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# Model for evaluating the industrial structure optimization in Hunan Province

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## ABSTRACT

In this paper, we investigate the multiple attribute decision making problems for evaluating the industrial structure optimization industrial structure optimization in Hunan Province in the intuitionistic fuzzy setting. An optimization model based on the ideal solution and min-max operator is established to determine the attribute weights. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one (s) according to the correlation coefficient. At last, an illustrative example for for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information is given to verify the developed approach and to demonstrate its practicality and effectiveness.

## KEYWORDS

Decision-making; Intuitionistic fuzzy numbers; Industrial structure optimization; Evaluation.

## INTRODUCTION

It's important for a country or region to realize economic growth and social stability by industrial structural optimization, upgrading and employment promotion. Industrial structural optimization, upgrading can promote sustainable and stable growth of the regional economy, and it can drive corresponding increase of the employment scale and improve the employment structure. Each country or region' foundation, economic system etc. are different, and it depends on the actual situation of China to realize coordinated development between industrial structural optimization, upgrading and employment. The dissertation analyzes the question of coordinated development between China's industrial structural optimization, upgrading and the employment scale, the employment structure. The content of this dissertation includes a theoretical study of industrial structural optimization, upgrading and employment, the experience of foreign countries, the domestic situation and influencing factors, the implementation mechanism analysis. Somebody makes a theoretical study between industrial structural optimization, upgrading and employment, and the conclusion is as follows: The industrial structural optimization, upgrading and the employment scale come from the factor endowment structure in a country or region. A country or region should mainly develop the labor-intensive industry when the labor force accounts for the comparative advantage, and it should develop the capital-intensive industry when the capital is gradually accounts for the comparative advantage, and the capital can play a leading role on the economic growth, then it will make the coordinated development between China's industrial structural optimization, upgrading and employment. Upgrading of enterprises can promote each other with high levels of labor employment. They make the following conclusions by analyzing economic experience of the United States and Japan: Japan made capital accumulation based on factor endowments, and made appropriate technological innovation and developed some rational industrial policies, and those measures make coordinated development between Japan's industrial structural optimization, upgrading and employment scale. Japan actively constructed its national value chain, and it gradually eased the imbalance of high and low level of labor employment by enterprises upgrading. American experiences told us that China's economy should be built on the real economy and should prevent China's economy from the situation of excessive de-industrialization and excessive industry virtualization. The analysis of the status and constraints of coordinated development between China's industrial structural optimization, upgrading and the employment scale draws the following conclusions: China's industrial structure optimization, upgrading and employment don't coordinate with each other. The factors restricting the coordinated development of employment and economic growth in industrial structure optimization and upgrading include the factor price distortion, capital market distortion and so on; while the factors restricting the balanced employment of high and low level labor force in enterprises upgrading are mainly because that domestic enterprises are generally restricted on the low end of the value chain by foreign multinational enterprises which have great power in technology and market, and thus a limited space for upgrading. Many authors also analyze the implementation mechanism of coordination between China's industrial structural optimization, upgrading and the employment scale. Coordination of regional industrial development strategy is the premise, and improving the land, capital and other factor markets is the basic term. Promoting technological progress is the inherent power which has different effect in promoting coordination development between China's industrial structural optimization, upgrading and the employment scale in different regions while reasonable industrial policy is the external power, and different region needs use different industrial policies to promote China's industrial structural optimization and upgrading. The analysis of the implementation mechanism of coordination between China's industrial structural optimization, upgrading and the employment structure makes the following conclusions: the enterprise upgrading policy is the external power for coordinated development between China's industrial structural optimization and upgrading and the employment structure while agglomeration economies are the intrinsic power. Corporate tax incentives, R&D spillovers, service mechanism innovation, search costs of labor can play an important role informing agglomeration economies. In this dissertation, we propose a coordinated development mode based on GVC and NVC, and the mode is that "firstly forming the domestic value chain, achieving the integration between GVC and NVC, then leading some global value chains", and the order of development is joining the global value chain, the national value chain, development the integration between GVC and NVC monopoly of some global value chains. At last, trends of China's industrial structural optimization and upgrading's impact on employment scale are that employment scale of the first industry will reduce in short term, and which will increase in long term. The employment scale of the second and third industry will increase in the future, but the third industry will increase much faster than the second one. China's employment scale will increase much faster and imbalance of employment will be eased by China's industrial structural optimization and upgrading.

In this paper, we investigate the multiple attribute decision making problems[1-8] for evaluating the industrial structure optimization industrial structure optimization in Hunan Province in the intuitionistic fuzzy setting. An optimization model based on the ideal solution and min-max operator is established to determine the attribute weights. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one (s) according to the correlation coefficient. At last, an illustrative example for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information is given to verify the developed approach and to demonstrate its practicality and effectiveness.

## PRELIMINARIES

In the section, we shall introduce the basic concepts of the intuitionistic fuzzy sets.

Definition 1. An IFS $A$ in $X$ is given by

$$A=\left\{\left\langle x,\mu_A(x),\nu_A(x)\right\rangle \middle| x\in X\right\} \quad \textbf{(1)}$$

where $\mu_A : X\to[0,1]$ and $\nu_A : X\to[0,1]$, with the condition

$$0\le\mu_A(x)+\nu_A(x)\le 1,\ \forall\ x\in X$$

The numbers $\mu_A(x)$ and $\nu_A(x)$ represent, respectively, the membership degree and non- membership degree of the element $x$ to the set $A$ [9-10].

Definition 2. Suppose that $\tilde{a}_1=(\mu_1,\nu_1)$ and $\tilde{a}_2=(\mu_2,\nu_2)$ are two intuitionistic fuzzy numbers, then the Hamming distance between $\tilde{a}_1=(\mu_1,\nu_1)$ and $\tilde{a}_2=(\mu_2,\nu_2)$ is shown:

$$d(\tilde{a}_1,\tilde{a}_2)=\frac{|\mu_1-\mu_2|+|\nu_1-\nu_2|}{2} \quad \textbf{(2)}$$

Definition 3. Let $\tilde{a}_j=(\mu_j,\nu_j)$ $(j=1,2,\cdots,n)$ be a set of intuitionistic fuzzy values, then the information energy of the set $\tilde{a}$ is defined as follows[11]:

$$E(\tilde{a})=\sum_{j=1}^{n}\mu_j^2+\nu_j^2 \quad \textbf{(3)}$$

Definition 4. Let $\tilde{a}^{(1)}=\left(\mu_j^{(1)},\nu_j^{(1)}\right)$ $(j=1,2,\cdots,n)$ and $\tilde{a}^{(2)}=\left(\mu_j^{(2)},\nu_j^{(2)}\right)$ $(j=1,2,\cdots,n)$ be two sets of intuitionistic fuzzy values, then the correlation of intuitionistic fuzzy sets $\tilde{a}^{(1)}$ and $\tilde{a}^{(2)}$ is defined as follows[11]:

$$C\left(\tilde{a}^{(1)},\tilde{a}^{(2)}\right)=\sum_{j=1}^{n}\left(\mu_j^{(1)}\mu_j^{(2)}+\nu_j^{(1)}\nu_j^{(2)}\right) \quad \textbf{(4)}$$

Definition 5. Let $\tilde{a}^{(1)}=\left(\mu_j^{(1)},\nu_j^{(1)}\right)$ $(j=1,2,\cdots,n)$ and $\tilde{a}^{(2)}=\left(\mu_j^{(2)},\nu_j^{(2)}\right)$ $(j=1,2,\cdots,n)$ be two sets of intuitionistic fuzzy values, then the correlation coefficient of intuitionistic fuzzy sets $\tilde{a}^{(1)}$ and $\tilde{a}^{(2)}$ is defined as follows[11]:

$$K\left(\tilde{a}^{(1)},\tilde{a}^{(2)}\right)=\frac{C\left(\tilde{a}^{(1)},\tilde{a}^{(2)}\right)}{\sqrt{E\left(\tilde{a}^{(1)}\right)E\left(\tilde{a}^{(2)}\right)}} \quad \textbf{(5)}$$

Definition 6. Let $\tilde{a}_j=(\mu_j,\nu_j)$ $(j=1,2,\cdots,n)$ be a set of intuitionistic fuzzy values, and let IFWA: $Q^n\to Q$, if

$$\begin{aligned}&\mathrm{IFWA}_\omega(\tilde{a}_1,\tilde{a}_2,\cdots,\tilde{a}_n)\\&=\sum_{j=1}^{n}\omega_j\tilde{a}_j \quad \textbf{(6)}\\&=\left(1-\prod_{j=1}^{n}(1-\mu_j)^{\omega_j},\prod_{j=1}^{n}\nu_j^{\omega_j}\right)\end{aligned}$$

where $\omega = \left(\omega_1, \omega_2, \cdots, \omega_n\right)^T$ be the weight vector of $\tilde{a}_j \left(j = 1, 2, \cdots, n\right)$, and $\omega_j > 0$, $\sum_{j=1}^{n} \omega_j = 1$, then IFWA is called the intuitionistic fuzzy weighted averaging (IFWA) operator[12].

## MODEL FOR EVALUATING THE INDUSTRIAL STRUCTURE OPTIMIZATION IN HUNAN PROVINCE

The following assumptions or notations are used to represent the intuitionistic fuzzy MADM problems for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information:

(1) The alternatives are known. Let $A = \left\{A_1, A_2, \cdots, A_m\right\}$ be a discrete set of alternatives;

(2) The attributes are known. Let $G = \left\{G_1, G_2, \cdots, G_n\right\}$ be a set of attributes;

(3) The information about attribute weights is incompletely known. Let $w = \left(w_1, w_2, \cdots, w_n\right) \in H$ be the weight vector of attributes, where $w_j \geq 0$, $j = 1, 2, \cdots, n$, $\sum_{j=1}^{n} w_j = 1$, $H$ is a set of the known weight information. Suppose that $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n} = \left(\mu_{ij}, \nu_{ij}\right)_{m\times n}$ is the decision matrix with intuitionistic fuzzy information, where $\mu_{ij} \subset \left[0,1\right], \nu_{ij} \subset \left[0,1\right]$, $\mu_{ij} + \nu_{ij} \leq 1$, $i = 1, 2, \cdots, m$, $j = 1, 2, \cdots, n$.

Definition 7. Let $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n} = \left(\mu_{ij}, \nu_{ij}\right)_{m\times n}$ be an intuitionistic fuzzy decision matrix, $\tilde{r}_i = \left(\tilde{r}_{i1}, \tilde{r}_{i2}, \cdots, \tilde{r}_{in}\right)$ be the vector of attribute values corresponding to the alternative $A_i$, $i = 1, 2, \cdots, m$, then we call.

$$
\begin{aligned}
&\tilde{r}_i = \left(\mu_i, \nu_i\right) \\
&= \mathrm{IFWA}_w\left(\tilde{r}_{i1}, \tilde{r}_{i2}, \cdots, \tilde{r}_{in}\right) \\
&= \left(1 - \prod_{j=1}^{n}\left(1 - \mu_{ij}\right)^{w_j}, \prod_{j=1}^{n} \nu_{ij}^{\ w_j}\right)
\end{aligned}
$$

$$i = 1, 2, \cdots, m. \tag{7}$$

the overall value of the alternative $A_i$, where $w = \left(w_1, w_2, \cdots, w_n\right)^T$ is the weight vector of attributes.

In the situation where the information about attribute weights is completely known, i.e., each attribute weight can be provided by the expert with crisp numerical value, we can weight each attribute value and aggregate all the weighted attribute values corresponding to each alternative into an overall one by using Eq. (7). Based on the overall attribute values $\tilde{r}_i$ of the alternatives $A_i \left(i = 1, 2, \cdots, m\right)$, we can rank all these alternatives and then select the most desirable one (s). The greater $\tilde{r}_i$, the better the alternative $A_i$ will be.

Definition 8. Let $\tilde{R} = \left(\tilde{r}_{ij}\right)_{m\times n} = \left(\mu_{ij}, \nu_{ij}\right)_{m\times n}$ be an intuitionistic fuzzy decision matrix, $\tilde{r}^+ = \left(\left(\mu_1^+, \nu_1^+\right), \left(\mu_2^+, \nu_2^+\right), \cdots, \left(\mu_n^+, \nu_n^+\right)\right)$ be the positive ideal alternative $A^*$, defined as follows

$$\left(\mu_j^+, \nu_j^+\right) = \left(\max_i \mu_{ij}, \min_i \nu_{ij}\right),$$

$$j = 1, 2, \cdots, n. \tag{8}$$

In the real life, there always exist some differences between the vector of attribute values corresponding to ideal alternative and the vector of attribute values corresponding to the alternative $A_i \left(i = 1, 2, \cdots, m\right)$. The basic principle of the proposed method is that the chosen alternative should have the "shortest distance" from the positive ideal solution.

Obviously, for the weight vector given, the smaller $d\left(\tilde{r}_i,\tilde{r}^+\right)$, the better alternative $A_i$ is. But the information about attribute weights is incompletely known. So, we can establish the following multiple objective optimization models to calculate the weight information. By Definitions 4, in what follows we define the weighted hamming distance $d\left(\tilde{r}_i,\tilde{r}^+\right)$ between the vector of attribute values $\tilde{r}^+$ of positive ideal alternative and the vector of attribute values $\tilde{r}_i$ corresponding to the alternative $A_i\left(i=1,2,\cdots,m\right)$:

$$D_i\left(w\right)=d\left(\tilde{r}_i,\tilde{r}^+\right)$$
$$=\sum_{j=1}^{n}\left(\left|\mu_{ij}-\mu_j^+\right|++\left|\nu_{ij}-\nu_j^+\right|\right)w_j \quad \textbf{(9)}$$

Obviously, the smaller $D_i\left(w\right)$, the better the alternative $A_i$ will be. Thus, a reasonable weight vector $w^*=\left(w_1^*,w_2^*,\cdots,w_n^*\right)$ should be determined so as to make all the distances $D_i\left(w\right)$ $\left(i=1,2,\cdots,m\right)$ as smaller as possible, which means to minimize the following distance vector:

$$D\left(w\right)=\left(D_1\left(w\right),D_2\left(w\right),\cdots,D_m\left(w\right)\right) \quad \textbf{(10)}$$

under the condition $w\in H$, where $H$ is the set of the known weight information.
In order to do that, we establish the following multiple objective optimization models:

$$\left(\text{M-1}\right)\begin{cases}\text{minimize } D\left(w\right)=\left(D_1\left(w\right),D_2\left(w\right),\cdots,D_m\left(w\right)\right)\\ \text{subject to } w\in H\end{cases}$$

We utilize the min-max operator proposed by Zimmermann and Zysco [18] to integrate all the differences $D_i\left(w\right)$ $\left(i=1,2,\cdots,m\right)$, i.e., we get a single-objective programming model:

$$\left(\text{M-2}\right)\begin{cases}\text{minimize } \lambda_1\\ \text{subject to: } D_i\left(w\right)\le\lambda_1,\quad i=1,2,\cdots,m\\ w\in H\end{cases}$$

Where

$$\lambda_1=\max_i D_i\left(w\right)$$

By solving the model $\left(\text{M-2}\right)$, we get the optimal solution $w^*=\left(w_1^*,w_2^*,\cdots,w_n^*\right)$, which can be used as the weight vector of attributes.

Based on the above models, we develop a practical method for solving the MADM problems for finding users with similar interests in online social networks, in which the information about attribute weights is incompletely known, and the attribute values take the form of interval-valued intuitionistic fuzzy information. The method involves the following steps:

Step 1. Let $\tilde{R}=\left(\tilde{r}_{ij}\right)_{m\times n}$ be an intuitionistic fuzzy decision matrix, where $\tilde{r}_{ij}=\left(\mu_{ij},\nu_{ij}\right)$, which is an attribute value, given by an expert, for the alternative $A_i\in A$ with respect to the attribute $G_j\in G$, $\tilde{r}_i=\left(\tilde{r}_{i1},\tilde{r}_{i2},\cdots,\tilde{r}_{in}\right)$ be the vector of attribute values corresponding to the alternative $A_i$, $i=1,2,\cdots,m$, $\tilde{r}^+=\left(\tilde{r}_1^+,\tilde{r}_2^+,\cdots,\tilde{r}_n^+\right)$ be the positive ideal alternative, defined as in Definition 11, $w=(w_1,w_2,\cdots,w_n)\in H$ be the weight vector of attributes, where $w_j\ge 0$, $j=1,2,\cdots,n$, $\sum_{j=1}^{n} w_j=1$, $H$ is a set of the known weight information.

Step 2. If the information about the attribute weights is incompletely known, then we solve the model (M-2) to obtain the attribute weights.

Step 3. Utilize the weight vector $w^*=(w_1^*,w_2^*,\cdots,w_n^*)$ and by Eq. (7), we obtain the overall values $\tilde{r}_i$ of the alternatives $A_i\,(i=1,2,\cdots,m)$ and $\tilde{r}_i$ of the positive ideal alternative $A^*$.

Step 4. Calculate the information intuitionistic energy of an alternative $A_i\,(i=1,2,\cdots,m)$ and the positive ideal alternative $A^*$, respectively, as follows

$$E_i(A_i)=\mu_i^2+\nu_i^2 \tag{11}$$

$$E^*(A^*)=(\mu_i^+)^2+(\nu_i^+)^2 \tag{12}$$

Step 5. Calculate the correlation between an alternative $A_i\,(i=1,2,\cdots,m)$ and the positive ideal alternative $A^*$ as follows

$$C_i(A_i,A^*)=\mu_i\mu_i^+ +\nu_i\nu_i^+ \tag{13}$$

Step 6. Calculate the correlation efficient $K_i\,(i=1,2,\cdots,m)$ between an alternative $A_i\,(i=1,2,\cdots,m)$ and the positive ideal alternative $A^*$ as follows

$$K_i(A_i,A^*)=\frac{C_i(A_i,A^*)}{\sqrt{E^*(A^*)E_i(A_i)}} \tag{14}$$

Step 7. Rank all the alternatives $A_i\,(i=1,2,\cdots,m)$ and select the best one (s) in accordance with $K_i(A_i,A^*)$ $(i=1,2,\cdots,m)$. The greater $K_i(A_i,A^*)$, the better the alternative $A_i$ will be.

Step 8. End.

## ILLUSTRATIVE EXAMPLE

In the following, we shall investigate the multiple attribute decision making problems for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information. There are five possible cities $A_i\,(i=1,2,3,4,5)$ to be evaluated the industrial structure optimization industrial structure optimization in Hunan Province. The expert groups want to make decision according to four attributes as following: G1 is the industrial structure level; G2 is the Industry growth degree; G3 is the Industrial openness; G4 is the Industry sustainable development. The expert groups evaluate the five cities $A_i\,(i=1,2,3,4,5)$ with the intuitionistic fuzzy numbers, as showed the decision matrix as follows.

$$\tilde{R}=\begin{bmatrix}(0.3,0.6) & (0.7,0.3) & (0.3,0.6) & (0.4,0.3)\\ (0.5,0.4) & (0.5,0.4) & (0.3,0.5) & (0.2,0.5)\\ (0.4,0.4) & (0.3,0.6) & (0.5,0.4) & (0.4,0.5)\\ (0.7,0.2) & (0.4,0.5) & (0.4,0.4) & (0.6,0.3)\\ (0.4,0.6) & (0.3,0.2) & (0.3,0.6) & (0.5,0.3)\end{bmatrix}$$

The known weight information is as follows:

$$W = \{0.15 \le w_1 \le 0.25, 0.18 \le w_2 \le 0.39,$$
$$0.30 \le w_3 \le 0.45,\ 0.20 \le w_4 \le 0.35\}$$

In the following, we shall show the proposed approach with the illustrative example for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information.

Step 1. Determine the positive ideal alternative

$$\tilde{r}^+ = ((0.7,0.2) \quad (0.7,0.2) \quad (0.5,0.4) \quad (0.6,0.3))$$

Step 2. Utilize the model (M-2) to establish the following single-objective programming model:

$$\begin{aligned} &\text{minimize } \lambda_1 \\ &s.t.\ 0.43w_1 + 0.22w_2 + 0.53w_3 + 0.62w_4 \le \lambda_1 \\ &\quad 0.25w_1 + 0.21w_3 + 0.13w_4 \le \lambda_1 \\ &\quad 0.42w_1 + 0.37w_2 + 0.32w_4 \le \lambda_1 \\ &\quad 0.21w_2 + 0.26w_3 + 0.87w_4 \le \lambda_1 \\ &\quad 0.62w_1 + 0.56w_2 + 0.39w_3 \le \lambda_1 \\ &\quad w \in H, \sum_{j=1}^{4} w_j = 1, w_j \ge 0,\ j = 1,2,3,4. \end{aligned}$$

Solving this model, we get the weight vector of attributes: $w = (0.15\ \ 0.20\ \ 0.40\ \ 0.25)^T$

Step 3. Utilize the weight vector $w^* = (w_1^*, w_2^*, w_3^*, w_4^*)$ and by Eq. (7), we obtain the overall values $\tilde{r}_i$ of the alternatives $A_i\ (i = 1,2,3,4,5)$ and the overall values $\tilde{r}^+$ of the city $A^*$.

$$\tilde{r}_1 = (0.335, 0.557), \tilde{r}_2 = (0.448, 0.323)$$
$$\tilde{r}_3 = (0.456, 0.426), \tilde{r}_4 = (0.467, 0.417)$$
$$\tilde{r}_5 = (0.256, 0.351), \tilde{r}^+ = (1,0)$$

Step 4. Calculate the information intuitionistic energy of an alternative $A_i\ (i = 1,2,3,4,5)$ and the positive ideal solution $A^*$.

$$E_1(A_1) = 0.412, E_2(A_2) = 0.287$$
$$E_3(A_3) = 0.379, E_2(A_2) = 0.376$$
$$E_5(A_5) = 0.237, E^*(A^*) = 0.354$$

Step 5. Calculate the correlation between an city $A_i\ (i = 1,2,3,4,5)$ and the positive ideal solution $A^*$

$$C_1(A_1, A^*) = 0.321, C_2(A_2, A^*) = 0.345$$
$$C_3(A_3, A^*) = 0.365, C_4(A_4, A^*) = 0.389$$
$$C_5(A_5, A^*) = 0.239$$

Step 6. Calculate the correlation efficient $K_i\left(i=1,2,3,4,5\right)$ between an city $A_i\left(i=1,2,3,4,5\right)$ and the positive ideal solution $A^*$

$$K_1\left(A_1,A^*\right)=0.865, K_2\left(A_2,A^*\right)=0.909$$
$$K_3\left(A_3,A^*\right)=0.821, K_4\left(A_4,A^*\right)=0.694$$
$$K_5\left(A_5,A^*\right)=0.806$$

Step 7. Ranking all the cities $A_i\left(i=1,2,3,4,5\right)$ and select the best city by $K_i\left(A_i,A^*\right)\left(i=1,2,3,4,5\right)$: $A_2 \succ A_1 \succ A_3 \succ A_5 \succ A_4$, and thus the most desirable city is $A_2$.

## CONCLUSION

In this paper, we investigate the multiple attribute decision making problems for evaluating the industrial structure optimization industrial structure optimization in Hunan Province in the intuitionistic fuzzy setting. An optimization model based on the ideal solution and min-max operator is established to determine the attribute weights. We utilize the intuitionistic fuzzy weighted averaging (IFWA) operator to aggregate the intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one (s) according to the correlation coefficient. At last, an illustrative example for for evaluating the industrial structure optimization industrial structure optimization in Hunan Province with intuitionistic fuzzy information is given to verify the developed approach and to demonstrate its practicality and effectiveness.

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