdgs-Based Prioritization and Network Construction

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Abstract. The 17 Sustainable Development Goals are a blueprint for a better and sustainable future for all. In order to achieve these 17 SDGs faster and to explore the relationship between these SDGs, this study prioritizes among the SDGs and develops several models to address these issues. First, this study identifies priorities based on the SDGs and the network structure that effectively drives the work of the United Nations. Based on this, each SDG was prioritized using the DEMATEL-ISM model. Second, to more clearly demonstrate the interrelationships among the 17 SDGs, this study combines GRA (gray relational analysis) and ISM (explanatory structural model) to propose a coupled GRA-ISM model to construct a relational network of the 17 SDGs. Then, this study assumes that one of the SDGs has been achieved, and using the above model, the remaining 16 SDGs are re-networked and given a new priority order. Finally, the model developed in this study is useful for the United Nations in making decisions on the path to achieve the SDGs.

Keywords: Neural Network, DEMATAL-ISM, GRA-ISM, Big Data.

1. Introduction

Quality of life is closely related to us [1]. Global hunger has been on the rise every year since 2015. in 2017, an estimated 9 million people died from hunger and hunger-related diseases, and 822 million people were undernourished. But this is just a snapshot of the poor. Due to other irresistible factors, the quality of life of many people around the world is deteriorating. The United Nations has set 17 sustainable development goals that can improve the quality of life for people around the world. Therefore, it is crucial to make good use of these indicators [2].

This study will build a DEMATAL-ISM model to seek the priority order among the 17 sustainable development indicators and get the priority ranking for implementing the development goals. It is proposed to combine GRA and ISM methods to build a coupled GRA-ISM model to construct a network of relationships among development indicators and discuss the possible changes of the network or the change of the priority order after achieving a certain goal. This study is hoped to be useful for the future deployment of the UN's strategic plan for sustainable development.

2. Data Introduction

2.1. Data acquisition and pre-processing

The data for this study were obtained from the official website of the United Nations (https://www.un.org/sustainabledevelopment/zh/). We crawled the data of 17 SDGs from the official website for the 20-year period of 2000-2020. We applied regression functions to pre-process and clean the crawled data [3]. The processed data basically meet the needs of this study.

3. Model building and solving

3.1. DEMATEL-ISM Model of SDGs

In this study, the DEMAETEL-ISM model was developed through the steps in the figure below to analyze the priority relationships of the 17 SDGs.

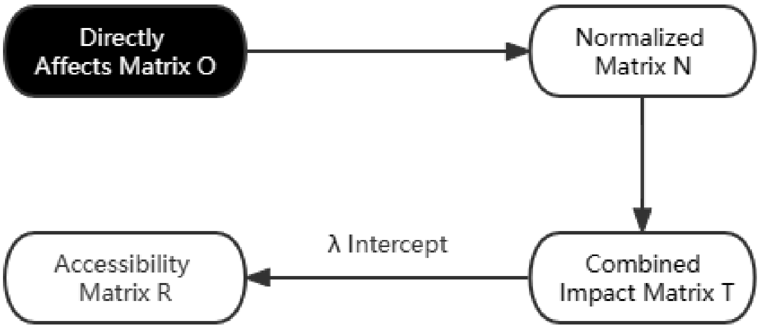

Figure 1. Steps of Establish DEMATEL-ISM Model

3.2. Compute Accessiblity Matrix

By the steps of constructing the accessibility matrix, the study firstly constructs the directly affects matrix $O = (o_{ij})$ from normalization correction matrix as the follows [4]:

$$o_{ij} = \begin{cases} 0, & Z_i^j < 0.625 \text{ or } i = j \\ 1, & Z_i^j \in [0.625, 0.75] \\ 2, & Z_i^j \in [0.75, 0.875] \\ 3, & Z_i^j > 0.875 \end{cases} \tag{1}$$

From the directly affects matrix O, the normalized matrix $N = (n_{ij})$:

$$n_{ij} = \frac{o_{ij}}{\max_i\left(\sum_{j=1}^{n} o_{ij}\right)} \tag{2}$$

Then the combined impact matrix $T = (t_{ij})$:

$$T = \sum_{k=1}^{\infty} N^k = N(1 - N)^{-1} \tag{3}$$

From the combined impact matrix T,compute the mean $\bar{T}$ and standard deviation $s(T)$ of T, which defined by

$$\bar{T} = \frac{1}{17n} \sum_{i=1}^{17} \sum_{j=1}^{n} t_{ij} \tag{4}$$

$$s(T) = \sqrt{Var(T)} = \sqrt{\frac{1}{17n} \sum_{i=1}^{17} \sum_{j=1}^{n} \left(t_{ij} - \bar{T}\right)^2} \tag{5}$$

Reference [5], an accessibility matrix can be constructed by comparing the entries and thresholds of the overall impact matrix, i.e.

$$r_{ij} = \begin{cases} 1, & h_{ij} \geq K, \\ 0, & h_{ij} < K. \end{cases} \tag{6}$$

After substituting the value, $K = 0.8869$ can be calculated.

3.3. Divide the hierarchy

In order to delineate the hierarchy of SDGs, the reachable set and precursor set are then constructed. The reachable set and precursor set are defined as

$$\begin{aligned} R(x_i) &= (r'_{ij})_{j\in J}, \text{where } r'_{ij} = \begin{cases} 1, & r_{ij} = 1 \\ 0, & \text{otherwise} \end{cases} \\ Q(x_j) &= (r''_{ij})_{i\in I}, \text{where } r''_{ij} = \begin{cases} 1, & r_{ij} = 1 \\ 0, & \text{otherwise} \end{cases} \end{aligned} \tag{7}$$

If $R(x_i) \cap (Q(x_i))^T = R(x_i)$ then x_i is considered to be at this level and vice versa.

In order to delineate the SDG hierarchy, this study will follow the following process:

1) By constructing the reachable set $R(x_i)$and the precursor set $Q(x_i)$, we determine whether x_i belongs to this level according to the judgment conditions $R(x_i) \cap (Q(x_i))^T = R(x_i)$.

2) Repeat the steps above, till the $R(x_i) \cap (Q(x_i))^T = \varnothing$.

3) Grades are assigned in the order of the grade steps.

Based on the above steps, this study divides the 17 SDGs into three tiers as shown in Figure 2. From the figure, the hierarchy in which each SDG is placed can be seen, with the order of the tiers going from top to bottom, with the topmost development goal being the highest tier.

Figure 2. Divide the Hierarchy of SDGs

3.4. GRA-ISM Model of SDGs

In order to build sub-models to extend the relationships between SDGs, this study combines two methods - Gray Relational Analysis (GRA for short) [6] and Interpretive Structural Modeling (ISM for short) - to build a network of SDGs. The ISM approach was introduced into GRA with the help of reference [7], and the new model developed in this study is called the GRA-ISM model.

3.5. The Principle of Grey Relational Analysis

The steps of Grey Relational Analysis can be roughly divided into the following processes:
1) Defining problems and response variables or quality characteristics.
2) Data collection.
3) Normalizing data for smaller the better or larger the better-quality characteristics.
4) Find gray relation coefficient for normalized data.
5) Calculate gray relation grade.
6) Select optimum level based on grade value.

According to the research needs, some modifications were made to the traditional GRA model [7] in this study. The data processing process in the model of this paper is as follows:
1) Normalizing data.
2) Determine the analysis sequence.
3) Preprocess the variables.
4) The correlation coefficients of each characteristic in the subsequence and the parent sequence are calculated.
5) Calculate the characteristic relational degree and draw the conclusion.

As described in the processing, the data is first normalized. Typically, there are four types of data that need to be normalized as follows:
1. Larger the better-quality characteristic.
2. Smaller the better-quality characteristic.
3. Closer to some exact value the better-quality characteristic.
4. Closer to some integer the better-quality characteristic.

It is not necessary to consider all these types of data in this study. There are only two types in the collated obtained data, where SDGs 1, 2, 11, 13, and 16 are the smaller, better-quality features and the others are the larger, better-quality features. In this section, the larger, better-quality features are treated as the first type of features (abbreviated as 1-char), while the smaller, better-quality features are treated as the second type of features (abbreviated as 2-char). Thus:
• The 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 15, 17th SDG are 1-char
• The 1, 2, 11, 13, 16th SDG are 2-char.

For 1-char, normalized value $\left(X_i^j\right)$ is given by.

$$X_i^j = \left(\frac{x_i^j - x_i^{min}}{x_i^{max} - x_i^{min}}\right) \tag{8}$$

and for 2-char, normalized value is given by.

$$X_i^j = \left(\frac{x_i^{max} - x_i^j}{x_i^{max} - x_i^{min}}\right) \tag{9}$$

where x_i^{max} and x_i^{min} are the maximum and minimum values of the original sequence x_i^j .

By the formula given above, compute the normalization correction matrix.

$$X = \left(X_i^j\right) = \begin{pmatrix} X_1^1 & X_1^2 & X_1^3 & \cdots & X_1^n \\ X_2^1 & X_2^2 & X_2^3 & \cdots & X_2^n \\ X_3^1 & X_3^2 & X_3^3 & \cdots & X_3^n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{17}^1 & X_{17}^2 & X_{17}^3 & \cdots & X_{17}^n \end{pmatrix} \tag{10}$$

The result of calculation is posted in Appendix A.1.

The normalization of characteristics could reflect the positive influence on the improvement of the life quality. But due to the different ranges of the sequence $\left(x_i^j\right)_{j\in J}$, couldn't compare them straightly. Therefore, normalization of the normalized correction matrix is required.

$$Z = \left(Z_i^j\right) = \begin{pmatrix} Z_1^1 & Z_1^2 & Z_1^3 & \cdots & Z_1^n \\ Z_2^1 & Z_2^2 & Z_2^3 & \cdots & Z_2^n \\ Z_3^1 & Z_3^2 & Z_3^3 & \cdots & Z_3^n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Z_{17}^1 & Z_{17}^2 & Z_{17}^3 & \cdots & Z_{17}^n \end{pmatrix} \tag{11}$$

With the entries Z_i^j

$$Z_i^j = \frac{x_i^j}{\sqrt{\sum_{i=1}^{17}\left(x_i^j\right)^2}} \tag{12}$$

It's easy to check that $Z_i^j \in [0,1]$.Check if $Z_i^j \in [0,1]$ holds. The purpose of unifying ranges of characteristics was thus achieved. The matrix in 1 is called the regularization correction matrix. The result of the calculation in 1 is posted in Appendix A.2.

3.6. Calculating Correlation Degree

As defined in [8] for the gray correlation coefficient, the characteristic correlation coefficient is defined to reflect the degree of correlation of the SDG.

Definition 6.1. If $x_i^j \in (x_i)$ and $x_{i'}^{j'} \in (x_{i'})(i \neq i')$ are regularization entries, we define $\rho\big((x_i),(x_{i'})\big)$*as the characteristic correlation coefficient between* (x_i) *and* $(x_{i'})$ *as the following formula*

$$\rho\left(x_i^j, x_{i'}^j\right) = \frac{a+\lambda b}{\left|x_i^j - x_{i'}^j\right| + \lambda b} \tag{13}$$

with $a = min_i min_j \left|x_i^j - x_{i'}^j\right|, a = max_i max_j \left|x_i^j - x_{i'}^j\right|, k = 0.5.$

From then, we can evaluate the correlation degree $\rho\big((x_i),(x_{i'})\big)$ *between* (x_i) *and* $(x_{i'})$, *that is.*

$$\rho\big((x_i),(x_{i'})\big) = \frac{1}{n}\sum \lim_{j=1} \rho\left(x_i^j, x_{i'}^j\right) \tag{14}$$

From the definition of the characteristic correlation coefficient above,compute the first SDG and other SDGs by taking Z_i^j and $Z_{i'}^j$ to x_i^j and $x_{i'}^j$ respectively. The result is posted as Figure.3.

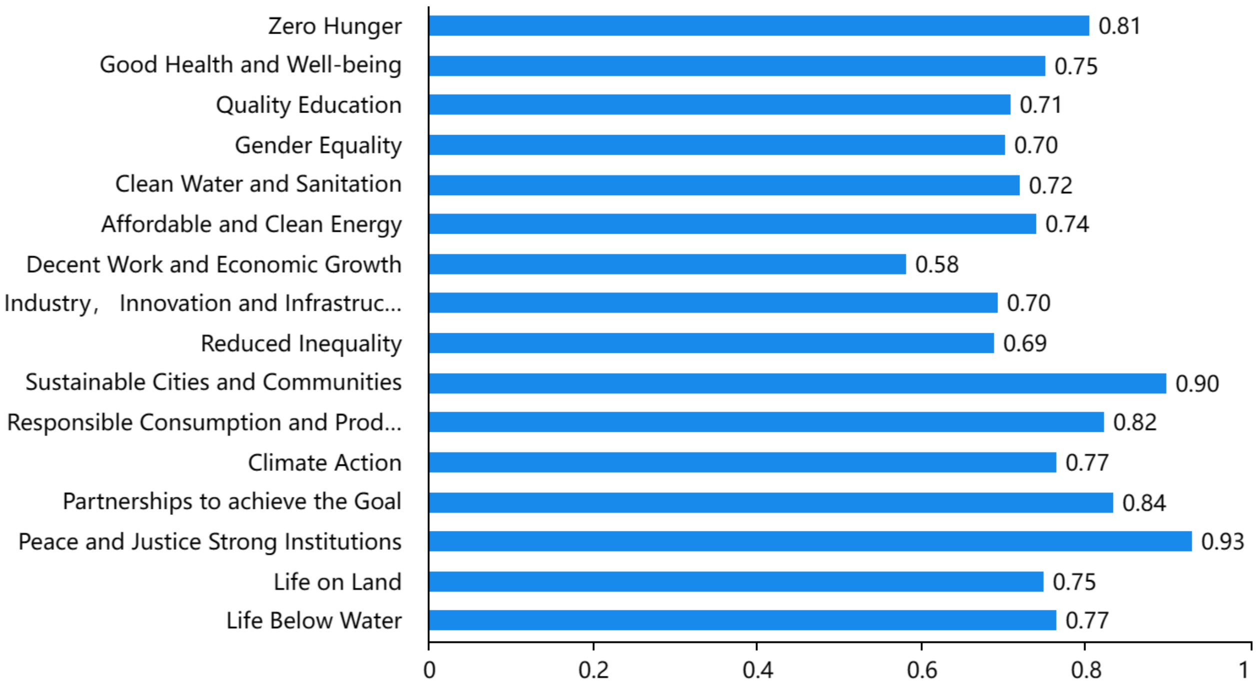

Figure 3. The characteristic correlation coefficient between 1st SDG and others

The characteristic correlation coefficients between the other SDGs were calculated sequentially as described above.

3.7. The Application of Interpretative Structural Modeling

The study in this part is to establish networks of the relationships between the 17 SDGs by using the characteristic correlation coefficients gained above.

The relationship between the 17 SDGs is represented by a heat map as shown in Figure 4.

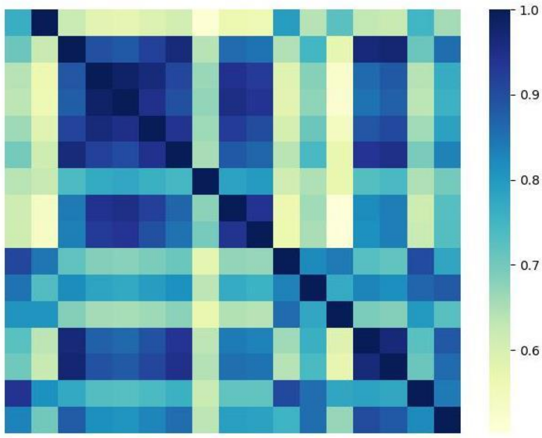

Figure 4. The Heat map about Relations between SDGs

As done in [9], the matrix in 1 is redefined as a proximity matrix. Create a new matrix, called the reachable matrix, whose entries satisfy the following conditions:

$$r_{ij} = \begin{cases} 1, & Z_i^j \geq 0.8 \\ 0, & \text{otherwise} \end{cases} \tag{15}$$

The ISM model was used from the reachability matrix to build a network of 17 SDGs. The results are shown in Figure 5.

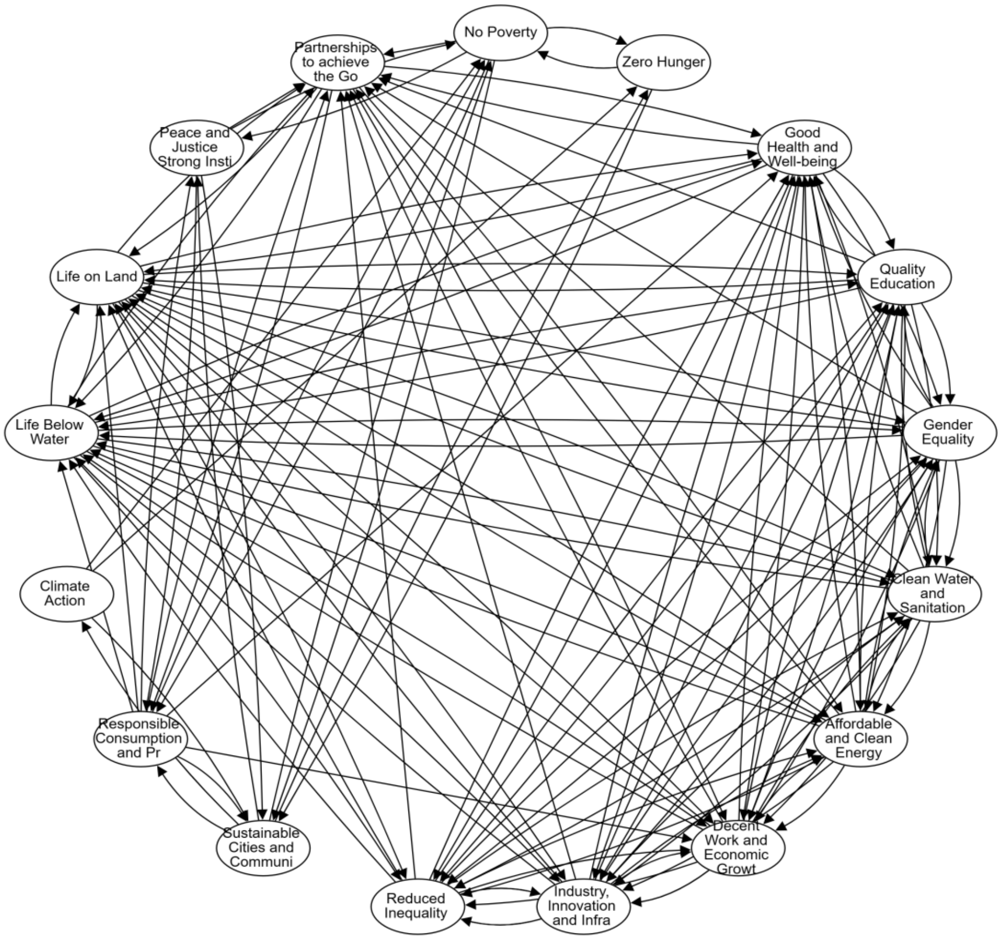

Figure 5. Network of 17 SDGs

3.8. ISM Models in New Conditions

The basic model is built, and next, this study will discuss how the model will change if the number of SDGs changes, which means that a particular SDG is achieved in the future [10] .

3.9. When the number of SDGs Decreases

When one of SDGs is achieved, how the network and the effectiveness of the priority of SDGs will change?

Without generality, assume the first SDG—No Proverty—has been achieved, the remaining 16 SDGs are now analyzed in conjunction with the previously developed model.

When the first SDG has been achieved, the number of SDGs becomes 16. Then we use $I' = \{2,3,4,\cdots,17\}$ as the index set of X instead of $I = \{1,2,3,\cdots,17\}$. Then

$$X = \left(X_i^j\right) = \begin{pmatrix} X_2^1 & X_2^2 & X_2^3 & \cdots & X_2^n \\ X_3^1 & X_3^2 & X_3^3 & \cdots & X_3^n \\ X_4^1 & X_4^2 & X_4^3 & \cdots & X_4^n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{17}^1 & X_{17}^2 & X_{17}^3 & \cdots & X_{17}^n \end{pmatrix} \tag{16}$$

The adjustment correction matrix can be obtained by (2):

$$Z = \left(Z_i^j\right) = \begin{pmatrix} Z_2^1 & Z_2^2 & Z_2^3 & \cdots & Z_2^n \\ Z_3^1 & Z_3^2 & Z_3^3 & \cdots & Z_3^n \\ Z_4^1 & Z_4^2 & Z_4^3 & \cdots & Z_4^n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ Z_{17}^1 & Z_{17}^2 & Z_{17}^3 & \cdots & Z_{17}^n \end{pmatrix} \tag{17}$$

clearly that $Z_i^j \in [0,1]$. By def 6.1 the feature correlation coefficients between one of the SDGs and the other SDGs were calculated. The results of the feature correlation coefficients between the second SDG-Zero Hunger- and the other SDGs are shown in Figure 6.

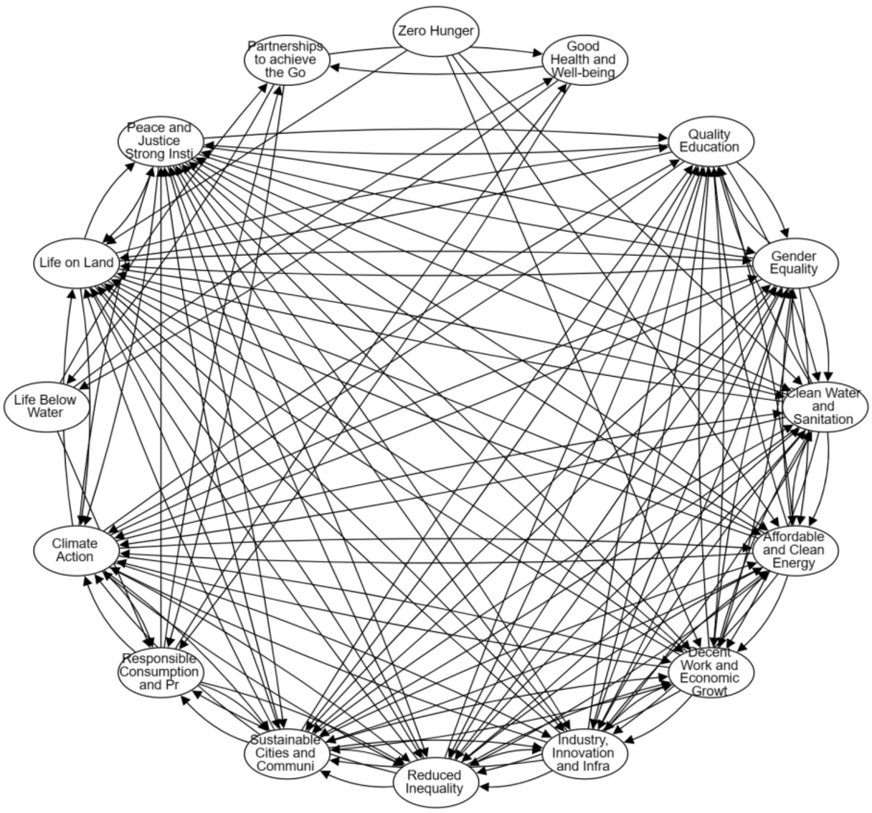

Figure 6. The characteristic correlation coefficient between 2nd SDG and others

The rest of the relevant results can be obtained in the same way as above.

Cause to the different choose of index set, there is some change to (3) and the new directly affects matrix $O' = (o'_{ij})$ is

$$o'_{ij} = \begin{cases} 0, & Z_i^j < 0.625 or i - 1 = j \\ 1, & Z_i^j \in [0.625, 0.75] \\ 2, & Z_i^j \in [0.75, 0.875] \\ 3, & Z_i^j > 0.875 \end{cases} \tag{18}$$

The normalized matrix $N = (n_{ij})$:

$$n_{ij} = \frac{o'_{ij}}{\max_i\left(\sum_{j=1}^{n} o'_{ij}\right)} \tag{19}$$

Compared to the previous one, the following threshold K' is obtained without changing the following processes:

$$K' = \bar{T} + s(T) = \frac{1}{16n}\sum_{i=1}^{16}\sum_{j=1}^{n} t_{ij} + \sqrt{\frac{1}{16n}\sum_{i=1}^{16}\sum_{j=1}^{n}\left(t_{ij} - \bar{T}\right)^2} = 0.9315 \tag{20}$$

where $T = N(1 - N)^{-1}$ still holds.

The 16 SDGs were hierarchically divided by threshold $K' = 0.9315$ using the ISM method, and the results are shown in Figure 7.

Figure 7. New Hierarchical When the number of SDGs decreases

By the process we analyze the relations between 16 SDGs, we fifind there is little difffference with in methods we used in section 6. Comparing the Figures 2 and 6 as in Figure.8, we find the constructure of network surely has changed.

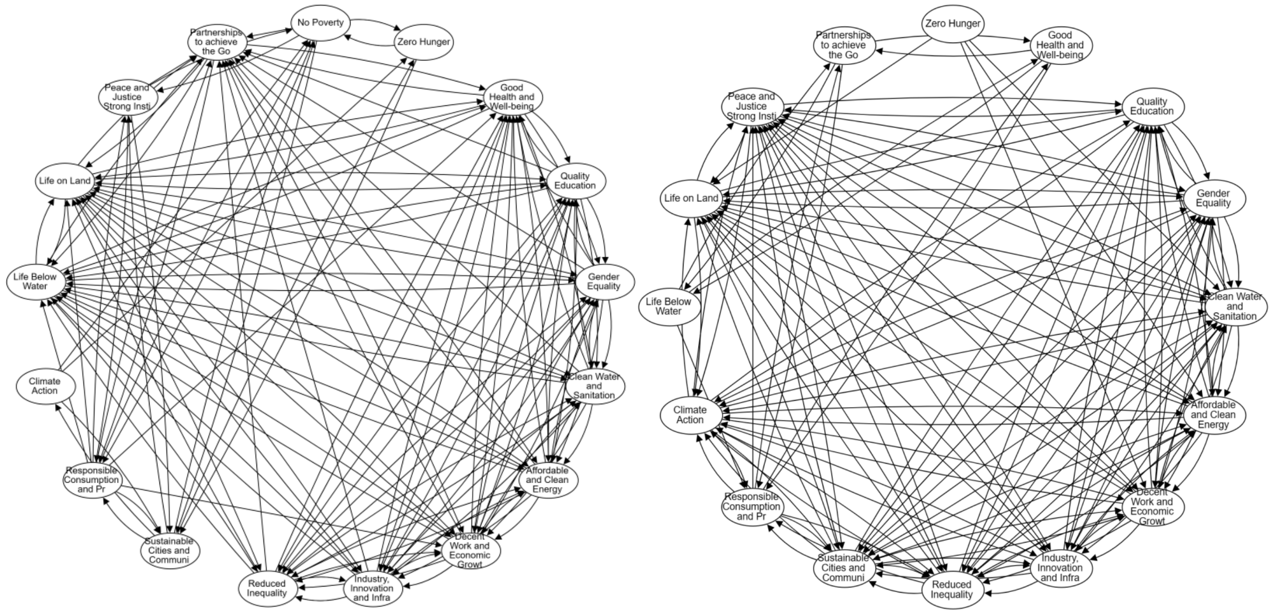

Figure 8. Comparison Between The Networks

Comparing two hierarchicals as Figure.9, we find the divisions of two hierarchicals are difffferent. This shows that in the process of reducing the factors, the level of hierarchicals changes very much. Thus, the achievement of No Proverty impact our team's priorities hard.

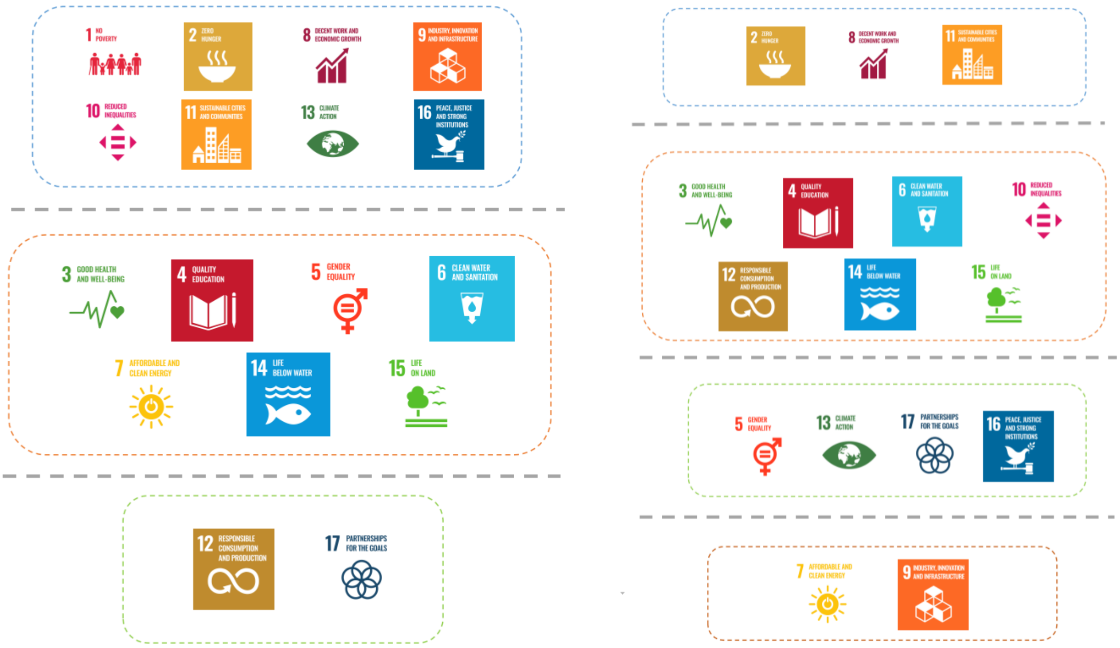

Figure 9. Comparison Between the Hierarchicals

4. Conclusions

The Sustainable Development Goals (SDGs) aim to achieve global sustainable development and address important social, economic and environmental issues. And the prioritization of sustainability goals is crucial. Prioritizing development goals ensures maximum use of resources and maximum impact, transparency and accountability, synergies and maximum impact within a limited time.This paper prioritizes the 17 SDGs by constructing a DEMATEL-ISM model, and constructs a GRA-ISM model to establish a network of development goals, clearly showing the potential relationship between development goals.It has certain reference value for the deployment and implementation of future development goals and plans of the United Nations.

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