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Research of Logistics Time Performance Evaluation Based on Linguistic Variables, a Case Study of Urgent Transportation between China and Thailand

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Abstract

While the world economy has become increasingly regionalized, the trade volume between China and ASEAN has grown significantly. However, the logistics performance is not developing synchronously, and the situation is unsatisfactory. This paper takes the urgent transportation between China and Thailand as an example, and proposes a model of time-based performance evaluation. The model presents an approach to fuzzy algorithms on linguistic variables based on analyzing the main influencing factors. Thus, it is practical when accurately measurable data is unavailable, and it can also be used to select a relatively optimal solution from several alternatives.

Keywords

Performance Evaluation, Influencing Factor, Linguistic Variable, Fuzzy Quantifier

1. Introduction

In recent years, the global trade environment has undergone substantial changes, which have caused the conventional worldwide supply and manufacturing chains to be disrupted and dispersed. This transformation is fueled not just by the rise of trade protectionism but also by the expansion of regional commerce on a bilateral and multilateral basis (Majchrowska, 2006). It is particularly prevalent in Asia, where there have been many regional trade agreements, such as the Regional Comprehensive Economic Partnership (RCEP) and the China-ASEAN

Free Trade Agreement (CAFTA). Closer ties will benefit several Asian nations by creating regional value chains and Asian factories, fostering regional development through trade and investment, and utilizing economies of scale and specialization (Scholvin et al., 2022).

According to statistics from the United Nations Conference on Trade and Development (UNCTAD, 2022), intra-regional exports accounted for 59% of Asian total trade in 2021. Since 2020, China and ASEAN have emerged as each other's largest trading partners (Ong, 2022). Furthermore, according to a report from BOI (2023), China has been the largest direct foreign investment source country of Thailand, which is the second-largest economy within ASEAN. This regionalized cross-border investment is expected to result in an increased demand for supply chain logistics within the region.

However, according to a report from The World Bank (2023), when it comes to the punctuality rate in logistics, China and Thailand scored respectively 3.7 and 3.5 on a scale of 5. Their logistics performances are not in the first grade, even lagging behind Singapore and Hong Kong SAR of China's 4.3 and 4.0. It is necessary to study the management of logistics time performance between China and Thailand, especially in the aspect of urgent transportation.

2. Literature Review

Logistics management can be regarded as a "total material flow, from component source to final user, as an entity" (Christopher, 1986). Its operation is in a chain shape with interlocking upstream and downstream links.

Due to the difficulty of a single logistics provider independently meeting all logistics demands of shippers, it is necessary to cooperate with other overseas logistics enterprises and even form some special cross-border organizations. Such chain cooperation is vertical and just like "sequential interdependence" (Daft, 2001), which normally exists in the traditional resource-dependent organization, e.g., manufacturing assembly line. In the sequential form of interdependence, the contribution of the unit to the group is specified in relation to the contributions of others. "This is a value-added system of specialists, each performing his portion of the larger task and passing the job on to the next one" (Thompson, 1974). The sequential interdependence requires more demands for effective coordination among the linked departments or nodes, or greater needs for communication technologies and control mechanisms. And it would be inefficient when the organization is too long-linked, or has too many nodes. To manage the performance of logistics operations effectively, it is important to avoid too long-linked organizational structures and set up a control mechanism.

Mentzer (1993) suggested that, for those logistics channel organizations, quality will cease to be a basis for competitive advantage and evolve into a standard of performance. Channels that cannot identify and deliver the aspects of quality demanded by customers will lose those customers to channels that can. Usually, it would be helpful for us to control quality, if standardized operation or processes were adopted (Rhymer, 2023). It is possible to improve the efficiency of logistics system and the performance of quality control mechanisms by computerized simulation or optimizing technologies, including some common logistics applications, e.g., vehicle routing problem-solving (Holland et al., 2017; Qiao, 2022; Zhao, 2023), inventory optimizing (Utama et al., 2022), real-time positioning (Li, 2021), and so on. However, it is difficult to find a solution for so special and urgent transportation. The previous literature has rarely involved the issue. It is hard to establish a suitable mathematical model because influencing factors cannot be accurately measured by traditional statistical methods. It is most important that the quality performance of urgent transportation operations lies in time control. This paper begins with the analysis of time performance influencing factors and then studies the optimal one of all solutions.

3. Research Methodology

3.1. Analysis Approach

The analysis approach includes the following three steps:

Step 1, we can analyze the influencing factors of urgent transportation by listing the whole process nodes, then obtain the main factors and their order of importance based on the pairwise comparison by 1 - 9 scale method. At the same time, a judgment matrix can be derived from the importance order. After calculating the eigenvector of the matrix and normalizing the vector, then checking the consistency of the judgment matrix, a weight vector would be obtained.

Step 2, while all factors are being treated as linguistic variables and assigned fuzzy values, the comprehensive time performance evaluation of all factors will be obtained by use of the weight vector combined with fuzzy composite operators, and through matrices operation.

Step 3, by taking the urgent transportation line between China and Thailand as an example, we can compare several different possible routes and derive the relatively optimal solution.

3.2. Problem Definition

Urgent transportation service normally is provided by air cargo agents with the demand for quick delivery of samples, spare parts, and so on. The following services cover a varied range (IATA, 1994):

1) SMALL PARCELS SERVICE: for small and medium shipments that have several house waybills(HWBs) and are consolidated under one master air waybill(MAWB) issued by airlines.

2) EXPRESS SERVICE: for shipments that have only one HWB under one MAWB and are not consolidated with other shipments. It is also named NEXT FLIGHT OUT SERVICE, or NFO.

3) COURIER SERVICE: for shipments carried on board passenger aircraft as carry-on or checked luggage and are not consolidated. This kind of service has only one HWB and no MAWB. It is also named ON BOARD COURIER, or

OBC.

The above-mentioned services have one common character. The shipments are delivered from door to door. COURIER SERVICE, or ON BOARD COURIER is the most urgent method among them. All these kinds of services consist of logistics operation processing nodes including pick-up at the shipper's premises, air transportation, customs formalities, and delivery to the consignee's address at least. The whole process of door-to-door air cargo transportation is shown in Figure 1, while it does not include all nodes of all kinds of transportation modes all the time, i.e., there is a different quantity of nodes for each different mode. Table 1 illustrates the differences among the three modes, with numbers "1" and "0" representing "yes" and "no" respectively.

Table 1. Different modes of urgent transportation.

No.	operation processing node	modes		
		small parcels	NFO	OBC
1	space booking	1	1	0
2	pick-up	1	1	1
3	consolidation	1	0	0
4	export customs declaration	1	1	1
5	deliver to an airport of origin	1	1	0
6	airport-to-airport	1	1	1
7	import customs clearance	1	1	1
8	recover from an airport of destination	1	1	0
9	break bulk	1	0	0
10	delivery	1	1	1
	node quantity	10	8	5

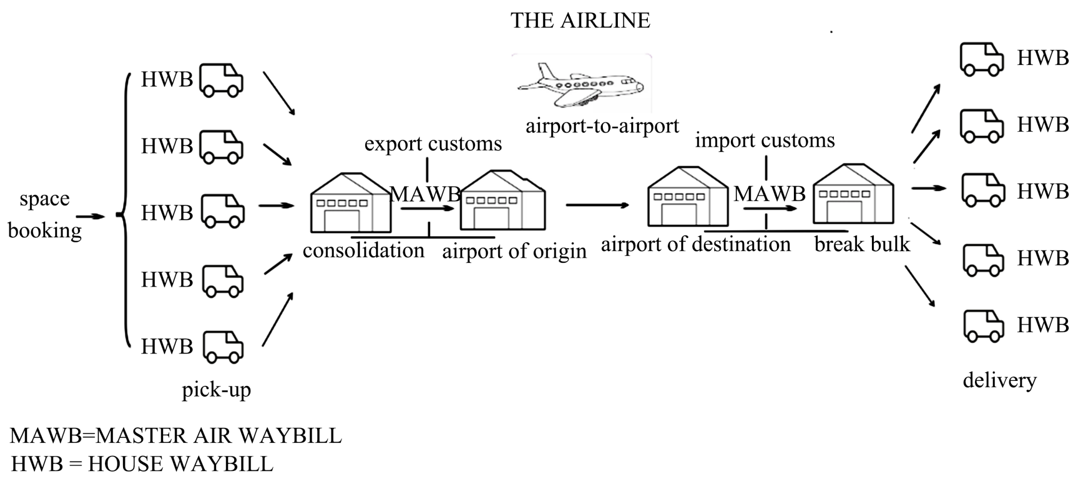

Figure 1. The whole process of door-to-door air cargo transportation.

Lead time performance is the most important quality standard of all for urgent transportation. The shorter the process chain was, or the fewer nodes, the better the time performance would be. Obviously "on board courier" (OBC) mode has the fewest nodes. Taking the OBC mode as an example, consider these nodes as factors influencing time performance. Analyze these factors, establish a mathematical model, and evaluate the comprehensive time performance of each factor.

3.3. Analysis of Influencing Factors

It is important to analyze these factors, either what they are, or how they influence performance, etc.

First, we group the nodes with similar attributes and refine the influencing factors. There are several main operational component parts for OBC mode transportation, each part includes one or several nodes:

1) Trucking service (pick-up and delivery).

2) Customs brokerage service (export declaration and import clearance).

3) Flight transportation service (airport-to-airport).

Next, the above parts are defined as factors, and each factor is an influencing variable of transportation performance, as Table 2 shows.

Then, when the factors or variables have been defined, it is necessary to determine priorities by making a judgment or pairwise comparison, for it would be very difficult to rank the importance or preference when many factors were compared together at the same time. Pairwise comparison involves comparing criteria or factors and ranking them in relation to each other. This paper uses the ranking method of a 1 - 9 scale, with 1 representing "equal importance" or "equal preference" and 9 representing "absolute importance" or "extreme preference". The method of the 1 - 9 scale was developed by Saaty (1994). As shown in Table 3, it helps represent the factors numerically and derive a weight vector of all factors, i.e., the order of their relative importance. However, because the results of such comparison are described by natural language, the sequential representation is not accurate but fuzzy. In other words, even if the factors' rough ranking can be obtained through a 1 - 9 scale method, it is still hard to get accurately measurable data which can be used to establish a mathematical model to reach a statistical result of factors' comprehensive influence. This paper combines the above factors' weight vector with linguistic variables of fuzzy theory so that the language-described factors would have clearer ranges or intervals.

Table 2. Influencing factors and corresponding variables.

variable	factor
u_1	trucking service
u_2	customs brokerage service
u_3	flight transportation service

Table 3. Method of 1 - 9 scale/Saaty descriptors.

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally.
3	Moderate importance	One is slightly more important than the other.
5	Strong importance	One is strongly more important than the other.
7	Very strong or demonstrated importance	One is significantly more important than the other.
9	Extreme importance	One is absolutely more important than the other.
2, 4, 6, 8	For a compromise between the above values	An interpolated compromise judgment numerically
Reciprocals of above	If factor A has one of the above numbers assigned to it when compared with factor B, then B has the reciprocal value when compared with A.	

Hence, the approach provides a path to obtain more accurately measurable data which helps set up a mathematical model for performance evaluation. The core of the 1 - 9 scale and fuzzy approach lies in how to derive the weight vector of factors, and "this vector itself is just a fuzzy set" (Hu, 2010).

On the detailed calculation in the following four steps, pairwise compare all the factors and rank their relative importance:

Step 1, we made a questionnaire survey among 20 logistics experts from three logistics companies, asking them to pairwise compare factors u_1, u_2, and u_3, choosing results out from "equally important", "slightly more important", "strongly more important", "significantly more important", and "absolutely more important", by the above 1 - 9 scale method. Scored results are shown in Table 4. Then, confidence intervals of u_1, u_2, and u_3 could be obtained on the scores as follows (shown in Table 5):

- Interval of u_1 equals 1.3 ± 0.29.
- Interval of u_2 equals 3.6 ± 0.37.
- Interval of u_3 equals 2.7 ± 0.68.

Confidence level is assumed as 0.90 here, it would be 0.95 or 0.99 for more accuracy.

In Table 5, values of the confidence interval show that $u_2 \geq u_3 > u_1$. When referring to the 1 - 9 scale of Table 3, it is obvious that u_2 is slightly more important than u_3, and u_2 is strongly more important than u_1.

Step 2, we establish a judgment matrix based on the factors' importance order and scoring method of a 1 - 9 scale, and then obtain their weight vector. Table 6 illustrates how to get the matrix, to be understood easier, the shown factors' sequence subjects to $u_2 \geq u_3 > u_1$.

Table 4. Comparison of factors by 1 - 9 scale method[a].

factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
u_1	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3
u_2	5	3	3	3	3	3	5	5	3	5	3	3	3	3	5	3	3	5	3	3
u_3	3	3	5	1	3	1	3	1	1	1	5	5	5	1	3	5	5	1	1	1

[a]The scores do not exceed 5 points, however, it is necessary that we take 1 - 9 scale, for subfactors will possibly need comparing, e.g., u_2 includes subfactors "export declaration" and "import clearance", according to experience, result will maybe show "import clearance is significantly or absolutely more important than export declaration", i.e., "7" or "9".

Table 5. Confidence intervals for factors.

factor	mean	standard deviation	sample size	confidence level	confidence interval
u_1	1.30	0.732695097	20	0.90	1.3 ± 0.29
u_2	3.60	0.940324692	20	0.90	3.6 ± 0.37
u_3	2.70	1.750187960	20	0.90	2.7 ± 0.68

Table 6. Judgment matrix of comparison.

influencing factor	variable	customs brokerage	flight transportation	trucking
		u_2	u_3	u_1
customs brokerage service	u_2	1	3	5
flight transportation service	u_3	0.33	1	3
trucking service	u_1	0.20	0.33	1

The following judgment matrix, denoted as $\boldsymbol{A}$, can be obtained in Table 6:

$$\boldsymbol{A} = \begin{bmatrix} 1 & 3 & 5 \\ 0.33 & 1 & 3 \\ 0.20 & 0.33 & 1 \end{bmatrix}$$

Step 3, we calculate the eigenvector and maximum eigenvalue of the judgment matrix $\boldsymbol{A}$, where the eigenvector is symbolized by the sign $\boldsymbol{W}$, and the maximum eigenvalue is λ_{max}. Normally, if the judgment matrix A is an n-order square matrix,

$$\boldsymbol{A} = \left(a_{ij}\right)_{n \times n}$$

where a_{ij} is the importance score of comparison between factor i and factor j, furthermore, let $\boldsymbol{W} = (w_1, w_2, \ldots, w_n)^{\mathrm{T}}$, where w_i symbolizes the weight of factor i in the whole eigenvector, the superscript T refer to a transposed matrix. Then,

$$W_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, i = 1, 2, \cdots, n$$

As the above example judgment matrix $\boldsymbol{A}$, where $n = 3$, then obtains the normalized eigenvector $\boldsymbol{W} = (0.63, 0.26, 0.11)^{\mathrm{T}}$ and maximum eigenvalue $\lambda_{\max} = 3.0387$.

Step 4, inconsistency is inherent in the judgment process, of experts' different experiences, knowledge, and available information. Hence, consistency checking of the judgment matrix is a must. There is a method to check whether the matrix is consistent or not, by comparing the deviation between $\lambda_{\max}$ and n, it means that if the deviation is less than some ratio, e.g. 0.10 (10%), then inconsistency can be considered a tolerable error in measurement. The consistency ratio's calculating processing is as follows:

$$CR = \left(\frac{\lambda_{\max} - n}{n-1}\right) \Big/ RI$$

where CR is the consistency ratio, $\lambda_{\max}$ is the maximum eigenvalue, n is the number of square matrix order, and RI is a random index. In this case, if $n = 3$, then $RI = 0.52$, thus $CR = 0.0372 < 0.10$. It means that the judgment matrix $\boldsymbol{A}$ is consistent, and its normalized eigenvector $\boldsymbol{W} = (w_1, w_2, \ldots, w_n)^{\mathrm{T}} = (0.63, 0.26, 0.11)^{\mathrm{T}}$ can be regarded as a weight vector, where $w_1 = 0.63$ is w_{u2}, $w_2 = 0.26$ is w_{u3}, and $w_3 = 0.11$ is w_{u1} in **Table 6**. Finally weight vector of factors is $\boldsymbol{W} = (w_{u1}, w_{u2}, w_{u3})^{\mathrm{T}} = (0.11, 0.63, 0.26)^{\mathrm{T}}$. Obviously, factor u_2 has the greatest weight, i.e., customs brokerage service is the most important factor.

3.4. Comprehensive Evaluation of All Factors

3.4.1. Linguistic Variable and Fuzzy Quantifier

It is already known that the influencing factors are variables ordered by the evaluation of their relative importance. As a matter of fact, the evaluation could be expressed by natural language like equally important, slightly important, more important, and so on. These factors could be called linguistic variables. The linguistic variable is a kind of fuzzy one that has no accurate value, while it could be described by "fuzzy quantifier" which denotes the collection of quantifiers in natural languages "whose representative elements are: several, most, much, not many, very many, not very many, few, quite a few, large number, small number, close to five, approximately ten, frequently, etc." (Zadeh, 1983).

The value of the linguistic variable is not an individual number but a set of all possible values within the range of a closed interval [0, 1]. Suppose there are three linguistic values for each factor, i.e., three possible ranges, then, factor A has values as: "normal A", "very A", "a little A", where "normal", "very" and "a little" is fuzzy quantifiers. Wang (1997) suggested that the quantifiers be used to assign numerical values for factors' linguistic evaluation through calculation, including square and square root. An example is as follows:

If the evaluation of factor A is "normally" (sign "H"), then the "very A" is the square of H, or H^2, and the "a little A" is the square root of H, or $H^{1/2}$. Thus, if the possibility of factor A is within the range of a closed interval [0, 0.9], then, its maximum possibility is 0.9 (90%), and the maximum possibility of "very A" is

$H^2 = 0.9^2 = 0.81$, the maximum possibility of "a little A" is $H^{1/2} = 0.9^{1/2} = 0.95$ respectively. The "H^2" or "$H^{1/2}$" is a kind of fuzzy operator. In the case of urgent transportation, the possible ranges of linguistic values are illustrated in Table 7.

3.4.2. An Example of Comprehensive Performance Evaluation

As described by natural language, the variables are not accurate and have fuzzy characteristics. It is a solution that variables are assigned values by using fuzzy data which is the fuzzy set of linguistic values, e.g., a fuzzy set of evaluation $\boldsymbol{V} = \{v_1, v_2, v_3\}$.

In the case of urgent transportation, suppose the restrictions are as follows:

- u_1 trucking service—very in time.
- u_2 customs brokerage service—a little smoothly.
- u_3 flight transportation—normally on time.

Obviously, where $u_1 = v_2$, $u_2 = v_3$, $u_3 = v_1$, and make u_i correspond to the row vector a_i of a boolean matrix $\boldsymbol{A}$, where $i = 1, 2, 3$, then:

$$\boldsymbol{A} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

Based on fuzzy set $\boldsymbol{V} = \{v_1, v_2, v_3\}$, we could get matrix $\boldsymbol{V} = (0.9, 0.81, 0.95)$, then, by the method of matrix multiplication, obtain $\boldsymbol{R} = \boldsymbol{A} \bullet \boldsymbol{V}^T = (0.81, 0.95, 0.9)^T$.

After that, considering the comprehensive influences of all factors with different weights, the final result could be obtained by use of a weight vector combined with the fuzzy composite operator, based on matrices operation, as follows:

- Fuzzy operator: $M(\bullet, +)$.
- Weight vector: $\boldsymbol{W} = (0.11, 0.63, 0.26)^T$.

Then, the final result of the calculation: $Z = \boldsymbol{W} \bullet \boldsymbol{R} = 0.9216$. Obviously, $0.9 < Z < 0.95$.

Table 7. Value of linguistic variable.

variable	factor	fuzzy set of evaluation $\boldsymbol{V} = \{v_1, v_2, v_3\}$		
		v_1 normally = H	v_2 very = H^2	v_3 a little = $H^{1/2}$
u_1	trucking	in time = H = 0.9	very in time = H^2 = 0.81	a little in time = $H^{1/2}$ = 0.95
u_2	customs brokerage	smoothly = H = 0.9	very smoothly = H^2 = 0.81	a little smoothly = $H^{1/2}$ = 0.95
u_3	flight transportation	on time = H = 0.9	very on time = H^2 = 0.81	a little on time = $H^{1/2}$ = 0.95
	range of possibility	[0, 0.9]	[0, 0.81]	[0, 0.95]

Finally, the evaluation of comprehensive-time performance is only between "normally" and "a little", and there is still a need for performance improvement. Furthermore, a better performance could only be reached through the improvement of variable u_2 or u_3, rather than u_1 which has already achieved the best. The following three examples show different methods of improvement based on the above case, where $u_1 = v_2$, $u_2 = v_3$, $u_3 = v_1$:

- Example 1. Suppose only raise the score of u_2 from v_3 to v_1, *then* $Z = \boldsymbol{W} \bullet \boldsymbol{R} = 0.8901$.
- Example 2. Suppose only raise the score of u_3 from v_1 to v_2, then $Z = \boldsymbol{W} \bullet \boldsymbol{R} = 0.8982$.
- Example 3. Suppose not only raise u_2 from v_3 to v_1, but also raise u_3 from v_1 to v_2 at the same time, then $Z = \boldsymbol{W} \bullet \boldsymbol{R} = 0.8667$.

The above three examples show all results (Z value) located within the range of $0.81 < Z < 0.9$, or the comprehensive performance between "very" and "normally", which means there is an improvement compared with the original range between "normally" and "a little". Among the three examples, the score of example 3 is point 0.8667, which has the minimum difference from point 0.81. Example 3 has the best improvement. However, it is difficult to operate because the two variables (u_2 and u_3) must be improved at the same time. Normally, it is easier to improve only one variable rather than both two in fact, particularly the one that has a heavier weight, e.g., favor u_2 over u_3 to get more effective improvement.

3.5. A Case Study of Urgent Transportation between China and Thailand

The outbreak of COVID-19 pandemic has greatly impacted on the operational mode of global and regional supply chains. As the pandemic has been passing slowly, the world economy is going to recover from recession. Many enterprises are increasingly inclined to adopt low-cost strategies. Some Chinese airlines have chosen Don Mueang International Airport (international airport code: DMK) as the destination airport from China to Thailand for the resumed and newly increased flights, rather than Suvarnabhumi International Airport (international airport code: BKK). These air routes depart from some Chinese medium airports, including Wuhan, Ningbo, Nanjing, etc., besides the original bigger ones like Beijing, Shanghai, and Guangzhou. Even from Shanghai, the Chinese biggest economic city, more and more flights seem going to arrive at DMK rather than BKK. This situation would generate two problems. On the one hand, compared with BKK, DMK is inferior to the former in terms of airport support and service capability as shown in **Table 8** (CAAT, 2023). On the other hand, because DMK's main target market is budget airlines (Hirsh, 2017), its throughput of passengers has kept increasing year by year. Such increasing passenger service demands would compress its inadequate airport capability, and erode its logistics support, e.g., slowing down terminal cargo break-bulk service, delaying

Table 8. Comparison of airport operation capability between DMK and BKK.

characters of airport operation ability	DMK	BKK	Reference
total apron capacity	99	148	(CAAT, 2023)
apron for wide-body aircraft	54	141	
maximum number of passengers per hour	arriving 5400 departing 5100	arriving 8690 departing 6700	

customs clearance, and so on. This weakening operational ability would negatively impact logistics time performance at last, especially for the urgent transportation solution.

Hereinafter take company X, a logistics enterprise, as an example, and evaluate the comprehensive time performance of its urgent transportation solution between China and Thailand. There are three main influencing factors including trucking service, customs brokerage service, and flight transportation service. Hence, assign variables u_1, u_2, and u_3 stand for the three factors respectively. First, suppose u_1 be v_2, next, obtain the value of u_2 through an experts' questionnaire survey, then get the value of u_3 according to the statistical information of flights' punctuality rate, where the value of u_2 is computed by the following rules in Table 9 and Table 10:

- If a flight arrived at DMK, then $u_2 \approx v_3$.
- If a flight arrived at BKK, then $u_2 \approx v_1$.

And the value of u_3 is obtained by the following rules in Table 11.

- If the range of flight's punctuality rate is between 90% and 95%, then $u_3 = v_1$.
- If the range of flight's punctuality rate is between 95% and 100%, then $u_3 = v_2$.
- If the range of flight's punctuality rate is between 80% and 90%, then $u_3 = v_3$.
- If the range of flight's punctuality rate is less than 80%, then ignore this solution.

Finally, we can calculate the value of Z. It is just the evaluation of the comprehensive time performance of this solution. The fuzzy value v_2 means "very", the best performance of one factor. If the value of Z is closer to 0.81 (value of v_2), better comprehensive performance is achieved. Hence, if there are several solutions based on different alternative routes, the one that has the minimum interval between Z value and 0.81 is the best one of all solutions.

- Route 1: $u_1 = v_2$, $u_2 \approx v_1$, $u_3 = v_2$, then

$$\boldsymbol{A}_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

and $\boldsymbol{V}^T = (0.9, 0.81, 0.95)^T$, then $\boldsymbol{R}_1 = \boldsymbol{A}_1 \bullet \boldsymbol{V}^T = (0.81, 0.9, 0.81)^T$. Furthermore, based on the fuzzy operator $M(\bullet, +)$ and combined with weight vector $\boldsymbol{W} = (0.11, 0.63, 0.26)^T$, we can obtain $Z_1 = \boldsymbol{W} \bullet \boldsymbol{R}_1 = 0.8667$.

Table 9. Survey of customs brokerage service at BKK.

u_2: customs brokerage service at BKK			v_1 normally = H = 0.9	v_2 very = H^2 = 0.81	v_3 a little = $H^{1/2}$ = 0.95
number of experts			15	1	4
u_2	mean	Standard deviation	sample size	confidence level	confidence interval
	0.9055	0.030344513	20	0.95	0.9055 ± 0.013
result of calculation: $u_2 \approx v_1$					

Table 10. Survey of customs brokerage service at DMK.

u_2: customs brokerage service at DMK			v_1 normally = H = 0.9	v_2 very = H^2 = 0.81	v_3 a little = $H^{1/2}$ = 0.95
number of experts			4	0	16
u_2	mean	Standard deviation	sample size	confidence level	confidence interval
	0.94	0.020519567	20	0.95	0.9400 ± 0.009
result of calculation: $u_2 \approx v_3$					

Table 11. The punctuality rate of some flights between China and Thailand.

route	origin-destination	sample of flights	30-day punctuality rate[a]	u_3 value	Z value
1	PEK-BKK	HU429	97%	v_2	0.8667
2	PVG-BKK	MU541	87%	v_3	0.9031
3	PVG-DMK	9C7421	87%	v_3	0.9346
4	WUH-DMK	FD571	93%	v_1	0.9216
5	NGB-DMK	9C7431	97%	v_2	0.8982

[a]Source: data collected by the author on July 18th, 2023.

- Route 2: $u_1 = v_2$, $u_2 \approx v_1$, $u_3 = v_3$, then

$$\boldsymbol{A}_2 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

and $\boldsymbol{V}^T = (0.9,0.81,0.95)^T$, then $\boldsymbol{R}_2 = \boldsymbol{A}_2 \bullet \boldsymbol{V}^T = (0.81, 0.9, 0.95)^T$. Moreover, based on fuzzy operator M(•, +) and combined with weight vector $\boldsymbol{W} = (0.11, 0.63, 0.26)^T$, we can obtain $Z_2 = \boldsymbol{W} \bullet \boldsymbol{R}_2 = 0.9031$.

- Route 3: $u_1 = v_2$, $u_2 \approx v_3$, $u_3 = v_3$, then

$$\boldsymbol{A}_3 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix}$$

and $\boldsymbol{V}^{\mathrm{T}} = (0.9, 0.81, 0.95)^{\mathrm{T}}$, then $\boldsymbol{R}_3 = \boldsymbol{A}_3 \bullet \boldsymbol{V}^{\mathrm{T}} = (0.81, 0.95, 0.95)^{\mathrm{T}}$. Furthermore, based on the fuzzy operator M(•, +) and combined with weight vector $\boldsymbol{W} = (0.11, 0.63, 0.26)^{\mathrm{T}}$, we can obtain $Z_3 = \boldsymbol{W} \bullet \boldsymbol{R}_3 = 0.9346$.

- Route 4: $u_1 = v_2$, $u_2 \approx v_3$, $u_3 = v_1$, then

$$\boldsymbol{A}_4 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

and $\boldsymbol{V}^{\mathrm{T}} = (0.9, 0.81, 0.95)^{\mathrm{T}}$, then $\boldsymbol{R}_4 = \boldsymbol{A}_4 \bullet \boldsymbol{V}^{\mathrm{T}} = (0.81, 0.95, 0.9)^{\mathrm{T}}$. Moreover, based on the fuzzy operator M(•, +) and combined with weight vector $\boldsymbol{W} = (0.11, 0.63, 0.26)^{\mathrm{T}}$, we can obtain $Z_4 = \boldsymbol{W} \bullet \boldsymbol{R}_4 = 0.9216$.

- Route 5: $u_1 = v_2$, $u_2 \approx v_3$, $u_3 = v_2$, then

$$\boldsymbol{A}_5 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

and $\boldsymbol{V}^{\mathrm{T}} = (0.9, 0.81, 0.95)^{\mathrm{T}}$, then $\boldsymbol{R}_5 = \boldsymbol{A}_5 \bullet \boldsymbol{V}^{\mathrm{T}} = (0.81, 0.95, 0.81)^{\mathrm{T}}$. Furthermore, based on fuzzy operator M(•, +) and combined with weight vector $\boldsymbol{W} = (0.11, 0.63, 0.26)^{\mathrm{T}}$, we can obtain $Z_5 = \boldsymbol{W} \bullet \boldsymbol{R}_5 = 0.8982$.

The above calculation shows $Z_1 < Z_5 < Z_2 < Z_4 < Z_3$, and Z_1 is the one closest to 0.81(value of v_2). Route 1 has the best evaluation of performance, or it is just the optimal solution. Besides, there are two following points that should be noticed. Comparing routes 2 and 3, supposing $u_1 = v_2$, $u_3 = v_3$, route 2 has better performance, for the flight arrived at BKK, superior to DMK. On the other hand, comparing routes 2 and 4, though the flight punctuality rate of route 4 is higher than route 2, the performance of route 4 is inferior to the other, for variable u_2 has a heavier weight than u_3.

4. Discussion

Concerning the above case study between China and Thailand, the values of u_1 and u_3 can be derived from the historical data of pick-up, delivery, and flight punctuality rates. However, the value of u_2 is based on experts' questionnaire survey which has subjectivism of humans. Such subjectivism would be also influenced by some secondary fuzzy factors including cultural differences, clan consciousness, policy uncertainty, and so on, which possibly lead to more inconsistency and difficulty to be measured accurately and numerically. Further research will focus on the possible algorithm of these factors' compromised or balanced solution in the future, e.g., what values the factors were assigned to, then there would be a better comprehensive performance of some kind of logistics operation.

5. Conclusion

Based on the study of the entire process of urgent transportation and its influencing factors, this paper proposes a performance evaluation method that combines linguistic variables with fuzzy calculations. When accurate and measurable data for these factors cannot be obtained, this method provides a convenient and practical mathematical model for evaluation. It also helps select the optimal solution from some alternatives.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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