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Fuzzy logic extensions-based simulation model for control of logistic performance index

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ABSTRACT

In this paper, an approach is proposed based on fuzzy logic extensions-based instruments to evaluate Logistic Performance Index (LPI). İnterval-valued intuitionistic fuzzy techniques are suitable in this regard to solve this kind of Weighted Linear Combination problems and simulate possible change extent in the overall index. Considering the fact that there is no generalized way for computation of global indices, and Principal Component Analysis is the common method, dealing with data uncertainty requires application of fuzzy logic and its extensions-based methods. The novelties of this study are: taking into account the fuzziness of crisp input data, and simulation of input data that conveys the possible change extent in LPI expressed as interval-valued intuitionistic fuzzy numbers. The methodology elaborated in this study can be considerable in the generalization of LPI computing methodology and for the any index control purposes.

1. Introduction

Logistics stimulating trade and transport facilitates economic development, and high-functioning domestic and international logistics is a prerequisite of competitiveness. Logistics is a network of services supporting the carriage of goods, and commerce across and within borders. comprising terminal operations, warehousing, express delivery, brokerage, and information management. The World Bank Logistics Performance Index (LPI) is a special measurement practice, providing assessment of policy impacts, and comparison of global developments in logistics above 160 countries. The six constituting components of the LPI–customs, infrastructure, ease of arranging shipments, quality of logistics services, and tracking and tracing, timeliness — indicate to policy functioning that respond to the challenges of each factor [1].

The LPI is established on a worldwide survey as the response to the logistics of the countries expressing the "friendliness" level. The LPI is constituted from both qualitative and quantitative measures based on feedback of logistics operators in the world and for logistics profiles building of the countries measuring the logistics performance in international and domestic perspectives.

The LPI indicators are incorporated employing principal component analysis (PCA), a statistical method used for dataset dimension reduction. Input variables for PCA are scores on questions 10-15 for countries on LPI components, averaged for all respondents. Then scores are

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normalized following subtraction the sample mean and division by the standard deviation. The weights are opted in order to maximize the variation in the LPI's core six indicators. The LPI is a weighted average of the survey scores. [2].

As an extension of intuitionistic fuzzy sets, interval-valued intuitionistic fuzzy sets (IVIFS) are more potent to deal with information uncertainty [3,4]. With the purpose to compute aggregated LPI, interval-valued intuitionistic fuzzy weighted averaging operator (IIFWA) is employed [5] that is effective in dealing with weighted linear combination problems to combine multiple values into a composite value.

The paper is organized as following: in paragraph 2 literature review is given, paragraph 3 covers a brief analysis of LPI dynamics for Azerbaijan, in paragraph 4 statement of the problem is presented, in paragraph 5 the solution algorithm for the problem is put forward. In the final paragraph, some parts from computation, and simulation process for overall LPI is provided.

2. Literature review

The trade conditions including regulations, tariffs, quotas, and other procedures negatively affect the mutual trade between developed and developing countries. Countries with the highest LPI are the main global transportation and logistics hubs or the important logistics service center while the countries with low LPI were often the isolated, suffering from improper governing that leads to trade difficulties, time wasting, and high transportation costs. This, in turn, prompts dependence on the other transit countries [6].

The research on the effect of logistics quality services on trade, based on indicators of the World Economic Forum's Enabling Trade Index and the LPI established that improvements logistics services quality has relationship with trade increments. There are strong and positive among the all the LPI components and countries with high logistics quality ensure timely delivery of shipments [7].

The impact of the LPI components on export in the Central Asian countries had significant results. Customs efficiency factor was the most important for the importing countries [8].

The correlation of the LPI with the economic and Human Development Index revealed that the countries spending on transport infrastructure do not have a weak relationship between GDP and LPI [9].

Comparison of the countries with LPI data between 2007 – 2012 with the application of gravity model disclosed the effect of high logistics functioning on the trade quantity of the countries [10].

The logistics performance effect of Brazil on its trade, the lowest LPI indicators - the efficiency of customs and the ease of arranging competitively priced shipments affected by the high tax burden. The report urged the policy makers to reduce the doubled tax burden compared to other BRICS countries [11].

The Turkish port service charges were low, due to delays this advantage was negligible. The implementation of the single-window system can upgrade the efficiency of customs. In addition, the turmoil and wars in border countries are the major reasons for delays in delivery [12].

A correlation analysis between World Economic Forum Global Competitiveness Index (GCI) and the LPI indicators revealed that the GCI are correlated with the logistics efficiency and variables contribute more to logistics performance based on the canonical correlation analysis [13].

A comparative analysis of the logistics performances of China, Japan, and Korea employing the LPI of 2015 determined the affecting critical factors of three countries bilateral trade and transportation infrastructure capacities, railways and port container traffics, telecommunications performance [14].

The logistics performance effect on countries imports and exports and correlation between LPI and GDP assess its effect on the countries international trade [15].

The impact of economic and social indicators on the overall logistics performance of the

country reveals that the level of infrastructure and technology development had the highest significant effect on the Logistics Performance of the countries [16].

Researchers conclude that [12, 14] improvement in the logistic performance would likely return large trade revenues.

3. Statement of the problem

In this paper, the aim is to develop a simulation model and a solution algorithm using interval-valued intuitionistic fuzzy techniques for the computation and control purposes of LPI. For the fuzzification the data for 2023 with their maxima and minima are taken from LPI Project Team [2] given in table 1.

Tab. 1

LPI data on Azerbaijan

№	Logistic Performance Index	Acronyms	Data for 2018	Best case	Worst case	Expert Data for 2023
1	The efficiency of customs and border management clearance (“Customs”)	C	2.53	4.09	1.57	2.53
2	The quality of trade and transport infrastructure (Infrastructure”)	I	2.69	4.37	1.56	3.00
3	The ease of arranging competitively priced shipments (Ease of arranging shipments”)	IS	2.56	3.99	1.80	2.85
4	The competence and quality of logistics services—trucking, forwarding, and customs brokerage (“Quality of logistics services”)	LQ	2.14	4.31	1.88	2.90
5	The ability to track and trace consignments (“Tracking and tracing”)	TT	2.18	4.32	1.64	2.18
6	The frequency with which shipments reach consignees within scheduled or expected delivery times (“Timeliness”)	T	2.62	4.41	2.04	3.58
	Overall LPI	---	2.45	---	---	2.84

4. A brief analysis of LPI dynamics for Azerbaijan

In the LPI survey conducted in 2018, Azerbaijan was 123rd in the ranking of world countries with 2.45 points. For information, let's note that in that survey Germany was the first with 4.19 points. But among some neighbor and CIS countries the scores of Türkiye and Kazakhstan were 3.29 and 2.77 respectively, taking higher places. Next comes Iran and Russia having 2.71 and 2.69 points, followed by Azerbaijan and Georgia both scoring 2.45 points. Azerbaijan's LPI index was not satisfactory on infrastructure and customs services mainly [2].

Since 2018, the works carried out in 6 components in Azerbaijan are given below:

On customs services:

One of the new projects implemented in the customs field of Azerbaijan is the "Green Corridor" gating system. This new gating system gives business participants an advantage in the following areas:

- Priority transit from border checkpoints;
- Priority when using customs services;
- Minimum physical control;
- Carrying out customs expertise in a priority order;
- Carrying out customs clearance autonomously from the client's workplace and working hours;
- Direct delivery of imported goods to a client without customs clearance;
- Export of goods directly from own warehouse without customs clearance.

Currently, 495 and 278 business partners have been granted the right to use this corridor for import and export operations respectively and work on the expansion of this system is ongoing.

In addition, the E-Customs and Smart Customs projects were successfully implemented. Thus, in the E-Customs project, all electronic services for individuals, legal entities and non-residents are concentrated in a single portal. In the Smart Customs project, a mobile application program was also launched for business participants or individuals to conduct foreign trade transactions [17].

On the infrastructure:

In terms of infrastructure, projects implemented including New Port of Baku, Baku-Tbilisi-Kars railway projects et. c. The New Port of Baku has all the necessary facilities for the rapid transit of goods in the East-West corridor and is one of the largest ports in the Caspian Sea with an annual handling capacity of 15 million tons, including 100,000 TEU containers. As of March 2022, in view of the current geopolitical situation, the increased cargo flows to the Middle Corridor have revealed the expansion urgency of the infrastructure along the corridor. The detailed information on infrastructure works carried out since 2018 are:

- The New Baku Port is completely under operation since 2018. It has an annual transshipping capacity of 15 million tons, including 100,000 TEU containers, and operates on an area of 400 hectares. Moreover, there are 3 terminals, 11 cargo and 1 service berths in the new Port of Baku in the first phase. Wagons and wheeled equipment (Trucks, Trailers, autos etc.) are transshipped at the ferry terminal, wheeled equipment (truck, trailers) at the Ro-Ro terminal, and containers and dry cargo at the general cargo terminal. Second phase of Port of Baku Development Project will be able to handle additional 10 million tons of cargo, including 400,000 TEU containers (total capacity of Port will be 25 million tons of cargo, including 500,000 TEU containers)
- The Baku-Tbilisi-Kars railway, actively operating since the end of 2017, allows containers to be sent directly to Turkey and then to Europe and other countries of the world without entering Georgian ports. Passenger transportation by Baku-Tbilisi-Kars railway is also expected in the future.
- The one-way 8.3 km long railway between Astara of Azerbaijan and Astara of Iran plays an important role in the development of the North-South corridor.
- The Red Bridge customs checkpoint was expanded, the number of traffic lanes was increased from 1 to 3, and 1 weighting-machines was installed.
- A new "Khanoba" crossing point for agricultural goods was established at the northern customs point, and a traffic crossing consisting of 2 lanes and 1 weighting-machine was installed. It is planned to increase the number of traffic lanes to 4 in the near future. In addition, the number of lanes at the old SDK customs checkpoint has been increased to 4, and there are a total of 4 weighting-machines, with 2 weighting-machines each at the entry and exit sections.
- In 2023-2024, Azerbaijan Railways has started the procurement process for the purchase of 605 container platforms, and works on the purchase of other types of wagons are also being continued.

- 2 new Ro-Pax ships and 3 tankers have been put into service by Azerbaijan Caspian Sea Shipping CJSC and 2 more new ships of the same type and 1 tanker have been ordered since 2018.
- On 13 August, 2018, the first private logistics center meeting international standards was established to conduct import-export operations
- On 18 September, 2018 the new 204 km long Alat-Astara highway was put into service.
- The new Baku-North highway, which can contribute to the development of the North-South corridor, is expected to be put into service this year being an alternative to the traditional Baku-Guba road.
- The implementation of the expanding throughput capacity of Akhalkalaki station, located in Georgia, is expected to begin this year by the Government of Azerbaijan.
- Extension of existing Boyuk-Kasik to Ganja alternating current communication up to Alat station. It should be noted that currently there is only direct current up to Ganja.
- In the near future, the works will be started for the expansion of the Alat railway station.
- Extension of railway lines in Port of Baku.

Projects expected in the near future in Port of Baku:

- Fertilizer terminal, planned for 2023 with annual handling capacity of 2.5 million tons;
- The transformation of the heavy cargo terminal (mobile cranes) allowing the transshipment of additional containers 35 thousand TEU per year;
- Grain terminal for 2024 with annual handling capacity of 1 million tons;
- Intermodal/multimodal terminal Project in the second phase.

Furthermore, let's note that currently the work on the technical and economic justification of the expansion of Port of Baku within the framework of the 2nd phase is also being continued.

Organization of international transportation, quality of logistics services, ability to track cargo, timely delivery of cargo:

As private and state logistics companies of Azerbaijan in the direction of management of international transportation, companies such as ADY Container, ADY Express state logistics companies, AlPort Baku (Albayrak Group), Maersk, MsC, Pace North, Trammo, Port Bonded, Caspian Global Logistics and etc. private companies are playing an important role at the international level in the management of international transportation. The role of the Trans-Caspian International Transport Route Association (TITR) should be underlined. The Association implements the agreed tariff policy by carrying out coordinated cargo transportation in the East-West corridor and that containers are being actively transported these days from China to the Western countries along the TITR route. Furthermore, Azerbaijan Railways implements a uniform tariff policy for each direction.

Since 2018, in terms of the quality of Azerbaijan logistics services the Port of Baku has been put into service and is currently providing quality transshipment services to cargo carriers and the work on the 2nd phase has been started recently. Beyond that in 2022, 2 Ro-Ro/Pax ships were built at the Baku Shipbuilding factory and put into use by Azerbaijan Caspian Sea Shipping CJSC. Azerbaijan Railways is also continuing work on the renovation of the wagon park, repair and expand rail lines along the East-West and North-South corridor. Moreover, a completely free market has been formed in the field of customs brokerage.

Regarding cargo tracking, Port Management Information system was integrated with railways and customs systems within Azerbaijan by Port of Baku and will be integrated with Caspian ports and other transport entities soon in order to decrease transit time with paperless work. Moreover, the ADY Smart system was implemented in railways, a module is in use allowing freight forwarders to track their cargo.

Block trains are currently running on a predetermined timetable in the East-West direction for on-time delivery of cargo [17].

5. An algorithm for computation of LPI

The algorithm developed for computation of LPI is presented below:

Step 1. Conversion of crisp data into interval-valued intuitionistic fuzzy numbers. For the fuzzification purpose interval-valued intuitionistic fuzzification triangular function is employed [18]:

$$\mu_A^-(x) = \begin{cases} \mu^- \frac{(x-a)}{(b-a)}, \\ \mu^-; \\ \mu^- \frac{(c-x)}{(c-b)}; \end{cases} \qquad \mu_A^+(x) = \begin{cases} \mu^+ \frac{(x-a)}{(b-a)}, & a < x < b \\ \mu^+; & x = b \\ \mu^+ \frac{(c-x)}{(c-b)}; & b < x < c \end{cases} \tag{1}$$

$$v_A^-(x) = \begin{cases} 1-(1-v^-)\frac{(x-a)}{(b-a)}, \\ v^-; \\ v^- + (1-v^-)\frac{(x-b)}{(c-b)}; \end{cases} \qquad v_A^+(x) = \begin{cases} 1-(1-v^+)\frac{(x-a)}{(b-a)}, & a < x < b \\ v^+; & x = b \\ v^+ + (1-v^+)\frac{(x-b)}{(c-b)}; & b < x < c \end{cases} \tag{2}$$

Where, $\mu^- : X \to [0,1]$, and $\mu^+ : X \to [0,1]$ denote the lower and upper membership degrees, $v^- : X \to [0,1]$, and $v^+ : X \to [0,1]$ denote the lower and upper non-membership degrees respectively.

Step 2. Construction of interval-valued intuitionistic fuzzy preference relation matrix (IVIFPRM).

In this stage based on the scale given in table 2, IVIFPRM is established [19].

Table 2

Linguistic terms for criteria preference

Linguistic terms	Acronyms	IVIFNs
Extremely important	EXI	([0.65,0.75],[0.10,0.25])
Very Important	VI	([0.60,0.70],[0.15,0.30])
Important	I	([0.55,0.65],[0.20,0.35])
Medium Important	MI	([0.50,0.60],[0.25,0.40])
Equally important	EI	([0.50,0.50],[0.50,0.50])
Medium Low Important	MLI	([0.45,0.55],[0.30,0.45])
Low Important	LI	([0.25,0.40],[0.50,0.60])

Step 3. Checking the additive consistency. If $R = (r_{ij})_{n\times n} \subset X \times X$, where $r_{ij} = [\underline{r}_{ij}, \bar{r}_{ij}]$ stands for the preference degree interval of alternative x_i over x_j. Then the following conditions must hold [20] for $\underline{r}_{ij}$, and $\bar{r}_{ij}$:

$$0 \le \underline{r}_{ij} \le \bar{r}_{ij} \le 1,\ \underline{r}_{ij} + \bar{r}_{ij} = 1,\ \underline{r}_{ij} = \bar{r}_{ij} = 0.5 \ \text{ for all i, j = 1,2,…,n} \tag{3}$$

Step 4. Checking the multiplicative consistency. For the multiplicative consistent interval-valued intuitionistic fuzzy preference relation $\tilde{R}$, the following equations [21] must hold:

$$\tilde{\mu}_{ij}^L = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^L \tilde{\mu}_{kj}^L}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^L \tilde{\mu}_{kj}^L} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-\tilde{\mu}_{ik}^L)(1-\tilde{\mu}_{kj}^L)}}, j > i+1 \tag{4}$$

$$\tilde{\mu}_{ij}^{U} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{U} \tilde{\mu}_{kj}^{U}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{U} \tilde{\mu}_{kj}^{U}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-\tilde{\mu}_{ik}^{U})(1-\tilde{\mu}_{kj}^{U})}}, j > i+1 \quad (5)$$

$$\tilde{v}_{ij}^{L} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{L} \tilde{v}_{kj}^{L}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{L} \tilde{v}_{kj}^{L}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-v_{ik}^{L})(1-\tilde{v}_{kj}^{L})}}, j > i+1 \quad (6)$$

$$\tilde{v}_{ij}^{U} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{U} \tilde{v}_{kj}^{U}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{U} \tilde{v}_{kj}^{U}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-v_{ik}^{U})(1-\tilde{v}_{kj}^{U})}}, j > i+1 \quad (7)$$

Step 5. Calculation of Entropy. Entropy measures are computed employing the approach established by Zhao and Xu [22] that is given below:

If $h(x) = \frac{\lg(1+x)}{lg2}$, then the entropy formula for IVIFSs is:

$$E_{ZX}(A) = \frac{1}{2n}\sum_{i=1}^{n} 1 - \frac{lg\,(1+|\mu_A^L(x_i)-v_A^L(x_i)|)}{2lg2} - \frac{lg(1+|\mu_A^U(x_i)-v_A^U(x_i)|)}{2lg2} + \frac{lg(1+\pi_A^L(x_i))}{2lg2} + \frac{lg(1+\pi_A^U(x_i))}{2lg2} \quad (8)$$

Step 6. Construction of Entropy matrix. Employing formula (8) entropy matrix $E = (e_{ij})_{m\times n}$ is constructed.

Step 7. Obtaining the criteria weights. Entropy information measure and criteria weights are computed [23] with the following equations:

$$E_j = \frac{1}{m}\sum_{i=1}^{m} e_{ij} \quad (9)$$

$$w_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \quad (10)$$

Step 8. In this stage, IIFWA is applied in order to combine interval-valued intuitionistic fuzzy numbers (IVIFNs) for LPI indicators [5]:

$$IIFWA_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \dots, \tilde{\alpha}_m) = \left(\left[1 - \prod_{i=1}^{m}(1-a_i)^{w_i}, 1 - \sum_{i=1}^{m}(1-b_i)^{w_i}\right], \left[\prod_{i=1}^{m} {c_i}^{w_i}, \prod_{i=1}^{m} {d_i}^{w_i},\right]\right) \quad (11)$$

Step 9. In this step, obtained IVIFNs are interpreted by linguistic terms for clear understanding [24]. The linguistic terms set with IVIFNs counterparts are given in table 3.

Table 3

Linguistic terms and their matching interval-valued intuitionistic fuzzy scale

Linguistic terms (LT)	IFNs membership and non-membership function value intervals $([\mu^-, \mu^+], [v^-, v^+])$
Very high (VH)	([1.00, 1.00], [0.00, 0.00])
High (H)	([0.70, 0.80], [0.05, 0.10])
Medium high (MH)	([0.60, 0.70], [0.15, 0.20])
Medium (M)	([0.50, 0.60], [0.25, 0.30])
Medium low (ML)	([0.30, 0.40], [0.45, 0.50])
Low (L)	([0.15, 0.25], [0.55, 0.60])
Very low (VL)	([0.00, 0.10], [0.85, 0.90])

Step 10. Simulation. The initial result is obtained employing the actual data. Then different scenarios are considered with the purpose to control the LPI index within the country level.

6. Computation and simulation results of LPI

In this section, some parts of the computation process for LPI is given. Following the conversion of expert data into IVIFNs, referring to steps 2 to 4, IVIFPR and consistent IVIFPR matrices are constructed as below (Tables 4, 5):

Table 4

Interval-valued intuitionistic fuzzy preference relation matrix – R

	C	I	IS	LQ	TT	T
C	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.55,0.65], [0.20,0.35])	([0.60,0.70], [0.15,0.30])	([0.65,0.75], [0.10,0.25])	([0.65,0.75], [0.10,0.25])
I	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.55,0.65], [0.20,0.35])	([0.60,0.70], [0.15,0.30])	([0.65,0.75], [0.10,0.25])
IS	([0.20,0.35], [0.55,0.65])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.55,0.65], [0.20,0.35])	([0.60,0.70], [0.15,0.30])
LQ	([0.15,0.30], [0.60,0.70])	([0.20,0.35], [0.55,0.65])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.55,0.65], [0.20,0.35])
TT	([0.10,0.25], [0.65,0.75])	([0.15,0.30], [0.60,0.70])	([0.20,0.35], [0.55,0.65])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])
T	([0.10,0.25], [0.65,0.75])	([0.10,0.25], [0.65,0.75])	([0.20,0.35][0.55,0.65])	([0.20,0.35], [0.55,0.65])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])

Table 5

Multiplicative consistent interval-valued intuitionistic fuzzy preference relation matrix – $\widetilde{R}$

	C	I	IS	LQ	TT	T
C	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.50,0.69], [0.10,0.31])	([0.55,0.74], [0.08,0.26])	([0.62,0.79], [0.05,0.21])	([0.65,0.82], [0.04,0.18])
I	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.50,0.69], [0.10,0.31])	([0.55,0.74], [0.08,0.26])	([0.58,0.78], [0.06,0.22])
IS	([0.10,0.31], [0.50,0.69])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60][0.25,0.40])	([0.50,0.69], [0.10,0.31])	([0.53,0.71], [0.09,0.27])
LQ	([0.08,0.26], [0.55,0.74])	([0.10,0.31], [0.50,0.69])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60], [0.25,0.40])	([0.50,0.69], [0.10,0.31])
TT	([0.05,0.21], [0.62,0.79])	([0.08,0.26], [0.55,0.74])	([0.10,0.31], [0.50,0.69])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])	([0.50,0.60], [0.25,0.40])
T	([0.04,0.18], [0.65,0.82])	([0.06,0.22], [0.58,0.78])	([0.09,0.27], [0.53,0.71])	([0.10,0.31], [0.50,0.69])	([0.25,0.40], [0.50,0.60])	([0.50,0.50], [0.50,0.50])

In the next stage, following the steps 5 and 6, entropy matrix is constructed:

$$E = \begin{array}{c} \\ C \\ I \\ IS \\ LQ \\ TT \\ T \end{array} \begin{array}{c} \begin{array}{cccccc} C & I & IS & LQ & TT & T \end{array} \\ \begin{pmatrix} 0.5000 & 0.4342 & 0.3838 & 0.3332 & 0.2752 & 0.2472 \\ 0.4342 & 0.5000 & 0.4342 & 0.3838 & 0.3332 & 0.2995 \\ 0.3838 & 0.4342 & 0.5000 & 0.4342 & 0.3838 & 0.3603 \\ 0.3332 & 0.3838 & 0.4342 & 0.5000 & 0.4342 & 0.3838 \\ 0.2752 & 0.3332 & 0.3838 & 0.4342 & 0.5000 & 0.4342 \\ 0.2472 & 0.2995 & 0.3603 & 0.3838 & 0.4342 & 0.5000 \end{pmatrix} \end{array}$$

The criteria weights are derived from entropy matrix based on equations given in step 7:

$E_1 = 0.3623$, $E_2 = 0.3975$, $E_3 = 0.4161$, $E_4 = 0.4116$, $E_5 = 0.3934$, $E_6 = 0.3708$

$w_1 = 0.1748$, $w_2 = 0.1651$, $w_3 = 0.1601$, $w_4 = 0.1613$, $w_5 = 0.1663$, $w_6 = 0.1725$

Finally, IIFWA output is obtained for the overall LPI.

$IIFWA_{LPI} = (1 - [((1-0.34)^{0.1748} * (1-0.46)^{0.1651} * (1-0.43)^{0.1601} * (1-0.38)^{0.1613} * (1-0.18)^{0.1663} * (1-0.58)^{0.1725}), ((1-0.36)^{0.1748} * (1-0.49)^{0.1651} * (1-0.46)^{0.1601} * (1-0.40)^{0.1613} * (1-0.19)^{0.1663} * (1-0.62)^{0.1725})], [(0.62^{0.1748} * 0.49^{0.1651} * 0.53^{0.1601} * 0.58^{0.1613} * 0.80^{0.1663} * 0.36^{0.1725}), (0.63^{0.1748} * 0.50^{0.1651} * 0.53^{0.1601} * 0.59^{0.1613} * 0.80^{0.1663}) * 0.37^{0.1725}] = ([0.41,0.44], [0.54,0.56])$

Table 6

Simulation results

№	Acronyms	Expert Data	V1	V2	V3	V4	V5
1	C	2.53	3.50	3.50	3.50	3.50	3.50
2	I	3.00	3.00	3.00	3.50	3.50	3.60
3	IS	2.85	2.85	2.85	2.85	3.50	3.50
4	LQ	2.90	2.90	2.90	2.90	2.90	3.20
5	TT	2.18	2.18	3.00	3.00	3.00	3.00
6	T	3.58	3.58	3.58	3.58	3.58	3.58
Average		2.84	3.00	3.14	3.22	3.33	3.40
IVIFVs		[0.41,0.44], [0.54,0.56]	[0.48,0.51], [0.46,0.47]	[0.52,0.55], [0.43,0.44]	[0.54,0.58], [0.40,0.41]	[0.59,0.62], [0.35,0.36]	[0.59,0.63], [0.34,0.35]
Ling. Terms		ML	M	M	M	MH	MH

Eventually, for the simulation five scenarios are introduced along with the expert data evaluation for the control and increment purposes of LPI level. The simulation to surge the LPI is carried out taking into account the priority weights of components. The process is started with upgrading values of Customs then Timeliness respectively, to which higher weights were appertained. The development of transportation and logistics infrastructure in Azerbaijan more likely will be entailed by enhancement in Ease of arranging shipments and Quality of logistic services. On that account the following five scenarios are set up based on growth of three indicators: I, IS, and LQ. The obtained results are illustrated in table 6 indicating that a unit change in Customs would strengthen LPI from medium low to medium, changes in Timeliness along with Infrastructure group might improve LPI index to the medium high level. As a consequence of the simulation process we derive that the LPI score can be improved from medium low (2.84) to medium high (3.40) level.

Even though the use of linguistic terms are reasonable to understand the change in overall index, IVIFNs are more analytical to track the dynamics of overall index within the simulation process.

7. Conclusion

In this paper, we propose a method based on interval-valued intuitionistic fuzzy techniques to evaluate Logistic Performance Index (LPI), that stands for sustainable economic development scope of the country. The introduced algorithm for computation and simulation of LPI makes up the core of the prepared approach. Obtained results on expert data and simulated scenarios indicate the LPI level in the country for the present day and its possible change extent respectively. As a consequence of the simulation process, we derive that the LPI score level can be improved from medium low to medium high. The developed approach can be used for the score improvement and management of the LPI in the course of logistic performance development. The elaborated method can also be an option in the generalization of computing methodology of LPI and for the control projects.

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