Mobility industry call center location selection under sustainability: a two-phase decision-making approach

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Abstract

Purpose – This paper aims to solve the facility location problem of mobility industry call centers comprehensively, considering both investment efficiency and long-term development efficiency.

Design/methodology/approach – In this paper, a two-phase decision-making approach within a multi-criteria decision-making (MCDM) framework has been proposed to help select optimal locations among various alternate locations. Both quantitative and qualitative information is collected and processed based on fuzzy set theory and fuzzy analytic hierarchy process. Then the fuzzy technique for order preference by similarity to an ideal solution method is incorporated in the framework to assess the overall feasibility of all alternates.

Findings – A real case of a mobility giant in China is applied to verify the effectiveness of the proposed framework. Sensitivity analysis also proves the robustness of the framework.

Originality/value – This two-phase MCDM framework allows the mobility industry call center location to be selected considering economic, human resource and sustainability elements comprehensively. The framework proposed in this paper might be applicable to other companies in the mobility industry when deciding optimal locations of call centers.

Keywords Fuzzy TOPSIS, Sustainability, Fuzzy AHP, Call center, Location selection, Mobility industry

Paper type Research paper

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1. Introduction

Over the years, the mobility industry has gained great expansions all over the world and the development is significant especially in China owing to the huge potential market. Till the end of 2018, the user scale in the mobility industry had reached up to 330 million in China with a total market scale of more than US$40bn. Then, it is expected to double in 2025 according to the *China Automotive Smart Shared Mobility Development Report 2019* (China Society of Automotive Engineers, 2019). Stimulated by the rapid development, some domestic players have quickly grown into international mobility giants such as Uber and Didi.

However, apart from the surging demand side, the service supply side is not always capable of providing guaranteed mobility service to passengers. Especially in China, many cases of passengers' property loss or even cases of passengers killed by taxi drivers happened in recent years (Echo Huang, 2019). To take deep thinking of this problem, the outsourced call center service should be responsible for this. In recent years, mobility service providers tend to communicate with the passengers via the outsourced call centers, just like many other service industries: banks and telecom companies. However, the outsourced telephone clerks have very limited authority to deal with some emergency cases when passengers are in danger, time might be wasted in telephone clerks' internal reporting.

Currently, to better protect the safety of passengers and improve service quality, some mobility service providers (e.g. Didi) in China have realized the importance of call centers and have decided to self-run the business (Jesse Pottinger, 2019). While for practice, problems emerge when mobile service providers are considering building their own call centers, as site location selection is much more complex than other industries. On the one hand, mobility service telephone clerks need to be more professional (e.g. they need to have a proficient mastery of car and/or mobility-related knowledge) than clerks serving other industries. So, the supply of plenty of qualified telephone clerks or well-educated undergraduates is critical when considering potential selection cities. On the other hand, as pioneers of sharing economy, mobility companies need to take long-term sustainability (e.g. environmental-friendly factors) into considerations when deciding which city to locate the call centers to show their social responsibilities.

However, as mobility service (especially the ride-sharing service) is a relatively new business type that emerged in recent years, limited research has been done to explore the problem of call center location selection while considering the service quality and long-term sustainability. Hence, the aim of this research is to fill the research gap and propose a generic decision-making framework for the mobility call center location selection problem.

The rest of this article is organized as follows: Section 2 reviewed the related literature on the call center location selection problem. The research methodology, the proposed decision-making framework and the detailed evaluation criteria systems will be presented in Sections 3 and 4. A real case study of a large mobile service provider in China is shown in Section 5. Conclusions are drawn in Section 6.

2. Literature review

From the literature, the call center location selection problem can be seen as a particular case of facility location problem (FLP), the study of which first began in 1909 when Alfred Weber considered how to select a location for a warehouse to minimize the total distance between it and customers (Owen and Daskin, 1998). Much of the literature has proposed many decision-making models to address FLP in different areas. Basically, FLP is a complex and comprehensive issue, as there are many factors, both quantitative and qualitative, to be considered to make an optimal decision (Birgün and Güngör, 2014).

Much of the literature tried to address FLP under certainty situations, inputting deterministic parameters and deriving a certain optimal solution. However, in practical cases, the FLP of call centers is always addressed under uncertain situations. There are three main reasons for it:

(1) Unlike the logistics distribution center, whose total cost plays a decisive role in its optimal location selection, the FLP of the call center should take lots of goals into consideration. Thus, it is difficult to establish deterministic optimization models to select the optimal location;

(2) many qualitative parameters concerned with policy and sustainability are not able to obtain deterministic and certain information or data; and

(3) There are many political and economic uncertainty issues concerned with alternate locations in practice such as unpredictable restrictions or incentive policy on the mobility industry.

To select a suitable location for a call center, considerations such as promoting the sustainable development of the local economy, maximizing the customers' satisfaction, minimizing total investment and operation costs and sustainability of future expansions should be taken. The location selection of a call center should, therefore, be considered as a multiple-criteria decision-making (MCDM) problem under uncertain situations. MCDM indicates that to select the optimal site from all alternate locations, the decision-makers need to take multiple factors into consideration owing to the complexity and uncertainty of practical problems.

MCDM framework has been proved to be effective to solve FLP in different fields. Tsaur *et al.* (2002) established an MCDM model based on the analytic hierarchy process (AHP) for the selection of restaurant locations. Chu (2002) proposed an MCDM model based on the fuzzy technique for order preference by similarity to an ideal solution (TOPSIS) to solve the FLP under a group decisions environment. Tsaur *et al.* (2002) proposed an MCDM model combining AHP and TOPSIS to evaluate the service quality of the airline. Zhang and Lu (2003) proposed an integrated fuzzy group decision-making method so as to deal with the fuzziness of the decision-maker's preferences. Lili Yang (2007) studied how to find the optimal location for fire-station combining a fuzzy multi-objective programming and a genetic algorithm by considering the fuzzy nature of decision-makers in the optimization model. Chou (2008) proposed a new fuzzy MADM (multi-attribute decision-making) method named fuzzy simple additive weighting system to solve FLP. San Cristóbal (2011) used the VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method for solving the selection problem of a renewable energy project in Spain. He (2016) improved the TOPSIS method using weighted criterion distance to select the optimal location of a JDC (Joint Distribution Center). The validation of the model was tested by sensitivity analysis of comparing the improved model with traditional TOPSIS. Baušys and Juodagalvienė (2017) addressed the FLP of the garage at the parcel of a single-family residential house within the MCDM framework. AHP was used to calculate the weight of each criterion chosen.

Through extensive literature review, it can be found that no previous research has been done for call center location selection. In this case, it would be effective to address this problem within the MCDM framework owing to its generic applicability in solving FLP. Further, some special considerations should be taken when establishing the MCDM framework suitable for call center location selection.

- Apart from traditional benefit-related criteria, considerations of sustainability (e.g. environmental and social factors) and special characteristics of the industry should be taken when selecting the evaluation criteria.

- Large quantities of alternates are supposed to be evaluated in which case the ease of conduction and accuracy of results should be considered.
- Both qualitative and quantitative data should be collected and analyzed when selecting the optimal location of the call center owing to its complexity.

The main contributions of this paper are as follows:

- This is one of the first studies that provide detailed and comprehensive criteria systems to, respectively, evaluate development efficiency and sustainability for location selection of call centers in the mobility industry, which might provide a theoretical reference for practitioners.
- A generic two-phase decision-making framework has been proposed to select the optimal location in a more scientific way. This framework may provide a theoretical reference for call center enterprises or government authorities when making multi-criteria decisions under uncertain situations from perspectives of both sustainability and efficiency.

3. Decision-making framework

This paper aims to propose a two-phase decision-making framework for mobility call center location selection problems by incorporating economic and human resource considerations and long-term sustainability considerations. Two phases of decision-making aim to improve the overall efficiency and ensure the results' accuracy. In the first phase, alternate cities with bad performances in overall costs, high-quality human resource supply will be filtered out from the groups. As no further data collection and analysis will be conducted regarding these filtered alternates, the overall decision-making efficiency will be improved. As only the good performers can go to the second phase where sustainable elements will be emphasized and the most competitive alternate city will be chosen. As data concerned with sustainable elements are mainly qualitative, containing uncertainty and subjectivity, reduction in the size of evaluation groups will improve the decision-making accuracy. In this proposed framework, fuzzy AHP and fuzzy TOPSIS are applied to, respectively, determine the weights of criteria and select the optimal location.

3.1 Fuzzy analytic hierarchy process

The AHP was first proposed by (Saaty and Kearns, 1985) in 1985 which has the ability to incorporate both qualitative descriptions of decision-makers and quantitative factors into the decision-making process. The evaluation results can be obtained directly from the decision-maker's opinion represented by linguistics ratings. Then, the scope of AHP was extended by integrating with fuzzy set theory to address the issue of uncertainty. In this paper, the weights of different criteria are determined by fuzzy AHP. Decision-makers may get more accurate and adequate results compared with classical AHP. The steps of fuzzy AHP are shown as follows:

Step 1: Calculate the fuzzy synthetic extent

Let $X = \{x_1, x_2, \ldots x_n\}$ be an objective set and $U = \{u_1, u_2, [\ldots] u_m\}$ be a goal set. Based on the extent analysis method proposed by (Chang, 1996), we take each objective and perform extent analysis for each goal, respectively. Thus, we can get m extent analysis for each objective, respectively, as follows:

$$M_{gi}{}^{1}, M_{gi}{}^{2}, \ldots, M_{gi}{}^{m} \tag{1}$$

where each $M_{gi}{}^{m}$ is a triangular fuzzy number (TFN) set and the fuzzy synthetic extent can be calculated as:

$$S_i = \sum_{j=1}^{m} M_{gi}{}^{j} \odot \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}{}^{j}\right]^{-1} \tag{2}$$

Step 2: Comparison of fuzzy values

The degree of possibility of $M_1 \geq M_2$ is defined as:

$$V(M_1 \geq M_2) = \underbrace{sup}_{x \geq y}\left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y)\right]\right. \tag{3}$$

When there exists a pair (x,y) such that $x \geq y$ and $\mu_{M_1}(x), \mu_{M_2}(y)$, we have $V(M_1 \geq M_2) = 1$. As M_1 and M_2 are convex fuzzy numbers, they are expressed as follows:

$$V(M_1 \geq M_2) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) \tag{4}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}.When $M_1 = (l_1, m_1, n_1)$ and $M_2 = (l_2, m_2, n_2)$ then $\mu_{M_2}(d)$ are calculated as:

$$\mu_{M_2}(d) = \begin{cases} 0, & l_1 > n_2 \\ \dfrac{l_1 - n_2}{(m_2 - n_2) - (m_1 - l_1)}, & otherwise \\ 1, & m_2 > m_1 \end{cases} \tag{5}$$

For the comparison of M_1 and M_2, we need to calculate both values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 3: Priority weight calculation

$$V(M \geq M_1, M_2, \ldots M_k) = V\left[(M \geq M_1)\ and\ (M \geq M_2)\ \ldots and\ (M \geq M_k)\right] \tag{6}$$

$$V(M \geq M_1, M_2, \ldots M_k) = min V(M \geq M_i) \quad i = 1, 2, \ldots, k \tag{7}$$

If

$$m(P_i) = min V(S_i \geq S_K)\, for\ k = 1, 2, \ldots, n\, k \neq i \tag{8}$$

Then the weight vector is given as:

$$W_P = \left(m(P_1), m(P_2), \cdots m(P_n)\right)^T \tag{9}$$

Step 4: Calculation of normalized vector

Based on the normalization of W_P we can get the normalized weight vector as:

$$W = \left(w(P_1), w(P_2), \cdots w(P_n)\right)^T \tag{10}$$

where W is not the fuzzy number and it illustrates the priority weights of one alternate over others.

3.2 Fuzzy technique for order preference by similarity to an ideal solution

TOPSIS is a well-known MCDM method to solve the problem under uncertainty. It was first proposed by Hwang and Yoon (1981). The main logic behind this is that the best solution among all alternates should have the shortest distance between itself with the positive ideal solution and the longest distance with the negative ideal solution (Uygun and Dede, 2016). The biggest advantage of TOPSIS is the ease of conduction which means that decision-makers do not need to undertake cumbersome calculations to get the results of evaluations. At the same time, decision-makers can get stable and accurate results. Another advantage of TOPSIS is that it is easy and applicable to integrate with other methods to solve MCDM problems. However, traditional TOPSIS is also criticized for its limitations of linguistics ratings represented by a single numeric value. So, traditional TOPSIS can be improved by integrating with fuzzy theory to make more accurate evaluations. Instead of applying a single numeric value, fuzzy numbers are used to make linguistics judgments. Many researchers have incorporated traditional TOPSIS with fuzzy set theory to solve problems under uncertainty. In these research studies, different membership functions such as triangular and trapezoidal are used. Studies have shown that it is more appropriate to use TFNs, as it is easy to operate and it yields better evaluation results. Thus, in this research, fuzzy TOPSIS integrating traditional TOPSIS with fuzzy set theory using TFNs was applied.

The steps of fuzzy TOPSIS using TFNs are described as follows (Choudhary and Shankar, 2012; dos Santos *et al.*, 2019):

Supposing that there are a set of m alternates: $A = (A_1, A_2, \ldots, A_m)$, a set of n criteria: $C = (C_1, C_2, \ldots, C_n)$, a set of k decision-makers: $D = (D_1, D_2, \ldots, D_k)$

Step 1: Aggregate linguistics rating of all experts

Let $\tilde{a}_{ijk} = \left(a_{ijk}{}^L, a_{ijk}{}^M, a_{ijk}{}^R\right)$ be the linguistics rating of kth decision-makers regarding ith alternate in terms of jth criterion where $0 \leq a_{ijk}{}^L \leq a_{ijk}{}^M \leq a_{ijk}{}^R \leq 1$. So, the aggregating linguistics rating for the ith alternate with respect to the jth criterion can be calculated as:

$$\tilde{a}_{ij} = \frac{\tilde{a}_{ij1} \otimes \tilde{a}_{ij2} \otimes \ldots \otimes \tilde{a}_{ijk}}{k} \tag{11}$$

Step 2: Normalize the fuzzy decision matrix

The initial fuzzy matrix can be built up by equation (12). Based on the initial fuzzy matrix, we can normalize it by the following method. As we mentioned before, there are two kinds of criteria: cost-type and benefit-type criteria.

For cost-type criteria, we can normalize it by:

$$\tilde{b}_{ij} = \frac{max\{\tilde{a}_{ij},\ i = 1, 2, \ldots, m\} - \tilde{a}_{ij}}{max\{\tilde{a}_{ii}, i = 1, 2, \ldots, m\} - min\{\tilde{a}_{ii}, i = 1, 2, \ldots, m\}} \tag{12}$$

For benefit-type criteria, we can normalize it by:

$$\tilde{b}_{ij} = \frac{\tilde{a}_{ij} - max\{\tilde{a}_{ij}, i = 1, 2, \ldots, m\}}{max\{\tilde{a}_{ii}, i = 1, 2, \ldots, m\} - min\{\tilde{a}_{ii}, i = 1, 2, \ldots, m\}} \tag{13}$$

As a result, we can obtain the normalized fuzzy decision matrix:

$$B = \left(\tilde{b}_{ij}\right)_{m*n} = \begin{pmatrix} \tilde{b}_{11} & \cdots & \tilde{b}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1} & \cdots & \tilde{b}_{mn} \end{pmatrix} \tag{14}$$

Step 3: Calculate the weight of each criterion

The weight of each criterion can be calculated using equations (1)–(11).

Step 4: Calculate the weight-normalized fuzzy decision matrix

The weight-normalized fuzzy matrix can be calculated by:

$$C = \left(\tilde{c}_{ij}\right)_{m*n} = \begin{pmatrix} \tilde{b}_{11}*\tilde{w}_1 & \cdots & \tilde{b}_{1n}*\tilde{w}_n \\ \vdots & \ddots & \vdots \\ \tilde{b}_{m1}*\tilde{w}_1 & \cdots & \tilde{b}_{mn}*\tilde{w}_n \end{pmatrix} \tag{15}$$

Step 5: Define the positive and negative ideal solutions

We can obtain the positive and negative ideal solutions by taking the best and worst value of each alternates in terms of each criterion. Supposing that T_1 and T_2 represent the set of cost-type criteria and benefit-type criteria, respectively. Then, the positive and negative ideal solutions are calculated as:

$$\tilde{C}^{+} = \left(c_t{}^{+L}, c_t{}^{+M}, c_t{}^{+R}\right) = \left\{\max c_{ij} | j \in T_1, \min c_{ij} | j \in T_2\right\} \tag{16}$$

$$\tilde{C}^{-} = \left(c_t{}^{-L}, c_t{}^{-M}, c_t{}^{-R}\right) = \left\{\min c_{ij} | j \in T_1, \min c_{ij} | j \in T_2\right\} \tag{17}$$

Step 6: Calculate the distance of each alternate to the positive and negative ideal solutions

The distance of each alternate to positive and negative ideal solutions are calculated as:

$$d_i^{+} = \sqrt{\frac{\left[\left(c_{ij}{}^{L} - c_j{}^{+L}\right)^2 + \left(c_{ij}{}^{M} - c_j{}^{+M}\right)^2 + \left(c_{ij}{}^{R} - c_j{}^{+R}\right)^2\right]}{3}} \tag{18}$$

$$d_i^{-} = \sqrt{\frac{\left[\left(c_{ij}{}^{L} - c_j{}^{-L}\right)^2 + \left(c_{ij}{}^{M} - c_j{}^{-M}\right)^2 + \left(c_{ij}{}^{R} - c_j{}^{-R}\right)^2\right]}{3}} \tag{19}$$

Step 7: Calculate the relative closeness of each alternate

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{20}$$

Step 8: Rank all alternates based on relative closeness

Based on the relative closeness of each alternate regarding positive and negative ideal solutions, we can rank all alternates in descending of R_i.

3.3 Decision-making phases

3.3.1 Phase I – initial filtering by investment efficiency elements. In this phase, all potentially feasible locations will be identified by taking into consideration parameters highly related to the development efficiency of a call center. The procedures can be summarized as the following steps:

Step 1: Determine the base pool consisting of all intended cities. In this process, consideration in terms of feasibility and efficiency is not required. Certainly, this city pool contains both feasible and infeasible alternates.

Step 2: Establish the development efficiency criteria system to evaluate all alternate locations. Then, collect the quantitative data of all alternate locations regarding each criterion.

Step 3: Determine the weights of all criteria using fuzzy AHP. Linguistics ratings are represented by TFNs.

Step 5: Carry out the normalization process based on the type of each criterion. For cost-type criteria, the lower value of the criteria it has, the better it will be. For benefit-type criteria, the higher value of the criteria it has, the better it will be.

Step 6: Rank the weight-normalized values to select all potential locations. The specific requirements are determined by the call centers, as different enterprises set different requirements on feasibility.

3.3.2 Phase II – optimal filtering considering long-term sustainable elements. In this phase, the optimal location will be identified by taking into consideration parameters highly related to the long-term development sustainability of a call center. The procedures can be summarized as the following steps:

Step 1: Establish the sustainability criteria system to evaluate the long-term sustainability of potentially feasible locations. Then, collect qualitative information regarding each criterion for further evaluation.

Step 2: As the same as phase I, determine the weights of all criteria using fuzzy AHP. Linguistics ratings are represented by TFNs.

Step 3: Based on the information collected, evaluate all feasible locations regarding each criterion by linguistics ratings.

Step 4: Carry out the normalization process, calculate the weight-normalized value. Calculate the relative closeness of feasible locations using fuzzy TOPSIS.

Step 5: Rank the relative closeness values to select the optimal location.

In conclusion, the proposed two-phase decision-making framework can be summarized as follows: By inputting both quantitative data and qualitative data, we can obtain the optimal decision of location selection for a call center. Then, we establish two criteria index systems to, respectively, evaluate the development efficiency and sustainability of alternate locations. The research roadmap is illustrated by the following graph Figure 1.

4. Evaluation criteria

In this part, the criteria index systems are established to, respectively, evaluate the development efficiency and sustainability of alternate cities. The selection of evaluation criteria is based on the literature review and the practical needs of call centers. Thus, both

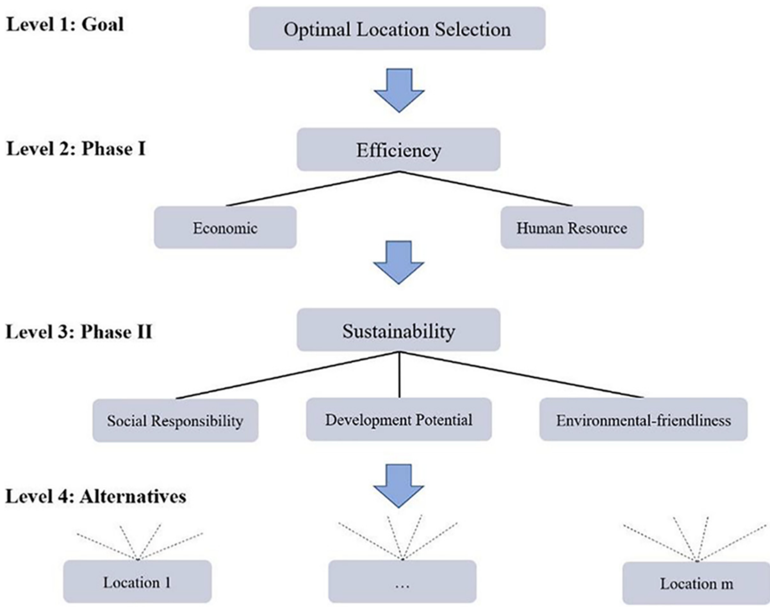

Figure 1. Research roadmap

generic consideration of FLP and special consideration regarding the mobility industry should be taken.

The hierarchy of evaluation criteria is shown in Figure 2.

4.1 Development efficiency criteria

In the first phase of evaluation, some elements of development efficiency are considered to evaluate the alternate locations. The efficiency criteria consist of 2 sub-criteria: criteria of economic and criteria of human resource. The details can be found in Table 1.

4.1.1 Economic criteria.

4.1.1.1 E1: Labor cost. A call center generally has hundreds of staff operating every day in which case the labor cost has a great impact on site selection (Birgün and Güngör, 2014). A higher labor cost will increase the total operation cost of a call center. The labor cost consists of salary expenditure, staff welfare, insurances fee and any other cost related to an employee. In this paper, the average salary of call center clerks in CNY per person per month in each alternate city is chosen to represent E_1.

4.1.1.2 E2: Land cost. Generally, a call center requires a huge working place to settle in hundreds of employees and fixed equipment. An increase in land cost will significantly influence the overall capital investment. So, the land cost has a critical impact on site selection (Rao *et al.*, 2015). In this paper, the average rent of office buildings in each alternate city in CNY per square meter is used for representing E_2.

4.1.1.3 E3: Tax policy. Tax is a very important parameter when evaluating the economic conditions of alternate cities. A city with better tax policies will certainly be more attractive owing to the lower total cost (He, 2017). Some cities will provide special tax policies to attract more investment from enterprises. Call centers are more prone to locate in these cities. In this paper, a binary variable is used to quantify this criterion. Alternate cities with appealing tax policies will be marked with 1, otherwise with 0 in this research.

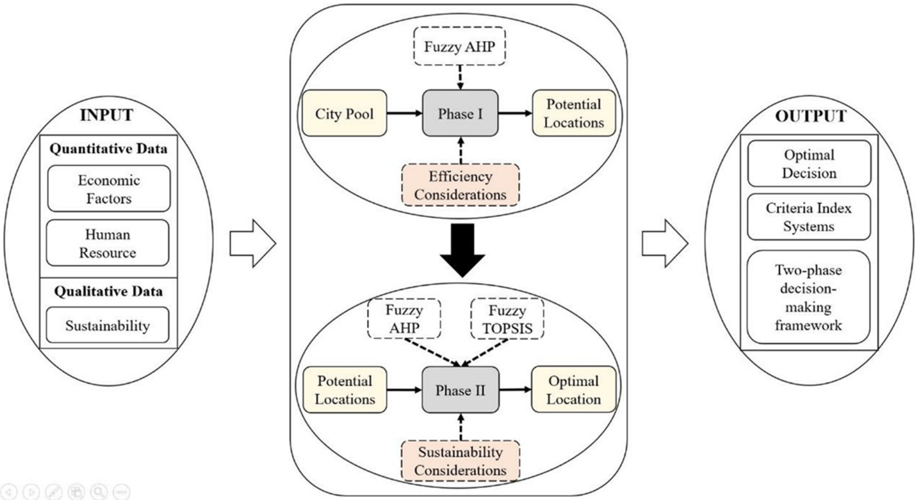

Figure 2.
Hierarchy structure of evaluation criteria systems

Table 1.
Efficiency evaluation criteria

Criteria	Sub-criteria	Type	Source
Economic	Labor cost	Cost	Birgün and Güngör (2014)
	Land cost	Cost	Rao *et al.* (2015)
	Tax policy	Benefit	He (2017)
	Investment incentive	Benefit	Özkan (2012)
	Urban agglomeration	Benefit	Model assumption
Human resource	Scale of employment in the service industry	Benefit	Model assumption
	Number of high education institutions	Benefit	Özkan (2012)
	Scale of high-educated graduates	Benefit	Özkan (2012)
	Scale of existing call centers	Cost	Model assumption

4.1.1.4 E4: Investment incentive. Different cities provide different investment incentive policies to attract investment from new enterprises such as a one-year-free rent policy (Özkan, 2012). Call centers are prone to select these cities to relieve the initial capital burden. As the same as “tax policy,” a binary variable is used to quantify this criterion.

4.1.1.5 E5: Urban agglomeration. A city in core urban agglomeration gains stronger competitiveness over other cities owing to better human resource conditions and potential development. Cities in core urban agglomerations will have more opportunities and better supporting policies both from the central government and provincial government levels (Chuanglin, 2015). As the same as “tax policy,” a binary variable is used to quantify this criterion. All alternate cities will be classified into “national” or “regional” depending on the urban agglomeration they are in.

4.1.2 Human resource criteria.

4.1.2.1 HR_1: Total employment in the service industry. Total employment in the service industry is a crucial criterion to evaluate the capability of human resource supply for call centers of alternate cities. In this paper, the total number of employees in the service industry of each alternate city is used to represent the index of HR_1, that a larger value of HR_1, the stronger capability of a city could provide the qualified human resource.

4.1.2.2 HR_2: Number of high education institutions The number of high education institutions illustrates the research and technology level of alternate cities. Locating in a city full of high education institutions will help call centers in operation when outsourcing projects (Özkan, 2012). In this paper, the total number of higher education institutions of each alternate city is used to represent the index. The larger value of HR_2, the stronger capability of technical cooperation a city could provide.

4.1.2.3 HR_3: Scale of high-educated graduates. Nowadays, especially in the mobility industry, advanced talents such as software engineers and IT engineers are urgently needed owing to the rapid development. The scale of high-educated graduates evaluates the education level of the present human resource market (Özkan, 2012). Cities with a larger scale of high-educated graduates are more appealing to call centers. In this paper, the total number of high-educated graduates of each alternate city is used to represent HR_3. With a larger value of HR_3, the stronger capability of a city could provide high-quality engineers.

4.1.2.4 HR_4: Scale of existing call centers. However, existing call centers in some cities will increase the recruitment cost and overall human resource cost even though they contribute to the large employment. Because business competition among call centers will generally help to increase the overall salary level of clerks. So, the scale of existing call centers will play a negative impact on the overall feasibility of alternate cities. In this paper, the total number of employees of call centers in each alternate city is used to quantify this criterion. The larger value of HR_4, the higher the competition pressure of a city would have.

4.2 Development sustainability criteria

For the second phase of evaluation and filtering, some sustainable elements will be considered and emphasized. The sustainability criteria consist of three sub-criteria: criteria of development potential, social responsibilities and environmental friendliness. The details can be found in Table 2.

4.2.1 Development potential.

4.2.1.1 D_1: Possibility of expansion. Possibility of expansion is a parameter to evaluate the development sustainability of alternate cities. It refers to the potential of alternate cities for a call center to enlarge its scale in the long run. With the rapid development of the mobility industry, a city with a higher possibility of expansion will certainly benefit a lot (Bouhana *et al.*, 2013; Awasthi *et al.*, 2011; Kuo, 2011).

4.2.1.2 D_2: Public facilities condition. A well-operated call center requires good and stable public facilities conditions to function properly such as stable network service, electricity supply and water supply (Elevli, 2014). The equipment in a call center is extremely expensive and vulnerable. An insufficient or unstable power supply will do great damage to the equipment.

4.2.1.3 D_3: Potential of urban agglomeration. Cities in different urban agglomeration have different development potential in terms of market of advanced talents, the opportunity of economic cooperation, level of technology innovation, etc. It is significant, therefore, to evaluate the potential of different urban agglomerations.

4.2.1.4 D_4: Government support. Mobility service providers, as a pioneer of sharing economy, appeal to lots of second-tier and third-tier cities. Local governments may provide special policies over tax and land use to attract these call centers (He, 2017; Özkan, 2012).

4.2.1.5 D_5: Technology level. The technology level should be considered, as the mobility industry is gaining rapid development nowadays. More and more advanced technologies

Criteria	Sub-criteria	Type	Source
Development potential	Possibility of expansion	Maximize	Awasthi *et al.* (2011) Bouhana *et al.* (2013) Kuo (2011)
	Public facilities condition	Maximize	Elevli (2014)
	Urban agglomeration	Maximize	Model assumption
	Government support	Maximize	He *et al.* (2017) Özkan (2012)
	Technology level	Maximize	Model assumption
Social responsibility	Impact of noise on nearby residents	Minimize	Rao *et al.* (2015) He *et al.* (2017)
	Role in promoting employment rate	Maximize	He *et al.* (2017)
	Role in promoting technological innovation	Maximize	Model assumption
	Role in promoting local economic planning	Maximize	He *et al.* (2017)
Environmental-friendliness	Impact on ecological landscape	Minimize	Bouhana *et al.* (2013) Guo and Zhao (2015) Vafa-Arani (2014)
	Natural conditions	Maximize	Chou *et al.* (2008)
	Compliance with environmental laws and regulations	Maximize	Dweiri *et al.* (2018)

Table 2. Sustainability evaluation criteria

have been applied in call centers to improve their overall performance in terms of customer satisfaction, cost management and personnel evaluation.

4.2.2 Social responsibilities.

4.2.2.1 S_1: Impact of noise on nearby residents. Social responsibility should also be considered when selecting the location of a call center. Thus, the location selection of a call center should consider the negative externalities it may cause (Rao *et al.*, 2015; He, 2017) Noise is a possible negative impact caused by a call center.

4.2.2.2 S_2: Role in promoting employment rate. Role in promoting employment rate illustrates how much can society benefit from call center enterprise (He, 2017). The higher role they play, the better the brand image they will have in society and the huger potential of opportunity to carry economic cooperation with the local government.

4.2.2.3 S_3: Role in promoting technological innovation. As the same as the role in promoting employment rate, role in promoting technological innovation is another external benefit can society gains from call centers. By cooperating with institutions and local government, technology innovation can be improved.

4.2.2.4 S_4: Role in promoting local economic planning. The Chinese government will make its development plans every five years and so do local governments. Some local governments aim to promote their information technology level in their five-year development plans (He, 2017). Locating in these cities is a win-win strategy for call centers.

4.2.3 Environmental-friendliness.

4.2.3.1 E_1: Impact on ecological landscape. A call center is supposed to harmonize with the surrounding landscape of alternates cities (Bouhana *et al.*, 2013; Guo and Zhao, 2015; Vafa-Arani *et al.*, 2014). Social responsibility as maintaining or improving the landscape without damaging its original image is important.

4.2.3.2 E_2: Natural conditions. When selecting the optimal location of a call center, comprehensive evaluation over the local natural environmental conditions such as temperature, wind and rainfall should be conducted, as it helps to reduce the risk of the construction and operation (Chou *et al.*, 2008).

4.2.3.3 E_3: Compliance with environmental laws and regulations. The location selection of a call center must comply with environmental laws and regulations released by the local government. Then, further, call centers should comprehensively consider the alternate cities' land-use planning, natural resource condition, etc. Compliance with the spatial structure of alternate cities is also relevant Dweiri *et al.* (2018).

5. Case study

The proposed two-phase decision-making framework was applied to a real case of call center location selection in China. This mobility service provider company has been operating a call center in Shanghai for two years and it decided to build up a new one in China, owing to the rapid development of its mobility business. Considering the high cost and development limitation of the existing call center, the company intended to find a better location with lower cost and better development sustainability. A group of four decision-makers, one from the marketing department, two from top-level managers, one from consulting organization came together to evaluate all possible locations to select the optimal one.

5.1 Phase I – potentially feasible locations

In this phase, all intended cities were first selected. Basically, first-tier cities are not considered owing to extremely high cost, just like the existing call center in Shanghai. At meanwhile, cities below the third-tier are not considered as well, as these less-developed cities tend to have the worse potential of future development and human resource condition (Jack, 2006). Through group discussion, the city pool was constructed, consisting of all possible cities shown in Appendix Table A1:

After building up the city pool, the data of all aspects was collected through different channels such as official documents from the Statistics Department of Government, a commercial report released by consulting organization and a database of third-party platforms. The details of all information were shown in Appendix Table A2. Further, data was normalized using a different method based on the type of each criterion, cost-type or benefit-type. The normalized data was shown in Appendix Table A3.

Then, the weight of each criterion was determined by the fuzzy AHP method. First, the different priority weights of all criteria and their sub-criteria were determined using the linguistics ratings and triangular scale defined by (Bozbura *et al.*, 2007) in Table 3.
By using the extent analysis approach proposed by (Chang, 1996), the priority weights based on the linguistics ratings from experts were calculated. The results were shown in Tables 4–6.

The process fuzzy AHP using the example of calculation with respect to four main criteria is illustrated below. First, the values of fuzzy synthetic extent were calculated as:

Linguistics ratings	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Absolutely more important	(2.5, 3, 3.5)	(0.2, 0.3, 0.4)
Very strongly more important	(2, 2.5, 3)	(0.3, 0.4, 0.5)
Strongly more important	(1.5, 2, 2.5)	(0.4, 0.5, 0.6)
Weakly important	(1, 1.5, 2)	(0.5, 0.6, 1)
Equally important	(0.5, 1, 1.5)	(0.6, 1, 2)
Just equal	(1, 1, 1)	(1, 1, 1)

Table 3. TFNs of comparison measures

$$S_1 = (2.3,\ 2.6,\ 3.2) \otimes (14.3,\ 17.3,\ 21.2)^{-1} = (0.1085,\ 0.1503,\ 0.2238)$$

$$S_2 = (4.5,\ 5.5,\ 6.5) \otimes (14.3,\ 17.3,\ 21.2)^{-1} = (0.2123,\ 0.3179,\ 0.4545)$$

$$S_3 = (4.5,\ 5.5,\ 6.5) \otimes (14.3,\ 17.3,\ 21.2)^{-1} = (0.2123,\ 0.3179,\ 0.4545)$$

$$S_4 = (3, 3.7, 5) \otimes (14.3, 17.3, 21.2)^{-1} = (0.1415,\ 0.2139,\ 0.3497)$$

Then, the V values were calculated using equations (3)–(5), the results are shown in Table 7. Based on the V values, the degree of possibility could be obtained by equations (6)–(8).

$$m(P_1) = min V(S_1 \geq S_K) = \min(1, 1, 1) = 0.064$$

Similarly

$$m(P_2) = m(P_3) = 1,\ m(P_4) = 0.569$$

Then the weight vector was calculated as:

$$W_P = (0.064, 1, 1, 0.569)^T$$

Table 4. The fuzzy comparison matrix within short-term evaluation criteria

Criteria	Economic	Human resource	Weight
Economic	(1, 1, 1)	(1, 1, 1)	0.5
Human resource	(1, 1, 1)	(1, 1, 1)	0.5

Table 5. The fuzzy comparison matrix within economic criteria

Criteria	E_1	E_2	E_3	E_4	E_5	Weight
E_1	(1, 1, 1)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1, 1, 1)	0.37
E_2	(0.5, 0.6, 1)	(1, 1, 1)	(1, 1.5, 2)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.23
E_3	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1, 1)	(1, 1, 1)	(0.4, 0.5, 0.6)	0.02
E_4	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1, 1)	(1, 1, 1)	(0.4, 0.5, 0.6)	0.02
E_5	(1, 1, 1)	(1, 1.5, 2)	(1.5, 2, 2.5)	(1.5, 2, 2.5)	(1, 1, 1)	0.37

Table 6. The fuzzy comparison matrix within human resource criteria

Criteria	HR_1	HR_2	HR_3	HR_4	Weight
HR_1	(1, 1, 1)	(0.4, 0.5, 0.6)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	0.02
HR_2	(1.5, 2, 2.5)	(1, 1, 1)	(1, 1, 1)	(1, 1.5, 2)	0.38
HR_3	(1.5, 2, 2.5)	(1, 1, 1)	(1, 1, 1)	(1, 1.5, 2)	0.38
HR_4	(1, 1.5, 2)	(0.5, 0.6, 1)	(0.5, 0.6, 1)	(1, 1, 1)	0.22

After the normalization process, we can get the normalized weight vector as:

$$W_P = (0.02, 0.38, 0.38, 0.22)^T$$

The rest calculation processes were not given here, as the procedure of calculation are all the same as the above. After finishing all calculations, the global and local weights of all criteria are shown in Table 8.

After finishing the weight of each criterion, the weight-normalized values were calculated combining the weight and normalized data of all intended cities, the results were shown in Table 9.

In the end, four potentially feasible cities, with the weigh-normalized values higher than 0.6, were chosen: Xi'an, Chongqing, Wuhan, Tianjin (thereafter represented as A_1, A_2, A_3 and A_4). The selection of potentially feasible cities was based on the following principles:

- Meet the practical needs of call center enterprises (e.g. intuitive judgment).
- No more than 6 to ensure the result accuracy in phase II based on linguistics ratings.
- The performance of selected alternates should be significantly better than others.

So, in the next phase, the sustainability of these four cities would be evaluated through group decisions.

5.2 Phase II – optimal location

Similarly, the weight of each criterion in the long-term criteria system would be calculated. The linguistic rating and weight were shown in Tables 10–14.

Then, fuzzy TOPSIS was applied to rank all the alternate cities. We used the linguistics ratings defined by Awasthi *et al.* (2011) to evaluate all alternate cities, shown in Tables 15 and 16. The weight-normalized matrix was shown in Table 17, based on which we can calculate the distance from alternate cities to positive and negative ideal solution and then calculate the relative closeness, the results were shown in Table 18.

V	HR_1	HR_2	HR_3	HR_4
HR_1		1	1	1
HR_2	0.06426		1	0.56905
HR_3	0.06426	1		0.56905
HR_4	0.56405	1	1	

Table 7. The V values of criteria

Criteria	Global weight	Sub-criteria	Local weight
Economic	0.50	Labor cost	0.37
		Land cost	0.23
		Tax policy	0.02
		Investment incentive	0.02
		Urban agglomeration	0.37
Human resource	0.50	Scale of employment in the service industry	0.02
		Number of high education institutions	0.38
		Scale of high-educated graduates	0.38
		Scale of existing call centers	0.22

Table 8. Global and local weights of short-term criteria

Table 9.
Weight-normalized value of all intended cities

Cities	Xi'an	Chongqing	Tianjin	Wuhan	Hangzhou	Harbin	Changsha	Hefei
Weigh-normalized value	0.662	0.661	0.648	0.635	0.597	0.593	0.590	0.588
Cities	Wuhu	Yangzhou	Chengdu	Luoyang	Nanchang	Shangrao	Taizhou	Shijiazhuang
Weigh-normalized value	0.584	0.583	0.582	0.576	0.574	0.561	0.557	0.554
Cities	Jinan	Wuxi	Xiamen	Ningbo	Dongguan	Weifang	Mianyang	Shenyang
Weigh-normalized value	0.522	0.501	0.484	0.472	0.466	0.439	0.427	0.418
Cities	Fuzhou	Anshan	Guiyang	Lanzhou	Foshan			
Weigh-normalized value	0.404	0.394	0.382	0.359	0.298			

By comparing the relative closeness values of all four alternate cities, we can draw a conclusion that A_3 (Wuhan) > A_2 (Chongqing) > A_4 (Tianjin) > A_1(Xi'an). Thus, Wuhan was recommended as the optimal location for the call center.

5.3 Sensitivity analysis

To investigate the robustness of the proposed model, sensitivity analysis was conducted to evaluate the performance of the decision-making process. Based on the decision-making logic of fuzzy TOPSIS, the optimal location should be the city with the highest relative closeness value.

The value of global weights of each criterion, which illustrates the overall importance of this main criteria and the value of the local weight, which illustrates the local importance within the main criterion, will be mutually exchanged within 2 criteria while the values of other criteria remain unchanged in the sensitivity analysis (Rosenhead, 1972). For example, the local weight of C_1 was exchanged with local weights of C_2, C_3, C_4 and C_5 sequentially. The relative closeness of different situations is calculated and observed the stability of decision-making rank. The results are shown in Table 19 and Figure 3.

Table 10. The fuzzy comparison matrix within long-term evaluation criteria

Criteria	C_1	C_2	C_3	Weight
C_1	(1, 1, 1)	(1, 1.5, 2)	(1.5, 2, 2.5)	0.57
C_2	(0.5, 0.6, 1)	(1, 1, 1)	(1, 1.5, 2)	0.35
C_3	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	(1, 1, 1)	0.08

Table 11. The fuzzy comparison matrix within development potential criteria

Criteria	D_1(0.4, 0.5, 0.6)	D_2	D_3	D_4	D_5	Weight
D_1	(1, 1, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1, 1, 1)	(1, 1.5, 2)	0.31
D_2	(0.4, 0.5, 0.6)	(1, 1, 1)	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(0.5, 0.6, 1)	0.05
D_3		(1, 1.5, 2)	(1, 1, 1)	(0.4, 0.5, 0.6)	(1, 1, 1)	0.17
D_4	(1, 1, 1)	(1.5, 2, 2.5)	(1, 1.5, 2)	(1, 1, 1)	(1, 1.5, 2)	0.31
D_5	(0.5, 0.6, 1)	(1, 1.5, 2)	(1, 1, 1)	(0.5, 0.6, 1)	(1, 1, 1)	0.17

Table 12. The fuzzy comparison matrix within social responsibility criteria

Criteria	S_1	S_2	S_3	S_4	Weight
S_1	(1, 1, 1)	(0.5, 0.6, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.22
S_2	(1, 1.5, 2)	(1, 1, 1)	(1.5, 2, 2.5)	(1, 1, 1)	0.38
S_3	(0.5, 0.6, 1)	(0.4, 0.5, 0.6)	(1, 1, 1)	(0.4, 0.5, 0.6)	0.02
S_4	(1, 1.5, 2)	(1, 1, 1)	(1.5, 2, 2.5)	(1, 1, 1)	0.38

Table 13. The fuzzy comparison matrix within environmental-friendliness criteria

Criteria	E_1	E_2	E_3	Weight
E_1	(1, 1, 1)	(1, 1.5, 2)	(0.5, 0.6, 1)	0.35
E_2	(0.5, 0.6, 1)	(1, 1, 1)	(0.4, 0.5, 0.6)	0.08
E_3	(1, 1.5, 2)	(1.5, 2, 2.5)	(1, 1, 1)	0.57

Table 14.
Global and local weights of all long-term criteria

Criteria	Global weight	Sub-criteria	Local weight
Development potential	0.57	Possibility of expansion	0.31
		Public facilities condition	0.05
		Urban agglomeration	0.17
		Government support	0.31
		Technology level	0.17
Social responsibility	0.35	Impact of noise on nearby residents	0.22
		Role in promoting employment rate	0.38
		Role in promoting technological innovation	0.02
		Role in promoting local economic planning	0.38
Environmental friendliness	0.08	Impact on ecological landscape	0.35
		Natural conditions	0.08
		Compliance with environmental laws and regulations	0.57

Table 15.
Transformation rules for linguistics ratings

Linguistics ratings	TFNs
Very low (VL)	(1, 1, 3)
Low (L)	(1, 3, 5)
Medium (M)	(3, 5, 7)
High (H)	(5, 7, 9)
Very high (VH)	(7, 9, 9)

Table 16.
Linguistics ratings of experts with respect to four feasible cities

Alternatives\Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
EP_1												
Xi'an	M	VH	VL	M	VH	VH	M	M	L	VH	H	M
Chongqing	M	M	VL	M	M	M	L	H	H	M	VL	H
Wuhan	VH	L	VH	H	H	L	M	M	M	VL	M	VH
Tianjin	M	VH	H	M	VH	H	M	VL	VL	H	H	L
EP_2												
Xi'an	H	H	M	M	H	M	H	L	VL	VH	VH	M
Chongqing	M	M	VL	H	L	VL	M	H	VH	M	VL	H
Wuhan	L	VL	H	VH	M	L	H	M	H	VL	VL	VH
Tianjin	H	VH	H	M	VH	H	M	L	L	VH	H	H
EP_3												
Xi'an	H	VH	M	H	VH	M	H	M	M	H	H	M
Chongqing	VH	M	VL	H	L	VL	M	VH	VH	L	M	H
Wuhan	H	L	VH	H	M	VL	H	M	VH	M	VL	VH
Tianjin	VH	VH	VH	H	H	H	H	VL	L	H	H	M
EP_4												
Xi'an	M	H	VL	M	VH	M	VH	L	VL	H	M	M
Chongqing	VH	M	L	VH	H	VL	H	H	VH	M	VL	H
Wuhan	M	M	H	H	M	VL	M	L	H	VL	M	VH
Tianjin	H	VH	VH	H	VH	H	M	VL	VL	VH	H	H

Criteria	Alternates Xi'an (A_1)	Chongqing (A_2)	Wuhan (A_3)	Tianjin (A_4)
C_1	(0.,0.,0.088)	(0.088,0.118,0.118)	(0,0,0)	(0.118,0.118,0.177)
C_2	(0.023,0.024,0.029)	(0.008,0.010,0.014)	(0,0,0)	(0.029,0.029,0.029)
C_3	(0.029,0.037,0.044)	(0,0,0)	(0.097,0.097,0.097)	(0.097,0.097,0.097)
C_4	(0,0,0)	(0.118,0.133,0.133)	(0.177,0.177,0.177)	(0.044,0.044,0.059)
C_5	(0.097,0.097,0.097)	(0,0,0)	(0.024,0.024,0.039)	(0.097,0.097,0.097)
C_6	(0.015,0.019,0.023)	(0.067,0.077,0.077)	(0.077,0.077,0.077)	(0,0,0)
C_7	(0.133,0.133,0.133)	(0,0,0)	(0.067,0.067,0.089)	(0.033,0.033,0.044)
C_8	(0.002,0.003,0.003)	(0.007,0.007,0.007)	(0.002,0.004,0.004)	(0,0,0)
C_9	(0,0,0)	(0.133,0.133,0.133)	(0.093,0.100,0.108)	(0,0.011,0.015)
C_{10}	(0,0,0)	(0.014,0.016,0.022)	(0.028,0.028,0.028)	(0,0,0)
C_{11}	(0,0,0.001)	(0.006,0.006,0.006)	(0.005,0.005,0.005)	(0,0,0)
C_{12}	(0,0,0)	(0.023,0.023,0.046)	(0.046,0.046,0.046)	(0.006,0.006,0.011)

Table 17. Weight-normalized matrix

Value	Alternates Xi'an (A_1)	Chongqing (A_2)	Wuhan (A_3)	Tianjin (A_4)
d_i^-	0.0321	0.0529	0.0667	0.0433
d_i^+	0.0742	0.0412	0.0297	0.0517
R_i	0.3021	0.5622	0.6921	0.4558

Table 18. Relative closeness values of four alternate cities

Experiment run	Weight exchange	Relative closeness				Rank
1	C_1–C_2	0.2547	0.4850	0.6921	0.3360	$A_3 > A_2 > A_4 > A_1$
2	C_1–C_3	0.3059	0.5322	0.6492	0.4150	$A_3 > A_2 > A_4 > A_1$
3	C_1–C_4	0.3021	0.5622	0.6921	0.4558	$A_3 > A_2 > A_4 > A_1$
4	C_1–C_5	0.2817	0.5322	0.7110	0.4150	$A_3 > A_2 > A_4 > A_1$
5	C_2–C_3	0.2832	0.5633	0.6600	0.4149	$A_3 > A_2 > A_4 > A_1$
6	C_2–C_4	0.2615	0.4509	0.5637	0.3353	$A_3 > A_2 > A_4 > A_1$
7	C_2–C_5	0.2809	0.5633	0.6701	0.4149	$A_3 > A_2 > A_4 > A_1$
8	C_3–C_4	0.3098	0.5134	0.6113	0.4029	$A_3 > A_2 > A_4 > A_1$
9	C_3–C_5	0.3021	0.5622	0.6921	0.4558	$A_3 > A_2 > A_4 > A_1$
10	C_4–C_5	0.2850	0.5134	0.6658	0.4029	$A_3 > A_2 > A_4 > A_1$
11	C_6–C_7	0.2972	0.5472	0.6408	0.4409	$A_3 > A_2 > A_4 > A_1$
12	C_6–C_8	0.2943	0.5091	0.6532	0.4558	$A_3 > A_2 > A_4 > A_1$
13	C_6–C_9	0.3061	0.5300	0.6420	0.4516	$A_3 > A_2 > A_4 > A_1$
14	C_7–C_8	0.2588	0.4810	0.5929	0.4207	$A_3 > A_2 > A_4 > A_1$
15	C_7–C_9	0.3021	0.5622	0.6921	0.4558	$A_3 > A_2 > A_4 > A_1$
16	C_8–C_9	0.2968	0.4203	0.5814	0.4462	$A_3 > A_4 > A_2 > A_1$
17	C_{10}–C_{11}	0.3021	0.5567	0.6868	0.4558	$A_3 > A_2 > A_4 > A_1$
18	C_{10}–C_{12}	0.3021	0.5602	0.6876	0.4547	$A_3 > A_2 > A_4 > A_1$
19	C_{11}–C_{12}	0.3021	0.5453	0.6746	0.4533	$A_3 > A_2 > A_4 > A_1$

Table 19. Sensitivity analysis results

It can be clearly seen that in each of the experiment runs alternate city (Wuhan) had the largest relative closeness value. This indicates that a stable rank could be obtained while exchanging the weights of criteria. Only in the 16th experiment run, a different rank: $A_3 > A_4 > A_2 > A_1$ appears, in which case alternate city (Tianjin) became the second-best alternate. This demonstrates the robustness and stability of the proposed model.

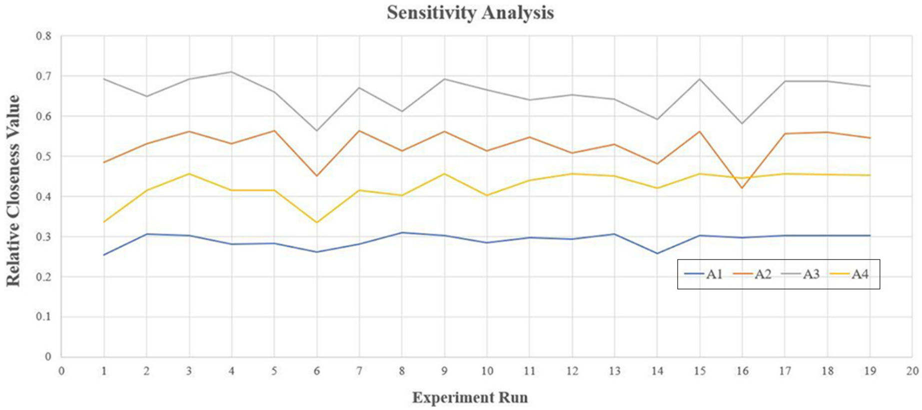

Figure 3.
Results of sensitivity analysis using fuzzy TOPSIS

6. Conclusion

A generic two-phase decision-making framework was proposed for the evaluation and selection of optimal locations for call centers in the mobility industry. A detailed evaluation criteria system involving 21 criteria was developed for assessing both development efficiency and long-term sustainability of call center location problem. The proposed decision-making framework is developed based on fuzzy MCDM and aims at solving the practical problems that emerged in the mobility industry, as MCDM models have been proved to be effective for solving FLP.

Compared with previous research works, the two-phase decision-making approach has two main theoretical advantages:

(1) Improving decision-making efficiency

To solve the location selection problem of call centers in the mobility industry, large quantities of alternates should be evaluated. However, it would be time-consuming and unnecessary to collect all quantitative and qualitative data overall alternates. Logically, an alternate city with poor conditions regarding human resource and investment factors is not likely to be the optimal location, unless some unpredictable issues occur. However, this kind of exception is not considered in this paper. By eliminating these poor-performed alternates from decision-making groups, the efficiency of decision-making would be improved significantly.

(2) Improving decision-making accuracy

Under an uncertain decision-making environment, qualitative data are collected based on experts' subjective judgments such as pairwise comparison using linguistics rating. When there are many alternates evaluated simultaneously, the decision-making results will be extremely inaccurate. By applying a two-phase decision-making approach, we only concentrate on these highlighting alternates. By reducing the frequency of pairwise comparison, the accuracy of decision-making will be improved significantly.

From the practical perspective, a large mobile service provider in Chin launched a real-world project of call center location selection. In this project, our proposed method was compared with competitors' frameworks and traditional methods and it was finally adopted, which validated the feasibility and robustness of the proposed decision-making framework practically.

The limitation of this research is that qualitative information was collected and evaluated based on linguistics ratings from experts. For further research, some other advanced expert evaluation systems could be applied to better evaluate the qualitative information.

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Appendix

City	Tier	Urban Agglomeration
Chengdu	Second	Chengdu-Chongqing Urban Agglomerations
Xi'an	Second	Guan Zhong Plain Urban Agglomerations
Jinan	Second	Shandong Peninsula Urban Agglomerations
Zhengzhou	Second	Central Plains Urban Agglomerations
Shangrao	Third	Triangle of Central China Urban Agglomerations
Hefei	Second	Yangtze River Delta Urban Agglomerations
Taizhou	Third	Yangtze River Delta Urban Agglomerations
Yangzhou	Second	Yangtze River Delta Urban Agglomerations
Ningbo	Third	Yangtze River Delta Urban Agglomerations
Wuxi	Third	Yangtze River Delta Urban Agglomerations
Wuhu	Third	Yangtze River Delta Urban Agglomerations
Tianjin	Second	Beijing-Tianjin-Hebei Urban Agglomerations
Xiamen	Second	Pearl River Delta Urban Agglomerations
Foshan	Third	Pearl River Delta Urban Agglomerations
Dongguan	Third	Pearl River Delta Urban Agglomerations
Wuhan	Second	Triangle of Central China Urban Agglomerations
Nanchang	Third	Triangle of Central China Urban Agglomerations
Changsha	Second	Triangle of Central China Urban Agglomerations
Chongqing	Second	Chengdu-Chongqing Urban Agglomerations
Luoyang	Third	Central Plains Urban Agglomerations
Harbin	Second	Harbin-Changchun megalopolis
Shijiazhuang	Second	Beijing-Tianjin-Hebei Urban Agglomerations
Shenyang	Second	South-central of Liao Urban Agglomerations
Anshan	Third	South-central of Liao Urban Agglomerations
Lanzhou	Third	Lanzhou–Xining Urban Agglomerations
Weifang	Third	Shandong Peninsula Urban Agglomerations
Guiyang	Third	Central of Qian Urban Agglomerations
Mianyang	Third	Chengdu-Chongqing Urban Agglomerations
Fuzhou	Third	Urban Agglomeration on the West Side of the Straits

Source: Chuanglin (2015)

Table A1. All intended cities

Table A2.
Data of alternate cities

Cities	Chengdu	Xi'an	Jinan	Zhengzhou	Shangrao	Hefei	Yangzhou	Taizhou	Wuxi	Ningbo	Wuhu	Tianjin	Shijiazhuang	Foshan
Labor cost (CNY)	67,533	65,793	62,378	60,764	54,720	65,068	67,200	61,025	69,655	69,105	61,325	60,657	64,608	69,750
Land cost (CNY)	16,200	14,800	10,100	15,800	7,900	16,400	15,600	9,300	13,400	17,500	7,650	11,700	13,500	12,200
Tax policy (B)	0	0	1	1	1	1	1	0	0	0	1	1	0	0
Investment incentive (B)	0	0	0	0	1	1	1	0	0	0	1	0	0	0
Urban agglomeration (B)	National	National	Regional	National	National	National	National	National	National	National	National	National	National	Regional
Number of high education institutions (per)	27	54	36	26	2	23	14	4	12	8	10	30	19	11
Scale of employment in service industry (per)	4,696,010	3,475,200	4,098,000	1,865,300	1,646,300	2,829,000	1,073,000	1,079,000	1,581,000	2,404,640	813,600	5,514,700	2,995,000	1,671,000
Scale of high-educated graduates (per)	390,597	292,340	491,800	243,200	77,253	263,389	97,058	54,259	84,500	108,703	74,239	364,847	277,005	99,220
Scale of existing call centers (per)	17,790	17,578	6,677	4,563	4,170	4,682	1,644	1,889	3,596	4,415	3,274	7,651	8,311	7,348
Cities	Wuhan	Nanchang	Changsha	Chongqing	Mianyang	Guiyang	Harbin	Luoyang	Lanzhou	Weifang	Fuzhou	Xiamen	Shenyang	Anshan
Labor cost (CNY)	67,495	66,000	58,390	74,445	59,400	64,650	63,598	58,100	60,300	62,400	59,895	67,245	52,274	58,200
Land cost (CNY)	22,300	17,300	9,600	20,500	8,080	9,720	13,400	12,576	11,000	8,640	12,700	14,900	14,200	8,760
Tax policy (B)	1	1	0	0	0	0	0	1	1	1	1	1	0	1
Investment incentive (B)	1	0	0	0	0	0	0	1	1	1	1	0	0	1
Urban agglomeration (B)	National	National	National	National	Regional	Regional	National	National	Regional	Regional	Regional	National	Regional	Regional
Number of high education institutions (per)	46	24	23	26	5	18	23	3	2	3	18	8	29	2
Scale of employment in service industry (per)	3,053,800	3,333,500	2,060,000	7,779,900	1,232,700	1,396,200	3,382,000	1,669,600	1,224,000	2,661,180	2,921,516	844,087	2,336,000	184,728
Scale of high-educated graduates (per)	299,894	248,226	217,267	837,505	117,253	231,880	332,778	134,460	181,290	190,015	180,806	118,665	203,252	35,599
Scale of existing call centers (per)	12,648	4,687	1,1563	15,189	1,569	7,110	5,801	1,901	3,549	1,638	3,776	5,711	8,491	1,870

Table A3. Normalized data of alternate cities

Cities	Chengdu	Xi'an	Jinan	Zhengzhou	Shangrao	Hefei	Yangzhou	Taizhou	Wuxi	Ningbo	Wuhu	Tianjin	Shijiazhuang	Foshan
Labor cost (CNY)	0.774	0.795	0.838	0.860	0.955	0.803	0.778	0.857	0.750	0.756	0.852	0.862	0.809	0.749
Land cost (CNY)	0.472	0.517	0.757	0.484	0.968	0.466	0.490	0.823	0.571	0.437	1.000	0.654	0.567	0.627
Tax policy (B)	0.000	0.000	1.000	1.000	1.000	1.000	1.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000
Investment incentive (B)	0.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
Urban agglomeration (B)	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
Number of high education institutions (per)	0.500	1.000	0.667	0.481	0.037	0.426	0.259	0.074	0.222	0.148	0.185	0.556	0.352	0.204
Scale of employment in service industry (per)	0.604	0.447	0.527	0.240	0.212	0.364	0.138	0.139	0.203	0.309	0.105	0.709	0.385	0.215
Scale of high-educated graduates (per)	0.466	0.349	0.587	0.290	0.092	0.314	0.116	0.065	0.101	0.130	0.089	0.436	0.331	0.118
Scale of existing call centers (per)	0.088	0.089	0.235	0.344	0.376	0.335	0.954	0.831	0.436	0.355	0.479	0.205	0.189	0.214
Cities	Wuhan	Nanchang	Changsha	Chongqing	Mianyang	Guiyang	Harbin	Luoyang	Lanzhou	Weifang	Fuzhou	Xiamen	Shenyang	Anshan
Labor cost (CNY)	0.774	0.792	0.895	0.702	0.880	0.809	0.822	0.900	0.867	0.838	0.873	0.777	1.000	0.898
Land cost (CNY)	0.343	0.442	0.797	0.373	0.947	0.787	0.571	0.608	0.695	0.885	0.602	0.513	0.539	0.873
Tax policy (B)	1.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	0.000	1.000
Investment incentive (B)	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	0.000	0.000	1.000
Urban agglomeration (B)	1.000	1.000	1.000	1.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000
Number of high education institutions (per)	0.852	0.444	0.426	0.481	0.093	0.333	0.426	0.056	0.037	0.056	0.333	0.148	0.537	0.037
Scale of employment in service industry (per)	0.393	0.428	0.265	1.000	0.158	0.179	0.435	0.215	0.157	0.342	0.376	0.108	0.300	0.024
Scale of high-educated graduates (per)	0.358	0.296	0.259	1.000	0.140	0.277	0.397	0.161	0.216	0.227	0.216	0.142	0.243	0.043
Scale of existing call centers (per)	0.124	0.335	0.136	0.103	1.000	0.221	0.270	0.825	0.442	0.958	0.416	0.275	0.185	0.839