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**Citation for published version (APA):**
Qaiser, F. H., De, A., Sykora, M., Shankar, R., & Choudhary, A. (2018). A hybrid decision-making methodology for prioritizing collaborative processes in sustainable freight transport. In J. Papathanasiou, P. Digkoglou, G. Tsaples, F. Dargam, I. Linden, & B. Mareschal (Eds.), Proceedings of the 4th International Conference on Decision Support System Technology – ICDSST 2018 & PROMETHEE DAYS 2018: Sustainable Data-Driven & Evidence-based Decision Support with applications to the Environment and Energy sector ICDSST – PROMETHEE DAYS 2018 4th International Conference on Decision Support System Technology – ICDSST 2018 & PROMETHEE DAYS 2018 22 – 25 May 2018.

**Published in:**
Proceedings of the 4th International Conference on Decision Support System Technology – ICDSST 2018 & PROMETHEE DAYS 2018

# A hybrid decision-making methodology for prioritizing collaborative processes in sustainable freight transport

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## ABSTRACT

This research proposes a decision-making method to prioritise collaborative processes for road freight transportation in the UK to ensure sustainable collaborative advantage. A hybrid multi-attribute decision-making (MADM) method is proposed, which combines intuitionistic fuzzy (IF) modified AHP (Analytic Hierarchy Process) and intuitionistic fuzzy (IF) modified TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution). A total of six sustainable collaborative advantages and six collaborative processes are identified from the literature as criteria and alternatives for the proposed MADM methodology respectively. IF-AHP is utilized to derive the weights of criteria while IF-TOPSIS is used to evaluate and prioritize the alternatives with respect to the criteria. We collect data from a global logistics company involved in road freight transportation operating in the UK. Our study has a practical application of delivering solutions to the road freight transport companies by prioritize their collaborative processes and achieve sustainable collaborative advantage by ensuring reduction in emission, congestion and road accidents. Our analysis reveals that incentive alignment and resource sharing are the two most important collaborative processes.

**Keywords:** Multi attribute decision-making, Sustainability, Freight transport, Collaborative advantage, IF-AHP, IF-TOPSIS

## INTRODUCTION

Collaborative advantage is a mechanism of joint value creation in a collaborative setting, which otherwise will not be achieved by an individual organization in isolation. In logistics collaboration, supply chain partners work as part of a single organization, which can increase collaborative advantage and enhance firm's performance. It is evident from literature that collaboration in logistics activities brings positive results to the collaborating partners. Several authors conducted a study with U.S. manufacturing firms to explore the role of supply chain collaboration with their partners and found positive impact on their collaborative advantage [1]. [2] studied the intensity of collaborative processes and its positive effects on the firm by taking into account the opinion of logistics managers in Swedish manufacturing companies.. Several researchers studied the importance of logistics collaboration in UK supply chain focusing on suppliers, logistics and retailers to make the supply chain more environmentally sustainable [3]. Similarly, [4] investigated the extent of supernormal benefits UK FMCGS (fast moving consumer goods) companies generate in saving freight transport costs and reducing $CO_2$ emission as a result of collaborating with each other. In the context of decision making, one of the challenges facing firms that which are the collaborative processes, which they should pay more attention to so that maximum sustainable collaborative advantage could be achieved. Though MADM methods have widely been used in the freight transport context ([5-6]), there is a lack of MADM methods to prioritize collaborative processes in freight transport using to achieve sustainable collaborative advantage.

We identify several research gaps as follows through an extensive literature review. 1) collaboration among supply chain partners in freight transport received little attention in MADM despite the value of collaboration in supply chain, 2) sustainability covering economic, environmental and social dimensions are still intermittently considered in freight transport literature, 3) very limited use of MADM based method in the context of UK freight transport considering collaboration and 4) IF-MADM methods are novel and have not been applied in logistics particularly in the freight transport case.

The aim of this paper is to develop a decision-making methodology based on a novel MADM approach, which supports freight transport managers decision making to prioritize their collaborative processes with supply chain partners to gain sustainable collaborative advantage. The paper also proposes a novel hybrid AHP and TOPSIS based decision-making methodology in an intuitionistic linguistic fuzzy environment to prioritize collaborative processes (alternatives) in road freight transport with respect to sustainable collaborative advantage (criteria) applied in a UK based case company.

## PROPOSED METHODOLOGY

The proposed MADM model combines AHP and TOPSIS in an intuitionistic fuzzy environment that is adapted from [7], [8] and [9]. In this study, intuitionistic fuzzy modified AHP is used to perform pair wise comparison of criteria to find criteria weights with automated correction of multiplicative consistency of decision matrices, whereas, intuitionistic fuzzy modified TOPSIS is employed to find the ranking of alternatives with respect to criteria. Though intuitionistic AHP and intuitionistic TOPSIS have been separately used in the literature, however, the traces of hybrid intuitionistic AHP-TOPSIS are very limited and this has not been applied in the collaborative freight transport context. A set of criteria and alternatives for the proposed MADM methodology is shown in Table 1.

### Intuitionistic fuzzy analytic hierarchy process

IF-AHP begins with obtaining pairwise comparisons of criteria from decision makers. The pairwise relation matrix of criteria *'j'* provided by decision maker *'g'* can be expressed as, $\rho_g = \left(p_{ik}^g\right)_{m\times m} = \left(\tau_{ik}^g, \theta_{ik}^g\right)_{m\times m}$, where *i, k = 1, 2, …, m*. A perfect multiplicative consistent intuitionistic preference relation $\overline{\rho} = \left(\overline{p}_{ik}\right)_{mxm} = \left(\overline{\tau}_{ik}, \overline{\theta}_{ik}\right)$ can be constructed using the relationship,

Table 1Criteria and alternatives for the proposed MADM method

| | |
|---|---|
| **Sustainable collaborative advantages (Criteria)** | |
| Process efficiency ($c_1$) | The degree to which a firm's collaboration process (information sharing, joint logistics process, joint product/service development, or joint decision-making) with its supply chain partners is cost competitive among primary competitors. |
| Offering flexibility ($c_2$) | Also known as customer responsiveness. This refers to the extent to which a firm's supply chain linkage supports change in product/service offerings (volume and/or speed). |
| Quality ($c_3$) | Quality is the degree to which an organization with its supply chain partners offers a product or service that is perceived as a higher value from customer's perspective. |
| Innovation ($c_4$) | This refers to the extent to which a firm works jointly with its supply chain partners in introducing new processes, products, or services. Collaboration enables firms to improve absorptive capacity and thus introduce new products and services fast and frequently. |
| Environmental advantage ($c_5$) | This refers to the extent to which supply chain partners combine complementary and related resources to achieve supernormal benefits in reducing energy consumption and GHG (greenhouse gas) emission. |
| Social advantage ($c_6$) | This refers to the extent to which supply chain partners combine complementary and related resources to achieve supernormal benefits in reducing traffic congestion and road accidents. |
| **Collaborative Processes (Alternatives)** | |
| Information sharing ($x_1$) | Information sharing refers to the extent to which a firm shares a variety of relevant, accurate, complete, and confidential information in a timely manner with its supply chain partners. |
| Goal congruence ($x_2$) | Goal congruence is the extent to which the objectives of supply chain partners coincide with that of supply chain objectives. |
| Decision synchronization ($x_3$) | This refers to the process by which supply chain partners orchestrate decisions in supply chain planning and operations that optimize the supply chain benefits. |
| Incentive alignment ($x_4$) | This refers to the process of sharing costs, risks, and benefits among supply chain partners |
| Resource sharing ($x_5$) | Resource sharing refers to the process of leveraging capabilities and assets and investing in capabilities and assets with supply chain partners. Resources include both tangible and intangible elements such as knowledge, technology and physical resources. |
| Joint knowledge creation ($x_6$) | The capture, exchange, and application of knowledge; such as process, technology, or market knowledge between supply chain partners, which leads to innovation and long term competitiveness of the whole supply chain. |

$$\overline{\tau}_{ik} = \frac{\sqrt[k-i-1]{\prod_{l=i+1}^{k-1} \tau_{il}\tau_{lk}}}{\sqrt[k-i-1]{\prod_{l=i+1}^{k-1} \tau_{il}\tau_{lk}} + \sqrt[k-i-1]{\prod_{l=i+1}^{k-1}(1-\tau_{il})(1-\tau_{lk})}}, k > i+1 \quad (1)$$

$$\overline{\theta}_{ik} = \frac{\sqrt[k-i-1]{\prod_{l=i+1}^{k-1} \theta_{il}\theta_{lk}}}{\sqrt[k-i-1]{\prod_{l=i+1}^{k-1} \theta_{il}\theta_{lk}} + \sqrt[k-i-1]{\prod_{l=i+1}^{k-1}(1-\theta_{il})(1-\theta_{lk})}}, k > i+1 \quad (2)$$

For $k = i+1$ , let $\overline{p}_{ik} = p_{ik}$ and for $k < i$, $\overline{p}_{ik} = (\overline{\theta}_{ki}, \overline{\tau}_{ki})$. Now, the distance between original and perfect multiplicative matrix is computed using the following equation,

$$d\left(\overline{\rho}, \rho\right) = \frac{1}{2(m-1)(m-2)} \sum_{i=1}^{m} \sum_{k=1}^{m} \left( \left| \overline{\tau}_{ik} - \tau_{ik} \right| + \left| \overline{\theta}_{ki} - \theta_{ki} \right| + \left| \overline{\pi}_{ki} - \pi_{ki} \right| \right) \quad (3)$$

If $d\left(\overline{\rho}, \rho\right) < \xi$ then $\rho$ is called an acceptable multiplicative consistent intuitionistic preference relation. $\xi$ is referred to as consistency threshold and is assumed to be 0.1 [7], from the maximum eigenvalue of a multiplicative preference relation. If $\xi$ is greater than 0.1, then it is considered that the transformed intuitionistic preference relation $\overline{\rho}$ does not reflect the initial preferences of the decision maker. For an acceptable preference relation, it should not only be multiplicative consistent but also retains the original preference of the decision maker as much as possible. Considering this, the original intuitionistic preference relation $\rho$ is fused with its respective perfect multiplicative intuitionistic relation $\overline{\rho}$ into a new intuitionistic relation $\tilde{\rho} = \left(\tilde{p}_{ik}\right)_{m\times m}$. An algorithm is presented to improve the consistency of initial intuitionistic preference relation and obtain the intuitionistic fuzzy weights using IF-AHP.

Step 1 starts the iteration $t$ and for $t = 1$ the perfect multiplicative consistent preference relation $\overline{\rho}$ is constructed from $\rho^{(t)}$. In step 2, the hamming distance $d\left(\overline{\rho}, \rho^{(t)}\right)$ between $\overline{\rho}$ and $\rho^{(t)}$ is computed using equation (3). If $d\left(\overline{\rho}, \rho\right) < \xi$ then output is $\rho^{(t)}$, otherwise the algorithm moves to step 3. Fused intuitionistic preference relation $\tilde{\rho}^{(t)} = \left(\tilde{p}_{ik}^{(t)}\right) = \left(\tilde{\tau}_{ik}^{(t)}, \tilde{\theta}_{ik}^{(t)}\right)$ is constructed in step 3 using the following equations, $\tilde{\tau}_{ik}^{(t)} = \frac{\left(\tau_{ik}^{(t)}\right)^{1-\mu}\left(\overline{\tau}_{ik}\right)^{\mu}}{\left(\tau_{ik}^{(t)}\right)^{1-\mu}\left(\overline{\tau}_{ik}\right)^{\mu} + \left(1-\tau_{ik}^{(t)}\right)^{1-\mu}\left(1-\overline{\tau}_{ik}\right)^{\mu}}$ and

$$\tilde{\theta}_{ik}^{(t)} = \frac{\left(\theta_{ik}^{(t)}\right)^{1-\mu}\left(\overline{\theta}_{ik}\right)^{\mu}}{\left(\theta_{ik}^{(t)}\right)^{1-\mu}\left(\overline{\theta}_{ik}\right)^{\mu} + \left(1-\theta_{ik}^{(t)}\right)^{1-\mu}\left(1-\overline{\theta}_{ik}\right)^{\mu}}$$

Where $i, k = 1, 2, \ldots, m$ and $\mu$ is a controlling parameter which is to be determined by the decision maker. The smaller the value of $\mu$, the closer $\tilde{\rho}^{(t)}$ to $\rho^{(t)}$ and the value of $\mu$ is assumed to be 0.8 [7]. Now, suppose $\rho^{(t+1)} = \tilde{\rho}^{(t)}$, that is $\tau_{ik}^{(t+1)} = \tilde{\tau}_{ik}^{(t)}$ and $\theta_{ik}^{(t+1)} = \tilde{\theta}_{ik}^{(t)}$. Let $t = t+1$ and then the algorithm moves to step 2. The weights are derived by using the following normalizing rank summation method [7] , $\omega_i = \left( \frac{\sum_{k=1}^{m} \tau_{ik}}{\sum_{i=1}^{m}\sum_{k=1}^{m}(1-\theta_{ik})}, 1-\frac{\sum_{k=1}^{m}(1-\theta_{ik})}{\sum_{i=1}^{m}\sum_{k=1}^{m}\tau_{ik}} \right)$, where each weight is an intuitionistic fuzzy value. The method is further extended by transforming intuitionistic fuzzy weight values $\omega_i$ into single crisp normalized weight value $\omega_q$ using following relationship [10],

$$\omega_q = \frac{\lambda_q + \delta_q\left(\frac{\lambda_q}{\lambda_q+\varphi_q}\right)}{\sum_{q=1}^{m}\left(\lambda_q + \delta_q\left(\frac{\lambda_q}{\lambda_q+\varphi_q}\right)\right)}, \text{ where } \delta_q = 1-\lambda_q-\varphi_q$$

**Intuitionistic fuzzy TOPSIS**

The decision matrix provided for the intuitionistic fuzzy TOPSIS method comprises of $G$ decision makers $(d_1, d_2, ..., d_t)$, $N$ alternatives $(x_1, x_2, ..., x_n)$ and $M$ criteria $(c_1, c_2, ..., c_m)$ where $g \in G,\ n \in N,\ m \in M$ and the matrix can be represented as $y^g = \left(y_{pq}^g\right)_{n\times m} = \left(\delta_{pq}^g, \phi_{pq}^g\right)_{n\times m}$. The weights of the criteria obtained using the IFAHP methodology obtained for decision makers $g$ can be expressed as, $\omega_q^g = \left(\omega_1^g, \omega_2^g, ..., \omega_m^g\right)$. Using the definition of intuitionistic fuzzy set, the intuitionistic fuzzy matrix deduced by the weights of the criteria can be represented in the following way, $Y^g = \left(\omega_q^g y_{pq}^g\right)_{n\times m} = \left(\overline{\delta}_{pq}^g, \overline{\phi}_{pq}^g\right)_{n\times m}$, here $\overline{\delta}_{pq}^g$ and $\overline{\phi}_{pq}^g$ are obtained using the following relationships, $\overline{\delta}_{pq}^g = 1-\left(1-\delta_{pq}^g\right)^{\omega_q^g}$ and $\overline{\phi}_{pq}^g = \left(\phi_{pq}^g\right)^{\omega_q^g}$. The individual positive ideal decision matrix $Y^*$ can be determined in the following way, $Y^* = \left(y_{pq}^*\right)_{n\times m} = \left(\tilde{\delta}_{pq}^*, \tilde{\phi}_{pq}^*\right)_{n\times m}$, where $\tilde{\delta}_{pq}^* = 1-\prod_{g=1}^{G}\left(1-\overline{\delta}_{pq}^g\right)^{1/G}$ and $\tilde{\delta}_{pq}^* = 1-\prod_{g=1}^{G}\left(1-\overline{\delta}_{pq}^g\right)^{1/G}$. The individual negative ideal decision matrix $Y_c^*$ can be represented as $Y_c^* = \left(\left(y_{pq}^*\right)^c\right)_{n\times m} = \left(\tilde{\phi}_{pq}^*, \tilde{\delta}_{pq}^*\right)_{n\times m}$, where $\left(y_{pq}^*\right)^c$ is the complement of $y_{pq}^* = \left(\tilde{\delta}_{pq}^*, \tilde{\phi}_{pq}^*\right)_{n\times m}$ or $\left(y_{pq}^*\right)^c = \left(\tilde{\phi}_{pq}^*, \tilde{\delta}_{pq}^*\right)_{n\times m}$. Now, the left maximum separation from the individual positive ideal decision matrix can be represented as $Y_l^- = \left(y_{pq}^{l-}\right)_{n\times m} = \left(\tilde{\delta}_{pq}^{l-}, \tilde{\phi}_{pq}^{l-}\right)_{n\times m}$, where $\tilde{\delta}_{pq}^{l-} = \min_g\left\{\overline{\delta}_{pq}^g\right\}$ and $\tilde{\phi}_{pq}^{l-} = \max_g\left\{\overline{\phi}_{pq}^g\right\}$ and $Y_l^-$ is referred to as left individual negative ideal decision matrix. The right maximum separation from the individual positive ideal decision matrix can be expressed as $Y_r^- = \left(y_{pq}^{r-}\right)_{n\times m} = \left(\tilde{\delta}_{pq}^{r-}, \tilde{\phi}_{pq}^{r-}\right)_{n\times m}$, where $\tilde{\delta}_{pq}^{r-} = \max_g\left\{\overline{\delta}_{pq}^g\right\}$ and $\tilde{\phi}_{pq}^{r-} = \min_g\left\{\overline{\phi}_{pq}^g\right\}$ and $Y_r^-$ is referred to as right individual negative ideal decision matrix. Now, hamming distance is computed for every $Y^g$ with individual positive and negative ideal decision matrices. Hamming distance of every linguistic intuitionistic fuzzy matrix $Y^g$ to

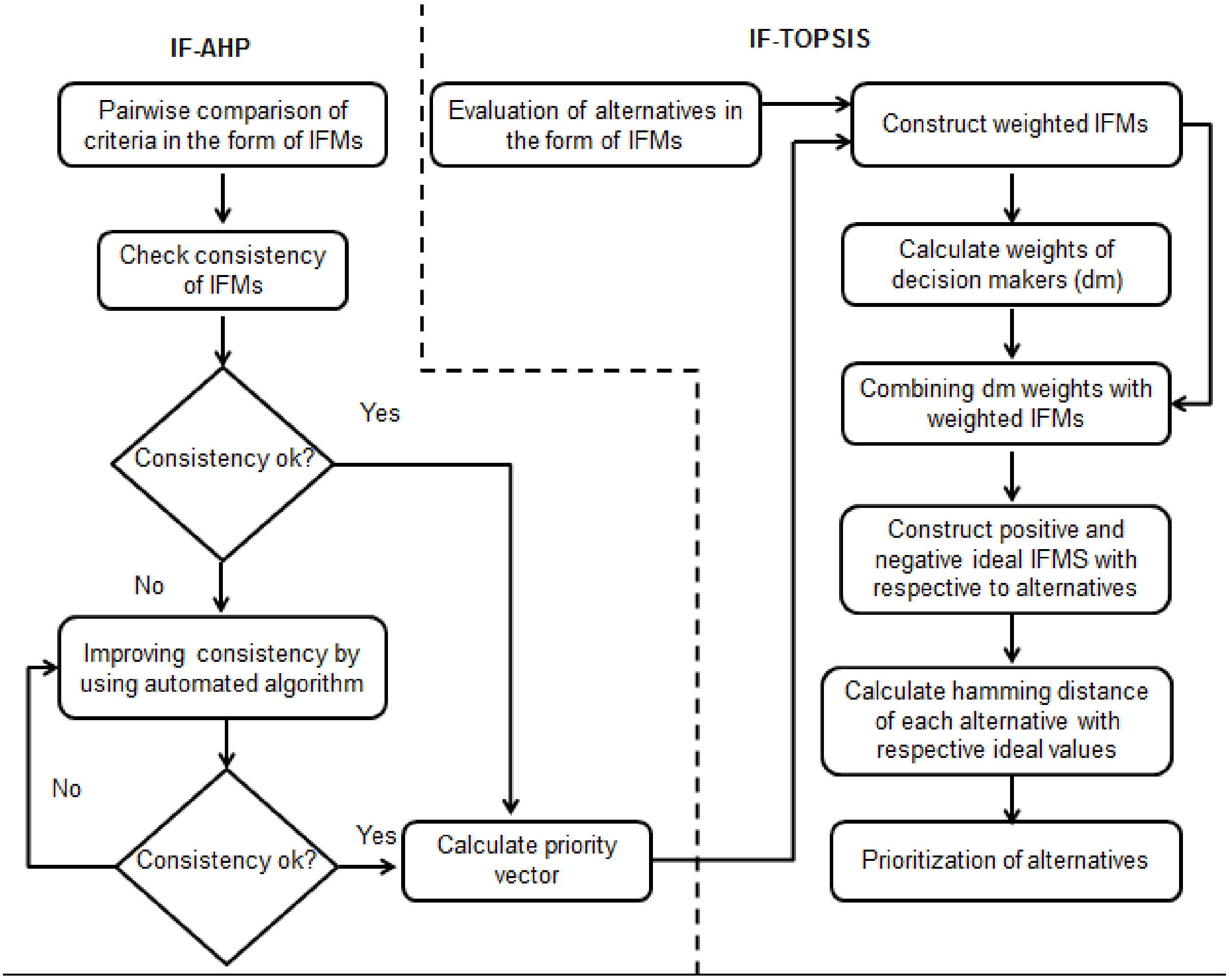
$Y^*$, $Y_c^*$, $Y_l^-$ and $Y_r^-$ is determined. The relative closeness of $Y^g$ with $Y^*$, $Y_c^*$, $Y_l^-$ and $Y_r^-$ is determined using the Hamming distance values. The weight of the decision maker can be computed using the value of the relative closeness. Please refer to [9] for obtaining further information about the equations related to Hamming distance, relative closeness and weight of the decision maker.

The weighted linguistic intuitionistic fuzzy decision matrix is represented as $Z^g = \psi^g Y^g = \left(\mu_{pq}^g, \tau_{pq}^g\right)_{n\times m}$, where $\mu_{pq}^g = 1-\left(1-\overline{\delta}_{pq}^g\right)^{\psi^g}$ and $\tau_{pq}^g = \left(\overline{\phi}_{pq}^g\right)^{\psi^g}$. Now, considering all the weighted linguistic intuitionistic fuzzy decision matrix of the decision makers (where $t$ is the total number of decision makers), for every alternative $\left(x_1, x_2, ..., x_n\right)$ the weighted linguistic intuitionistic fuzzy decision matrix with respect to each alternative is represented as $D_p = \left(z_{pq}^g\right)_{t\times m} = \left(\mu_{pq}^g, \tau_{pq}^g\right)_{t\times m}$. The positive and negative ideal solutions are determined based on the value of $D_p$ for $p = 1, 2, ..., n$. Intuitively, the best decision matrix of all the weighted linguistic intuitionistic fuzzy decision matrix of the decision makers is the positive ideal solution and it is represented as $D^+ = \left(\mu_q^{g+}, \tau_q^{g+}\right)_{t\times m}$, where $\mu_q^{g+} = \max_p \left\{\mu_{pq}^g\right\}$ and $\tau_q^{g+} = \min_p \left\{\tau_{pq}^g\right\}$. The worst solution for all the weighted linguistic intuitionistic fuzzy decision matrix with respect to the alternatives is referred to as the negative ideal solution and it has the maximum separation from $D^+$. Two negative ideal solutions are provide, one is complement of $D^+$ and it can be represented as $D_c^- = \left(D^+\right)^c = \left(\tau_q^{g+}, \mu_q^{g+}\right)_{t\times m}$. The other worst decision matrix $D^-$ with respect to all the criteria can be expressed as, $D^- = \left(\mu_q^{g-}, \tau_q^{g-}\right)_{t\times m}$, where $\mu_q^{g-} = \min_p \left\{\mu_{pq}^g\right\}$ and $\tau_q^{g-} = \max_p \left\{\tau_{pq}^g\right\}$. The separation of $D_p$ from $D^+$, $D_c^-$ and $D^-$ are referred to as separation measures. Please refer to [9] for obtaining further information about separation measures. The relative closeness for each alternative can be computed using the value of the separation measures. Please refer to [9] to obtain information about the equation pertaining to relative closeness for each alternative. The alternative having greater relative closeness is better than other alternative. Figure 1 shows the summary of proposed IF-AHP and IF-TOPSIS method.

## CASE STUDY APPLICATION

In order to demonstrate the application of proposed method, a case study is selected pertaining to a company engaged in providing logistics services including road freight transportation. The company has its origin in Europe with its operations span across the globe in 120 countries including United Kingdom (UK). Data is gathered from three experts (decision makers) of the case company, in the UK operating region, having more than ten years of logistics experience. The linguistic data provided by each decision maker is converted in to its respective intuitionistic fuzzy relations. The initial intuitionistic preference relations given by each decision maker is transformed into their respective perfect multiplicative intuitionistic relations $\overline{\rho} = \left(\overline{p}_{ik}\right)_{mxm} = \left(\overline{\tau}_{ik}, \overline{\theta}_{ik}\right)$ using the steps of IF-AHP method. For the purpose of demonstration, the perfect multiplicative consistent preference relation of the initial preference relation given by DM1 is presented in table 2. The multiplicative consistency of each initial preference relation is measuring by its hamming distance with its respective

Figure 1Proposed MADM method based on IF-AHP and IF-TOPSIS




perfect multiplicative relation. In the case of DM1, the calculated distance $d\left(\overline{\rho},\rho\right)$ = 0.1181,which is greater than 0.1. This shows that the initial intuitionistic preference relation is not an acceptable multiplicative consistent relation. This step is also applied on the initial preference relations of other two decision makers to check multiplicative consistency. Now, repairing the initial preference relation and obtaining a fused intuitionistic preference relation for DM1 which is presented in table 3. The calculated distance $d\left(\overline{\rho},\tilde{\rho}\right)$ = 0.0229, which is less than 0.1. This shows that an acceptable multiplicative consistent relation $\tilde{\rho}$ is achieved. The priority vectors of acceptable intuitionistic preference relations $\tilde{\rho}$ corresponding to each decision maker are obtained and then it is transformed into a single crisp weight value. The crisp priority vector for each of the decision maker is used as an input to the IF-TOPSIS method.

Intuitionistic preference relations containing evaluation of alternatives with respect to criteria given by each decision maker is obtained. The weighted intuitionistic preference matrix is computed by multiplying the crisp weight vector of each decision maker with their respective intuitionistic evaluation matrix and it is presented in table 4. The positive and negative ideal solutions are

Table 2: Perfect multiplicative consistent preference relation of DM1

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| $c_1$ | (0.5,0.5) | (0.6,0.3) | (0.3333,0.3913) | (0.6517,0.2466) | (0.6,0.3) | (0.6262,0.2725) |
| $c_2$ | (0.3,0.6) | (0.5,0.5) | (0.25,0.6) | (0.4375,0.2727) | (0.4142,0.4450) | (0.4425,0.4632) |
| $c_3$ | (0.3913,0.3333) | (0.6,0.25) | (0.5,0.5) | (0.7,0.2) | (0.7,0.2) | (0.6517,0.2466) |
| $c_4$ | (0.2466,0.6517) | (0.2727,0.4375) | (0.2,0.7) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |
| $c_5$ | (0.3,0.6) | (0.4450,0.4142) | (0.2,0.7) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |
| $c_6$ | (0.2725,0.6262) | (0.4632,0.4425) | (0.2466,0.6517) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |

Table 3: Acceptable multiplicative consistent preference relation of DM1

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| $c_1$ | (0.5,0.5) | (0.6,0.3) | (0.3648,0.4125) | (0.6416,0.2568) | (0.6210,0.2779) | (0.6416,0.2568) |
| $c_2$ | (0.3,0.6) | (0.5,0.5) | (0.25,0.6) | (0.4499,0.3133) | (0.4311,0.4559) | (0.4539,0.4706) |
| $c_3$ | (0.4125,0.3648) | (0.6,0.25) | (0.5,0.5) | (0.7,0.2) | (0.6811,0.2178) | (0.6416,0.2568) |
| $c_4$ | (0.2568,0.6416) | (0.3133,0.4499) | (0.2,0.7) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |
| $c_5$ | (0.2779,0.6210) | (0.4559,0.4311) | (0.2178,0.6811) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |
| $c_6$ | (0.2568,0.6416) | (0.4706,0.4539) | (0.2568,0.6416) | (0.5,0.5) | (0.5,0.5) | (0.5,0.5) |

constructed and the hamming distance related to each weighted distance matrix of decision makers is computed. Relative closeness and normalized weights with respect to each decision maker is obtained. Now, the weighted intuitionistic decision matrix of decision maker is obtained by multiplying the weight of decision makers with their respective decision matrices. The weighted intuitionistic decision matrix with respect to each alternative is constructed and the positive and negative ideal solutions for all the weighted intuitionistic decision matrices are obtained. The separation measures are computed and relative closeness is calculated using the values of the separation measures. The alternatives are ranked by considering their respective relative closeness. The relative closeness and rankings of alternatives are shown in the table 5.

It is pertinent to note that the relative closeness coefficient of $x_4$ and $x_5$ are nearly the same with a difference of 0.0001 in magnitude. Therefore, it is considered that $x_4$ and $x_5$ possess the same rank followed by $x_2$, $x_6$, $x_1$ and $x_3$. With these ranking results, it is revealed that incentive alignment ($x_4$) and resource sharing ($x_5$) are two important collaborative processes, which could play vital role in achieving sustainable collaborative advantage, followed by goal congruence ($x_2$), joint knowledge creation ($x_6$), information sharing ($x_1$) and decision synchronization ($x_3$).

Table 4: Criteria weighted intuitionistic evaluation of alternatives given by DM1

| | $c_1$ | $c_2$ | $c_3$ | $c_4$ | $c_5$ | $c_6$ |
|---|---|---|---|---|---|---|
| $x_1$ | (0.1331,0.828) | (0.1244,0.8398) | (0.1803,0.7701) | (0.151,0.8034) | (0.1612,0.7906) | (0.1622,0.7893) |
| $x_2$ | (0.172,0.7803) | (0.1244,0.8398) | (0.1396,0.8197) | (0.09,0.8828) | (0.0962,0.8748) | (0.126,0.8378) |
| $x_3$ | (0.2197,0.7178) | (0.1244,0.8398) | (0.1049,0.8604) | (0.1172,0.849) | (0.1252,0.8388) | (0.1622,0.7893) |
| $x_4$ | (0.2197,0.7178) | (0.1602,0.7919) | (0.1803,0.7701) | (0.151,0.8034) | (0.1612,0.7906) | (0.1622,0.7893) |
| $x_5$ | (0.2197,0.7178) | (0.0956,0.8756) | (0.1803,0.7701) | (0.09,0.8828) | (0.1252,0.8388) | (0.126,0.8378) |
| $x_6$ | (0.1331,0.828) | (0.1244,0.8398) | (0.2299,0.7052) | (0.1172,0.849) | (0.1252,0.8388) | (0.1622,0.7893) |

Table 5: Relative closeness co-efficient and ranking of alternatives

| Alternatives | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ |
|---|---|---|---|---|---|---|
| Relative closeness | 0.9631 | 0.9803 | 0.9599 | 0.9819 | 0.9820 | 0.9747 |
| Ranking | 5 | 3 | 6 | 2 | 1 | 4 |

## CONCLUSION

This study proposes a novel group MADM method based on IF-AHP and IF-TOPSIS, which helps freight transport companies to prioritize collaborative processes in order to make the most of sustainable collaborative advantages. To illustrate the feasibility of proposed model, the method is applied to a real global case company engaged in road freight transport. IF-AHP is employed to derive the weights of the criteria with an automated method of improving the multiplicative consistency of decision matrices. Moreover, IF-TOPSIS is used to conduct the evaluation of alternatives with respect to criteria and derive their ranking order. Data is collected, in the form of linguistic variables; from the experts belong to the UK region of the case company. It is found from the study that incentive alignment and resource sharing are two important collaborative processes besides others, which need special attention by freight transport companies to ensure attainment of sustainable collaborative advantage.

It is apparent that all research has some limitations on which future research eventually feed upon; this study is also of no exception in terms of limitations. The study has collected data from three experts in a same case company. However, in future research, the result of this study can be confirmed by collecting data from numerous experts from multiple companies. Moreover, the study can be conducted in different regions to compare and contrast the findings from the UK region. The criteria used in this study is limited to first level, hence second level of criteria can also be incorporated containing sub-criteria of first level criteria. Furthermore, the proposed MADM model is applied in the context of road freight transport; however, it can also be applied to other logistics functions or to the logistics business as a whole. Addressing these limitations in future would provide new insights and advancements in the field of MADM and sustainable logistics.

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