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Research Article

Capacitated Facility Location and Allocation with Uncertain Demand for Tourism Logistics: A Multiobjective Optimisation Approach

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The paper develops a Multiobjective Optimisation (MOO) model for addressing Capacitated Facility Location Problem (CFLP) in tourism logistics, where two objectives are total of cost and customer service level. Nondominated Sorting Genetic Algorithm II (NSGA II) is used to solve the model. The illustrative case with imaginary data demonstrates that the model can figure out the location of the nodes of tourism logistics network and allocation of these sites, while the total of cost is reduced by up to 56.75% and customer service level is increased by an average of 105%. The distinction of this study compared to the current papers is that our model incorporates both items A and B to the subject matter of tourism logistics, where items A refer to tourism-related products and items B involve personal goods of tourists. The model established is limited with one assumption and one limitation which are associated with Vehicle Routing Problem (VRP) and the boundary of tourism logistics activity. Therefore, further research for the elimination of these limits is recommended.

1. Introduction

Tourism Logistics (TL) is defined as a space- and time-related transformation of material, people, information, energy, waste, knowledge, and capital aiming to provide the quality tourism services at the lowest total of costs (TOC) [1–11]. Jin et al. [12] argue that tourism logistics ought to handle two types of goods; one is items A which can be traded in tourism industry such as food and hotel supplies and the other one is items B which belong to and are carried by a tourist such as personal luggage. Then, they point out that, from the perspective of systems approach, the basic goal of tourism logistics is to support a highly free separation and mergence between tourists and items. From an operational point to view, this goal can be translated into that tourists can easily obtain services (i.e., purchasing items A and delivering/collecting items B) from tourism logistics operators at any time in a tourism destination, namely, achieving a good customer service level (CSL).

Due to the essential significance of both TOC and CSL for tourism logistics, we have the following questions: in a tourism logistics network, where the facility locations should be placed (i.e., the selection of sites for items A and B delivery), which facilities are connected, and how much capacity ought to be for each site selected, in order to minimise TOC and maximise CSL simultaneously? In this regard, the question is associated with a type of Multiobjective Optimisation (MOO) related to Capacitated Facility Location Problem (CFLP). CFLP has been proved by Mirchandani and Francis [13] as an NP-hard problem in which none of the exactly best solution exists. As a result, with the development of MOO, CFLP has been generally treated as decision variables within MOO models to be solved [14, 15]. MOO aims to figure out optimal solutions, generally called Pareto Front and/or Pareto Optimal Solutions and/or Pareto sets [16–18] consisting of a series of good compromise solutions.

As for tourism logistics, however, while searching from three main databases consisting of Google Scholar, Elsevier, and ISI Web of Science with an addition of other publications through a wide search online, with the key words of "tourism logistics" and/or "multi-objective optimisation(optimization)" and/or "capacitated facility location", few paper, if any, directly related to the topic can be found. Apparently, in current studies there is lack of study on the trade-off between TOC and CSL under uncertain demand when considering Tourism Supply Chain Logistics (i.e., items A) and Tourists Express (i.e., items B) simultaneously. Therefore, by establishing and solving an MOO model, the purpose of the paper is to balance TOC and CSL for addressing CFLP in tourism logistics.

The rest of the paper is organised as follows. Section 2 reviews existing literature pertinent to our aim. Section 3 specifies the problem we are going to solve for a clear boundary of research, followed by Section 4 formulating the problem. With Section 5 introducing Nondominated Sorting Genetic Algorithm II (NSGA II) which is used to solve the MOO-CFLP model, Section 6 clarifies the methodology of conducting optimisation. Then, Section 7 subsequently presents an illustrative example for the application of the model. Finally, a summary of the paper and the suggestions for further research are drawn in Section 8.

2. Literature Review

As the context of the paper is tourism logistics, and the main point hereby is to solve CFLP in an MOO approach, this section is going to review the academic papers in the field of tourism logistics in the first place then move to the literature of MOO related to CFLP which is applied in logistics area. The papers reviewed can be found by searching in Google Scholar, Elsevier, and ISI Web of Science in addition to Google Search. For the collection of papers related to tourism logistics, the key words consist of "tourism" and/or "logistics". For the other part, the key words are "logistics" and/or "multi-objective optimisation" and/or "capacitated facility location".

2.1. Comparison of Items A and B in Tourism Logistics. Conventionally, tourism logistics is recognised as the forward/reverse logistics in a tourism destination as from a perspective of tourism supply chain [19–21]. In these opinions, the subject matter of tourism logistics generally refers to food-related products, hotel supplies, and commodities of which the expected customers are mainly tourists (e.g., art and craft) [21].

However, Jin et al. [12] point out that the items which belong to and are carried by a tourist can form a materials flow over time. Meanwhile, as Express (i.e., Parcel Delivery) industry creates value for its customers, Jin et al. [12] argue that this category of items should be incorporated into the range of the subject matter of tourism logistics owing to more convenience being released for tourists. For instance, a Japanese home-delivery service, called Takkyubin or Hands-free travel, uses retail stores for receiving the parcels and delivering to tourists in the destinations by collect-in-store or door-to-door services, taking the largest market share in competition with Japanese Post Office [22, 23]. Recently, such a service has been developed by a variety of companies, e.g., easyJet [24] and Skyscanner [25]. Given this, Jin et al. [12] categorise the subject matter of tourism logistics into items A and B as shown in Table 1, in which the traditional opinions and new-value-added ideas are integrated. The difference of items B from items A is that the ownership or right to use of the former belongs to tourists.

In essence, such a boundary of tourism logistics is the integration of tourism services and logistics services, creating value to tourism operators for the optimisation of last-mile logistics in tourism supply chain and to tourists for the enhancement of travel experience. Moreover, this boundary presents a new form of logistics that supply chain logistics and parcel delivery can be in operations in the meantime, namely, managing and operating logistics of both items A and B.

2.2. Operating and Managing Tourism Logistics. Some researchers discuss the significance of logistics in tourism. Muhcina and Popovici [5] believe that internal logistics activities in tourism supply chain refer to procurement, operational support, and some areas such as a physical distribution from raw materials suppliers to end consumers. While Piboonrungroj and Sangkakorn [6] state that infrastructure, information, intelligence, identification, and innovation are five dimensions of tourism logistics management; they also point out that logistics management is considerably important for supporting tourists' activities, reducing the costs, and promoting tourists' satisfaction, and such results are in keeping with Kochadze et al. [26]. Additionally, Bosun et al. [9] suggest that tourism enterprises have to adapt e-logistics owing to the huge development of Internet transforming the traditional logistics processes including logistics functions. Similar ideas are argued by Ngamsirijit [8] that value added and experience improved for tourists require the establishment and development of a logistics system to meet their needs as to coordinate with the increasing growth of tourism industry.

Some peers demonstrate the close relationships between tourism and logistics on various levels. Pinnock et al. [27] find out that the development of tourism is limited by local logistics capacity and efficiency by comparison of Martinique with Jamaica, Panama and Barbados, depending on the market conditions across the Caribbean. Thus, they claim that logistics provider is one of competitive factors in tourism. Likewise, Anderson [11] and Ajagunna et al. [28] conclude that there is a symbiotic relationship between tourism and logistics that updating logistics will improve the growth of tourism economy, through arguing the agriculture logistics in Cyprus and reviewing the papers on the topic of the development of tourism and logistics in Caribbean, respectively. In this case, Bennett [29] integrate the works of Raj et al. [30], Bhattacharya and Momaya [31], Jharkharia and Shankar [32], Ravi et al. [33], Thakkar et al. [34], Charan et al. [35], and Grzybowska [36] to reasonably come up with 16 "Enablers" including 59 factors for the symbiotic

Table 1: Classification of items in tourism logistics, sourced from Jin et al. [12].

General Category	Main Category	Subcategory
Items A	Food	Vegetables, meat, eggs, flour, soy products, seafood, spices, etc.
	Housing	Toothbrush, toothpaste, comb, shampoo, shower gel, etc.
	Shopping	Fruits, art and crafts, coconut processed food, coffee, dried sea products, tea, wine, etc.
Items B	Personal objects	Travel bags, clothing, shoes, electronics, digital products, cosmetics, books, etc.
	Sport equipment	Off-road bikes, riding equipment, surfboards, diving equipment, fishing equipment, golf clubs, adventure equipment, etc.

improvement of logistics and tourism industries. Additionally, Kordel [37] maintains that the relevant theories and methods of logistics are applicable to tourism that can be effective tools for the firms in a competitive marketplace to climb a higher market positioning.

A few papers directly focus on the management and operations of tourism logistics. For example, Ngamsirijit [7] demonstrate that fixed route mode with full lap can provide more service capacity on tourism logistics bus in Pattaya than semifixed route mode with partial lap does, using Capacity Flexibility Model. Then, planning of Demand Responsive Transportation (DRT) is proposed for the city with cultural creative travel needs and limited logistics infrastructure, including system responsiveness assessment, transportation selection, new route design, and implementation of DRT [8].

Besides, some papers related to Tourism Logistics System (TLS) can be found, but these obtained papers would less or unclearly perceive the material flow at tourists' side (i.e., items B). For instance, Segetlija and Lamza–Maronic [38] believe that a logistics system in a tourism destination includes order fulfilment, inventory management, warehousing and dispatch, packaging and regrouping and shipping. Such thesis was supported by Ivanovic and Baldigara [39] who stress the importance of studying the tourism destination as a whole, and then propose the logistics system in a tourism destination consisting of the operational system, information system, and management system. More specifically, Mrnjavac and Ivanovic [1] doubt that the TLS should include hospitality subsystem, tourist agency subsystem, transportation subsystem, and tourist attractions subsystem, which interact in complicated ways to manufacture the tourism products (both tangible and intangible services) acceptable to tourism market. Moreover, the macrotourism logistics system aims at the optimisation of a tourism destination or a certain region with a contrast to the microtourism logistics system within a tourism-related company or its internally logistical organisation. To be summarised, TLS planned above would merely emphasise the effects of logistics functions on material flow from upstream suppliers to end retailers in a tourism destination, but traveler logistics (i.e., items B) was excluded or not clarified.

In contrast, with the huge advancement and broad applications of information technologies, it is popular in the contemporary world that tourists may request a door-door delivery service at the end of shopping during the trip, so that for tourists the remaining activities can be more enjoyable without baggage accompanying [9]. As for tourism operators, such service can be of more reasonable significance because it will create more value and fairly improve the travel experience for tourists [40]. Therefore, the logistics activity of delivering tourists' baggage (including commodities purchased when traveling) to a destination appointed, namely, traveler logistics (i.e., items B), should be contained into the subject matter of tourism logistics [12].

In brief, the current studies have illustrated that logistics has significant impacts on tourism on the operational, tactical, and strategic levels, they are symbiotically linked, and tourism logistics can be optimised to a considerable extent with the utilisation of relevant theories and methods of logistics. To put our work in context, Table 2 presents the selected academic papers and their research methods, which mention the subject matter of tourism logistics in some ways (i.e., whether they clarify items A or B), in a bid to highlight the importance of items B and distinction of this paper conducting quantitative research.

As reviewed above, a majority of the current studies on tourism logistics unilaterally put emphasis on items A or items B, while this paper is going to optimise tourism logistics-related CFLP in a holistic manner with considerations of both items A and B. Next, due to the lack of the studies on MOO related to CFLP in tourism logistics, we are going to review the logistics-related papers.

2.3. MOO Related to CFLP in Logistics. There are many trade-offs within the operations of logistics, for example, cost and profits, responsive time to customer, and inventory level [18, 41]. From time to time we need a compromise solution to avoid unexpected results and achieve as close to the best of each goal as possible, while Multiobjective Optimisation (MOO) provides a chance to reach the target [17].

Specifically, MOO-CFLP models have been proposed in emergency logistics [42], disaster relief logistics [43], green/sustainable logistics [44], forward/reverse logistics [45], and parcel delivery [46–48]. The decision variables referred to include facility location, capacity, and customer allocation [49, 50]. The optimisation objectives (and constraints) include total of costs, reliability, customer service level, responsive time to customer, and CO_2 emissions [49, 51]. The methods to solve the MOO model generally consist of exact algorithm (e.g., TOPSIS, utility theory and minimax method), heuristics algorithm (e.g., hill climbing method), and metaheuristics algorithm (e.g., particle swarm algorithm,

Table 2: Academic studies related to items A and B.

References	items A	items B		Methodology	
		Allude to*	Key focus	Qualitative	Quantitative
Piboonrungroj and Sangkakorn [6]	√	√		√	
Kochadze et al. [26]	√	√		√	
Bosun et al. [9]	√	√		√	
Ngamsirijit [8]	√	√			√ (vehicle route planning)
Bennett [29]	√	√		√	
Mrnjavac and Ivanovic [1]	√	√		√	
Muhcina and Popovici [5]	√			√	
Pinnock et al. [27]	√			√	
Anderson [11]	√			√	
Ajagunna et al. [28]	√			√	
Kordel [37]	√			√	
Segetlija and Lamza–Maronic [38]	√			√	
Ivanovic and Baldigara [39]	√			√	
Mizutani and Uranishi [40]			√	√	
Bosun et al. [9].			√	√	
Jin et al. [12].	√		√	√	
Current Paper	√		√		√ (Network optimisation)

*: refers to the paper in which the concepts related to items B are mentioned but not clarified.

genetic algorithm, ant colony algorithm, and hybrid algorithm) [52–55].

Subsequently, MOO-CFLP related studies are summarised in Table 3, which shows the objective of each paper (i.e., if TOC or CSL is optimised), whether they consider the uncertainty of demand, the subject matter of logistics of each paper (i.e., items A, B or both), and the solving algorithm used in each study (i.e., whether NSGA II is used).

In comparison to the current studies in the field of MOO related to CFLP, Table 3 indicates that NSGA II has been a common use for solving MOO model, and the MOO-CFLP for both items A and B seems to be a gap. Therefore, the purpose of this paper is to address CFLP under uncertain demand in tourism logistics with simultaneous optimisation of TOC and CSL using NSGA II approach.

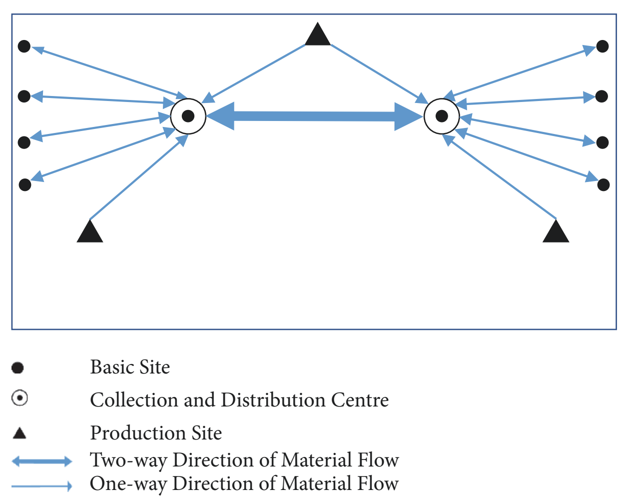


Figure 1: Network of tourism logistics.

3. Problem Description

Now we are going to introduce a simple tourism logistics network for clarifying the boundary of MOO-CFLP model prior to formulating the problem. This network can demonstrate the mechanism of how a tourism logistics carrier delivers services of both items A and B in a tourism destination. A tourism destination is universally defined as a geographic area consisting of a set of resources and attractions that are visited by tourists [56].

3.1. A Simple Network of Tourism Logistics. First of all, in this network, we have three key elements including Basic Site, Production Site and Collection and Distribution Centre (CDC). The first element is Basic Site (BS) where the demand of tourists purchasing items A and delivering items B occurs, e.g., transportation hub (i.e., coach station, train station, metro station, and airport), hotel, and retail stores around a tourist attraction. As seen in Figure 1, a BS can send goods to and receive from the assigned CDC, which is indicated by a double-sided arrow from a dot to a circle.

The reason why we call these sites as Basic Site is due to the fact that these sites are the desired space nodes of delivering

Table 3: Academic paper related to MOO and CFLP in logistics.

References	Objective		Uncertain demand	Optimisation for Items A	Optimisation for Items B	Optimisation for both	NSGA II
	TOC	CSL					
Najafi et al. [17]	√		√	√			
Caunhye et al. [42]	√	√	√	√			√
Deb [18]	√	√	√	√			√
Klose and Drexl [41]	√	√	√	√			√
Murray and Chu [46]	√	√			√		√
Čupić and Teodorović [47]		√			√		√
Çetiner et al. [48]	√		√		√		
Cao et al. [43]		√		√			√
Xifeng et al. [44]	√			√			
Harris et al. [49]	√			√			
Jane [50]	√			√			
Bozorgi-Amiri et al. [52]	√	√	√	√			
Current Paper	√	√	√			√	√

tourism services and logistics services at the same time and can attract a major percentage of tourists. For instance, Topolšek et al. [10] discover that different transport providers would integrate with travel agencies in various ways. The highest level is achieved by bus operators, followed by air carries, water carries, and rail carries. More importantly, these areas are also the geographical sites as well as destinations in which a majority of tourists come and go on the most regular basis, in addition to hotels, restaurants, tourist attractions, and other places [57]. As a result, these sites are ideal nodes to support the logistics of both items A and B, playing infrastructural roles in the operations of tourism logistics.

The second element is Production Site (PS), which is the supplier of regional Basic Site(s), e.g., food market and/or the whole retailer, hotel supplies agency. Also, it can be the distribution centre of supplier and/or supply chain. As seen in Figure 1, a PS sends goods to the assigned CDC indicated by a one-sided arrow from a triangle to a circle. The last element is Collection and Distribution Centre (CDC), which can collect items from BS then deliver to the destination assigned by customer (tourists) and meanwhile collect goods from PS and deliver to the BS appointed. CDC is selected amongst BSs and able to connect to other CDCs. As shown in Figure 1, a CDC can send goods to and receive from other CDCs indicated by a double-sided arrow from a circle to another.

As proposed above, the elements BS and PS are broadly existing in tourism industry and the element CDC is new. From an operational perspective, CDC takes a number of logistics-related responsibilities to enable the physical distribution of items A and B, in addition to BS which is the window of being in touch with tourists and, lastly, PS is merely a supplier of items B.

3.2. Visualisation of Expected Results. Here, we name and number each site as BS_i, CDC_j, and PS_k to denote Basic Site i, Collection and Distribution Centre j, and Production Site k, respectively. Then, the goal of the proposed model is to figure out that in a geographical region R (i.e., tourism destination) which BS_i and PS_k are allocated to which CDC_j, while the TOC is lowest and CSL is highest. The expected result can be visually presented as shown in Figure 2 that previously each PS supplied its own customers (i.e., corresponded BSs); after optimisation (while the geographical location of each node keeps stable), the nodes indicated by a dot in the left part of Figure 2, i.e., BS_2 and BS_8, are selected to be CDC_1 and CDC_2 which is respectively indicated by a dot with a circle as shown in the right part of Figure 2. Meanwhile, CDC_1 (i.e., previous BS_2) makes links to BS_1 BS_3, BS_4 and PS_1, and CDC_2 (i.e., previous BS_8) does to BS_5, BS_6, BS_7, BS_9, BS_{10}, PS_2, PS_3, PS_4, PS_5 and PS_6.

In addition, we are going to prove that the transportation cost is minimal if there is and only is the material flow of items B between CDCs. To be specific, for the same quantity of items A sent from PS_k to BS_i, there are two original routes occurring for delivering items A: as shown in Figure 3, **Route 1** starts at PS_k going to BS_i flowing via CDC_j, and **Route 2** starts at PS_k going to BS_i via CDC_h and CDC_j. The transportation distance of Route 1 equals to the distance *L1* between PS_k and CDC_j plus that *L2* between CDC_j and BS_i; the transportation distance of Route 2 equals to the distance *L3* between PS_k and CDC_h ($h \neq j$) plus that *L4* between CDC_h and CDC_j plus that *L2* between CDC_j and BS_i. Therefore, the sum of $Route\ 1 = L1 + L2$, $Route\ 2 = L3 + L4 + L2$. In the paper, we use linear distance known as Euclidean distance to measure the distance between sites. As a result, if PS_k, CDC_h, and CDC_j form a triangle, $L1 < L3 + L4$; if and only if PS_k, CDC_h, and CDC_j are on a straight line, $L1 = L3 + L4$. In summary, $L1 \leq L3 + L4$. Thus, when the number of items A needed is fixed, the transportation cost on *Route 1* is equivalent to or less than on *Route 2*.

3.3. Assumption and Limitation. The time consumed from receiving items B to delivering to tourists is related to Vehicle Routing Problem [58, 59], but the purpose of the paper is

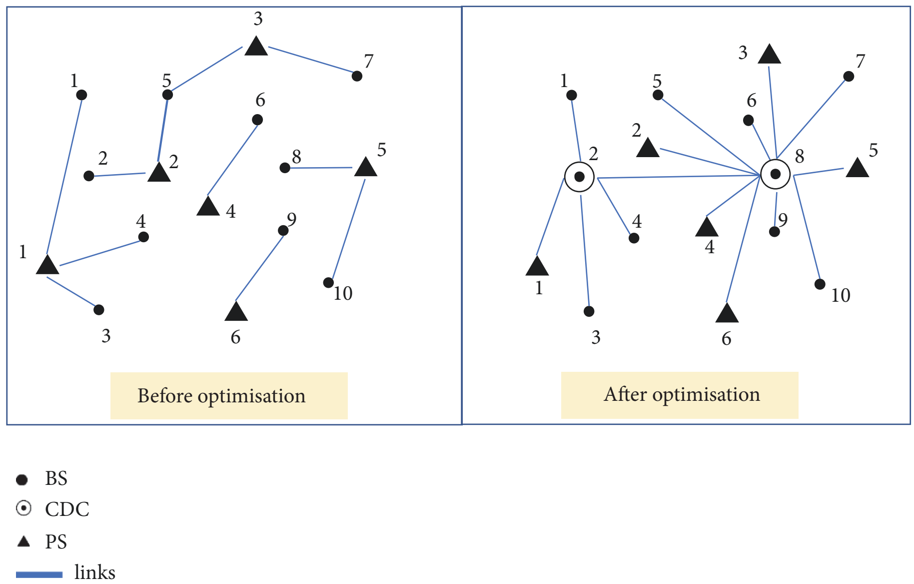


Figure 2: Logistics network before and after optimisation.

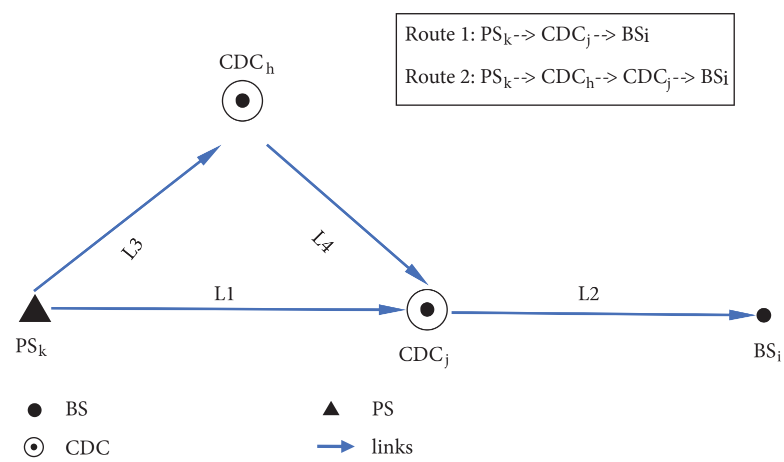


Figure 3: Two routes for delivering items A.

to handle CFLP in tourism logistics. As a consequence, for a fair consideration between items A and B, the following assumption and limitation are proposed to enable a clear boundary of research:

Assumption 1. If tourists can obtain the service from tourism logistics operator, items B will be delivered to the customer at an appointed site in due time.

Limitation 1. For items A supply chain, the first-tier site supplying the end store in a tourism destination will only be incorporated into consideration in this paper.

Consequently, the initial question aiming to simultaneously optimise TOC and CSL can be further specified into the following four questions:

RQ1 (Location Problem): which BS_i should be selected as CDC_j?

RQ2 (Allocation Problem): which BS_i and PS_k are allocated to which CDC_j?

RQ3: how many items A each PS should offer to its CDC(s)? and

RQ4: how much capacity ought to be for each BS and CDC?

4. Problem Formulation

The notation is used in our model as in the Notation section.

4.1. Maximising Customer Service Level. There are various definitions in terms of CSL depending on applied context [60]. This study develops its definition to suit with tourism logistics, based on the most common use in logistics [61], that CSL in tourism logistics is the rate of order fulfilment of tourists purchasing items A and delivering items B. We assume that tourists have an uncertain demand in items A and B (each corresponding to a single goods type), and a single product configuration for either items A or B is viewed as a product category where aggregated volumes have common characteristics, e.g., unit: kg. The uncertain demand of tourists is involved with the optimisation of capacity of each site.

Upon the definition of CSL as discussed above, the CSL of the entire tourism logistics network is related to Basic Site and CDC. However, all Basic Sites are potential CDCs so that we only need to deal with the CSL of all Basic Sites for maximising the CSL across the entire network. CSL of items A in BS_i (i.e., the rate of order fulfilment in BS_i), denoted by $CSL^A{}_i$ ($i \in V_{bs}$), can be measured as the probability that the actual demand of items A in BS_i during a periodic time is less than or equivalent to $bq^A{}_i$, capacity of items A of BS_i, namely, $CSL^A{}_i = P(ddpt^A{}_i \leq bq^A{}_i)$. The measurement is a common approach to modelling CSL in logistics [60, 61]. In the same way, we can obtain $CSL^B{}_i$. Then, we measure CSL of BS_i, denoted by CSL_i, as the mean of $CSL^A{}_i$ and $CSL^B{}_i$, namely, $CSL_i = (CSL^A{}_i + CSL^B{}_i)/2$. Likewise, we measure CSL of the entire network as the mean of the values of all Basic Sites. Thus, assuming the number of Basic Sites is n, the objective function of CSL of tourism logistics can be formulated as follows:

$$\max \text{CSL} = \frac{1}{n} \sum_{i \in V_{bs}} \frac{P\left(ddpt_i^A \leq bq_i^A\right) + P\left(ddpt_i^B \leq bq_i^B\right)}{2} \quad (1)$$

4.2. Minimising Total of Cost. We propose that *TOC* of the network consists of facility cost (*FC*) for a particular site and transportation cost (*TC*) for the linkages of sites, i.e., *TOC=FC+TC*. Specifically, according to general definition [13, 44, 49], facility cost consists of periodic fixed cost (denoted by *PFC*) for launching a CDC and periodic operational cost (denoted by *POC*) for running a site (BS and CDC), namely, *Facility cost = PFC + POC*. *PFC* is related to the construction of infrastructure for operating a CDC as this site plays a role of logistics hub as well as a depot in tourism logistics network as mentioned in Section 3. Thus, for the expression of the selection of CDC_j from Basic Sites, the binary variable z_j is used that equals 1 if CDC_j is chosen to operate and 0 otherwise. Besides, we assume that *PFC* of CDC_j is denoted by PFC_j and periodic fixed cost for opening a CDC_j is β, so $PFC_i = \beta \cdot z_j$ and *PFC* is the sum of PFC_j.

POC is varied as the capacity of a site. Here, based on Harris et al. [49], we develop a new definition of capacity in tourism logistics that capacity of items A refers to the number of expected inventory of items A in a site, and capacity of items B is the amount of desired handling of items B in a site. In this regard, we use POC_i to denote the periodic operational cost of BS_i and use POC_j for CDC_j and assume that periodic operational cost for each unit of capacity of items A is α^A and for items B is α^B. Hence, $POC_i = \alpha^A \cdot bq^A{}_i + \alpha^B \cdot bq^B{}_i$. However, due to CDC_j playing two roles that one is running as BS_j (i.e., j=i) and another is operating as a CDC for all connected BSs and other CDCs, POC_j thus consists of two parts, bq_j (capacity of CDC_j when only considering the role of BS it plays) and q_j (capacity of CDC_j when only considering the role of CDC it plays), namely, $cq_j = (bq_j + q_j)$ where cq_j is the total capacity of CDC_j. Nevertheless, the part of bq_j has been incorporated into POC_i so here when calculating TOC, we only use $q^A{}_j$ and $q^B{}_j$ for POC_j. As a result, POC_j can be expressed in same way, and *POC* is the sum of POC_i and POC_j.

For transportation, as seen in Figures 1 and 3, there are three types of the connections between sites across a tourism logistics network including ①BS_i and CDC_j, ②PS_k ($k \in V_{ps}$) and CDC_j as well as ③CDC_h and CDC_j ($h \neq j$, h, $j \in V_{cdc}$). For the differentiation of these transportation costs, we use TC_{ij}, TC_{kj}, and TC_{hj} to denote them so that *Transportation cost* equals to the sum of $(TC_{ij} + TC_{kj} + TC_{hj})$.

However, due to the complexity of every transportation cost involved with the orientations of the material flow and the categories of goods, a number of parameters for the calculation of the costs should be required and make the model be of more complication. Thus, for simplification, we use a periodic-cost measure to decouple the cost and the amount of goods flowing over the linkages, i.e., using γ^{AB} for denoting periodic transportation cost of both items A and B per distance, γ^A for only items A, and γ^B for only items B. As discussed in Section 3, there are the material flows of both items A and B between BS and CDC, only items A between PS and CDC, and only items B between CDCs. Subsequently, we can obtain $TC_{ij} = d^{bs}{}_{ij} \cdot \gamma^{AB}$, $TC_{kj} = d^{ps}{}_{kj} \cdot \gamma^A$ and $TC_{hj} = d^{cdc}{}_{hj} \cdot \gamma^B$, where $d^{bs}{}_{ij}$, $d^{ps}{}_{kj}$, and $d^{cdc}{}_{hj}$ denote the Euclidean distance of three types of the connections, respectively. Consequently, we can obtain the following objective function of TOC:

$$\begin{aligned} \min \text{TOC} = & \sum_{i \in V_{bs}} \left(\alpha^A bq_i^A + \alpha^B bq_i^B\right) \\ & + \sum_{j \in V_{cdc}} \left(\alpha^A q_j^A + \alpha^B q_j^B\right) + \sum_{j \in V_{cdc}} \beta z_j \\ & + \sum_{j \in V_{cdc}} \sum_{i \in V_{bs}} TC_{ij} x_{ij} + \sum_{j \in V_{cdc}} \sum_{k \in V_{ps}} TC_{kj} y_{kj} \\ & + \sum_{j,h \in V_{cdc}} \sum_{j \neq h} TC_{hj} \end{aligned} \quad (2)$$

We assume the required number of launching CDC(s) is w, and capacity of supply of items A from PS_k to BS_i is S_{ik}. Thus, both the objective functions (1) and (2) are subject to the following constraints:

$$\sum_{j \in V_{cdc}} x_{ij} = 1, \quad i \in V_{bs} \quad (3)$$

$$\sum_{i \in V_{bs}} bq_i^A x_{ij} \leq q_j^A, \quad j \in V_{cdc} \quad (4)$$

$$q_j^A \leq \sum_{k \in V_{ps}} Q_{kj}, \quad j \in V_{cdc} \quad (5)$$

$$Q_{kj} \leq \sum_{i \in V_{bs}} S_{ik} x_{ij}, \quad k \in V_{ps},\ j \in V_{cdc} \tag{6}$$

$$q_j^B \geq \sum_{i \in V_{bs}} b q_i^B x_{ij}, \quad j \in V_{cdc} \tag{7}$$

$$\sum_{j \in V_{cdc}} z_j = w \tag{8}$$

$$x_{ij} \in \{0,1\}, \quad i \in V_{bs},\ j \in V_{cdc} \tag{9}$$

$$y_{kj} \in \{0,1\}, \quad k \in V_{ps},\ j \in V_{cdc} \tag{10}$$

$$z_j \in \{0,1\}, \quad j \in V_{cdc} \tag{11}$$

$$q_i^A, q_i^B, q_j^A, q_j^B, Q_{kj} \geq 0, \quad i \in V_{bs},\ j \in V_{cdc},\ k \in V_{ps} \tag{12}$$

Constraints (3) ensure that each BS is allocated to only one CDC and the demand is satisfied by that CDC. (4), (5), and (6) ensure that capacity of supply of items A in each site is not violated, including, respectively, the capacity of CDC_j of delivering items A to itself and all Basic Sites it connects with, quantity of items A received from all linked PS in CDC_j assigned, and capacity of supply of items A from PS_k to BS_i. (7) ensures the capacity of CDC_j of handling items B for itself and all Basic Sites it links to is not violated. (8) ensures CDCs are opened in the required number. (9), (10), and (11) define decision variables as binary and (12) ensures the variables are positive.

5. Solving Algorithm

As reviewed in Section 2, NSGA II has been a common use to solve MOO model for addressing CFLP [41–43, 46] and is employed for handling the MOO model established in the paper. NSGA II is designed and developed by Deb et al. [62] that the algorithm can fast find optimum solutions, i.e., Pareto Front, in an iterative genetic approach that can compare good and bad amongst millions of feasible solutions to a given MOO model, so as to enable the gain of good compromise solutions for final decision made. In contrast to other relevant algorithms, it has advantages on a lower time complexity, better results of global search and good diversity preservation of Pareto set [62, 63].

Here, we are going to introduce the concept of domination to describe Pareto optimum which our model aims to obtain. Generally, there are two types in all feasible solutions including nondominated solution and dominating solution [64], where

(i) if and only if all values of objectives corresponding to Solution i are better than that to Solution j and at least one of that is equivalent to Solution j, Solution i is weakly dominated by Solution j;

(ii) if and only if all values of objectives corresponding to Solution i are better than and not equivalent to that to Solution j, Solution i is strongly dominated by Solution j; and

(iii) if and only if at least one of the values of objectives corresponding to Solution i are better than or equivalent to that to Solution j and at least one of that is worse than Solution j, Solutions i and j do not dominate each other.

As proved [65], for a particular Solution i, it must be a nondominated solution or dominating solution. Subsequently, each feasible solution can be offered a nondomination rank. Therefore, Pareto optimum is formed by a set of nondominated solutions that all have the highest nondomination rank throughout decision space, i.e., all feasible solutions. Due to the huge number of feasible solutions, it is hard to compare every solution for nondomination rank so that Pareto optimum can be reached by the loop iterations of a given population until the conditions provided are fulfilled, where a population refers to a set of feasible solutions.

Given this, the methodology of NSGA II is to randomly generate an initial population P of feasible solutions and evolve P by elitist sorting (with nondomination rank and crowding distance), genetic operations (including binary tournament selection, recombination, mutation and combination of parent and offspring populations), and iterations (i.e., loops of elitist sorting and genetic operations), in order to obtain Pareto optimum while searching throughout the entire decision space. Specifically, the number of nondominated solutions and the set of dominating solutions are calculated to enable a fast and elitist sorting for nondomination rank. Crowded-comparison operator, including nondominated sorting and crowding distance sorting, is used for sorting. The implementation of NSGA II can be summarised as follows [55, 62–64, 66]:

(1) Initial parent population P_0 with the size of N is randomly generated.

(2) Population P_0 undergoes a fast and elitist nondominated sorting, then the sorted population P_0’ is obtained.

(3) P_0’ goes through binary tournament selection to form a selected population P_0”.

(4) An offspring population Q_0 is created with the recombination and mutation of P_0”.

(5) Both populations P_0 and Q_0 are united into a population, R_0 (with the size of 2N).

(6) Population R_0 is sorted that all members are classified and put into Fronts ($F_1, F_2 \ldots F_n$).

(7) The best N individuals from R_t are selected based on the Fronts and then the new parent population, P_1, is made.

(8) Back to Step (4), until the termination criteria have been satisfied.

(9) Good compromise solutions can be found on the first front of the last parent population.

6. Research Methods: Optimisation in MATLAB

One of the goals of the paper is to introduce the MOO model which is established in Section 4 and can be solved using the

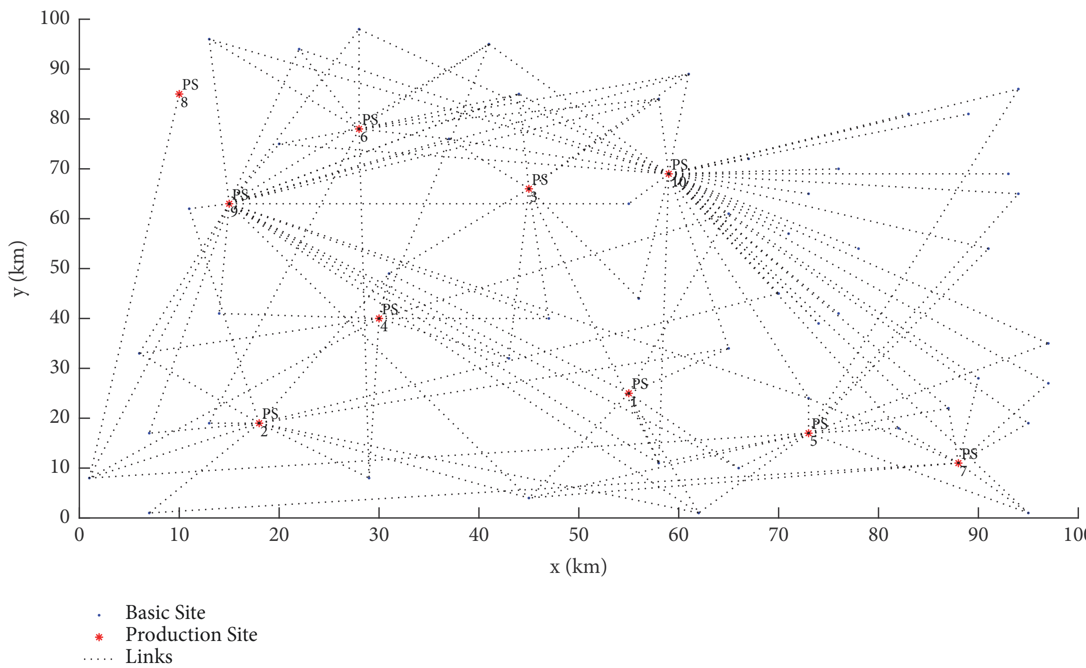


FIGURE 4: Distribution of and links between BSs and PSs in the case of Shanghai.

evolutionary algorithm of NSGA II. Thus, we are going to set up a computational case to explain how it can address CFLP while simultaneously optimising the objectives, TOC and CSL. For the data collection of the case, we are going to use imaginary data as the concept of tourism logistics employed in the paper is state-of-the-art and few, if any, real-world case can be found. Although there is a number of corporations which deal with the logistics of items A or items B over the world, such as DHL, Yamato Transport and so forth, none of them can do both, which has been reported in Sections 1 and 2. As a result, the case handled in the paper can be a reference for the real problem.

When we give the assumed data, reality-related facts have been in considerations, and we utilise mathematic techniques to avoid personal errors as much as possible. For example, the value of the demand for items A and B in BS and location of every BS and PS are randomly generated while we only give the lower and upper boundaries. Additionally, for a good observation of results, we use Minus CSL when calculating the value of the objectives but use CSL for analysis.

With the data given, then, we convey them into the computer to figure out the solutions for the case in response to the four research questions proposed in Section 2 using NSGA II approach. The experiment runs on a PC of Intel(R) Core(TM) i7-7500U CPU @ 2.70GHz 2.90GHz and RAM of 8.00GB. The applied software is MATLAB R2016a, and the code of NSGA II can be seen in Appendix C on the web page we created [67]. We operate genetic iterations using SBX (Simulated Binary Crossover) and polynomial mutation. Here, distribution index for crossover is 2, distribution index for mutation is 5, crossover probability is 0.5, and mutation probability is $1/V$ where V is the sum of variables. Binary tournament selection is used on crowded-comparison operator to generate a new population. When conducting trial, we will compare the results of Pareto set in distinct size (i.e., 50, 100, 500, and 1000) of population and various numbers (i.e., 1, 10, 50, and 100) of total generations. These two factors have significant impacts on the maturity and convergence of the consequences of iterations. With the comparison and contrast, the best conditions (i.e., population size and genetic number) will be applied for seeking good compromise solutions for the case. Next, the good compromise solutions will be present as tables and figures to indicate how the model makes an improvement on the objectives. Lastly, the best preferred solution to decision maker will be selected amongst these good compromise solutions for the presentation of the answers to the questions in Section 2.

7. An Illustrative Example

The example is going to be an imaginary Chinese TL company in Shanghai. Initially, it has 50 type-of-Basic-Site customers in Shanghai as shown as blue points in Figure 4, involved with airport, coach station, train station, metro station, restaurant, hotel, and tourist attraction. Meanwhile, the enterprise supplies these BSs with PSs of 10 in which each BS is supplied by no less than one PS. As indicated in Figure 4, PS is shown as a red star, and the connections between BSs and PSs are shown as dotted lines. All BSs and PSs are randomly distributed in Shanghai which is denoted by a two-dimensional coordinate system of 100x100 km^2 as shown in Figure 4.

Before we conduct the optimisation, the enterprise operates as a normal logistics company which merely transports items A from PSs to BSs. Now, tourists who come into Shanghai require the service in relation to left luggage and/or parcel delivery, especially luggage delivery, for an improved travel experience. For that, the enterprise not only would deliver items A from corresponding PSs to BSs for the latter's

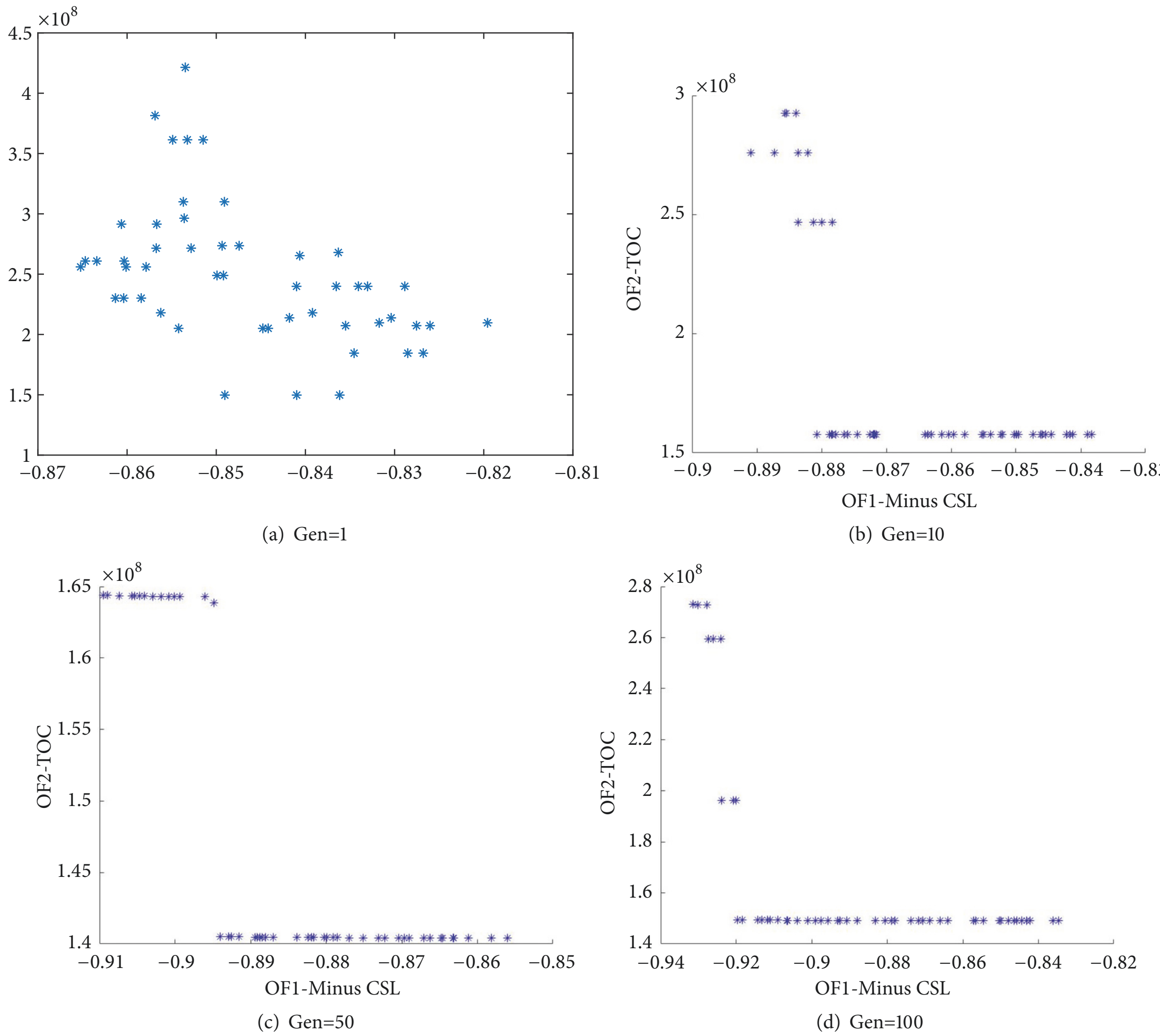


Figure 5: Pareto Front in the population of 50. Gen is the number of total generations. CPU time from (a) to (d) are 4.25s, 48.72s, 142.39s, and 232.14s, respectively.

daily operations, but the enterprise could also receive items B from tourists at the Basic Sites for either left luggage or delivery.

7.1. Experimental Data. In this way, we give all imaginary data (i.e., the values of the objectives-related variables) in Appendix A on the web page we created [67], regarding the demands for items A and B and location of every BS, the capacity of the PS offering items A to a BS, the sum of the capacity of the BS receiving items A from its corresponded PSs, and the location of every PS. Specifically, we assume that each site including BS and PS is dispersedly situated somewhere denoted by one point at a two-dimensional coordinate system; for example, BS_1 is located at (1, 8), and one of its corresponding Production Sites PS_2 is located at (18, 19). In terms of capacity S_{ik} in PS, zero indicates there is no trade between PS and BS, such as $S_{(1\text{-}1)}$, $S_{(1\text{-}3)}$ and $S_{(2\text{-}1)}$, while a digit indicates the maximal quantity of PS supplying items A to BS; for instance, $S_{(1\text{-}2)} = 2,156$ kg represents the capacity of 2,156 kg of PS_2 for BS_1.

For quantifying the uncertainty of demand, we use $D^A{}_i \sim N(\mu^A, \sigma^A)$ (and $D^B{}_i \sim N(\mu^B, \sigma^B)$) to denote that the daily demand of items A (and B) in BS_i is a standard normal distribution with the mean of μ^A (μ^B) and deviation of σ^A (σ^B), unit: kg. For instance, $D^A{}_1 \sim N(10000, 2408)$ represents that the daily demand of items A in BS_1 is subject to normal distribution and the mean is 10,000 kg and deviation is 2,408 kg. $D^B{}_1 \sim N(15264, 5780)$ represents the daily demand of receiving and dispatching items B in BS_1 subject to normal distribution and the mean is 15,264 kg and deviation is 5,780 kg.

Besides, we assume that α^A weekly operational cost for each kilogram of items A is 4 pounds/kg; α^B weekly operational cost for each kilogram of items B is 3 pounds/kg; β weekly fixed cost for opening a new CDC_j is 100,000 pounds; γ^{AB} weekly transportation cost of both items A and B for each kilometre is 120,000 pounds/km; γ^A weekly transportation cost of items A for each kilometre is 8,400 pounds/km; and γ^B weekly transportation cost of items B for

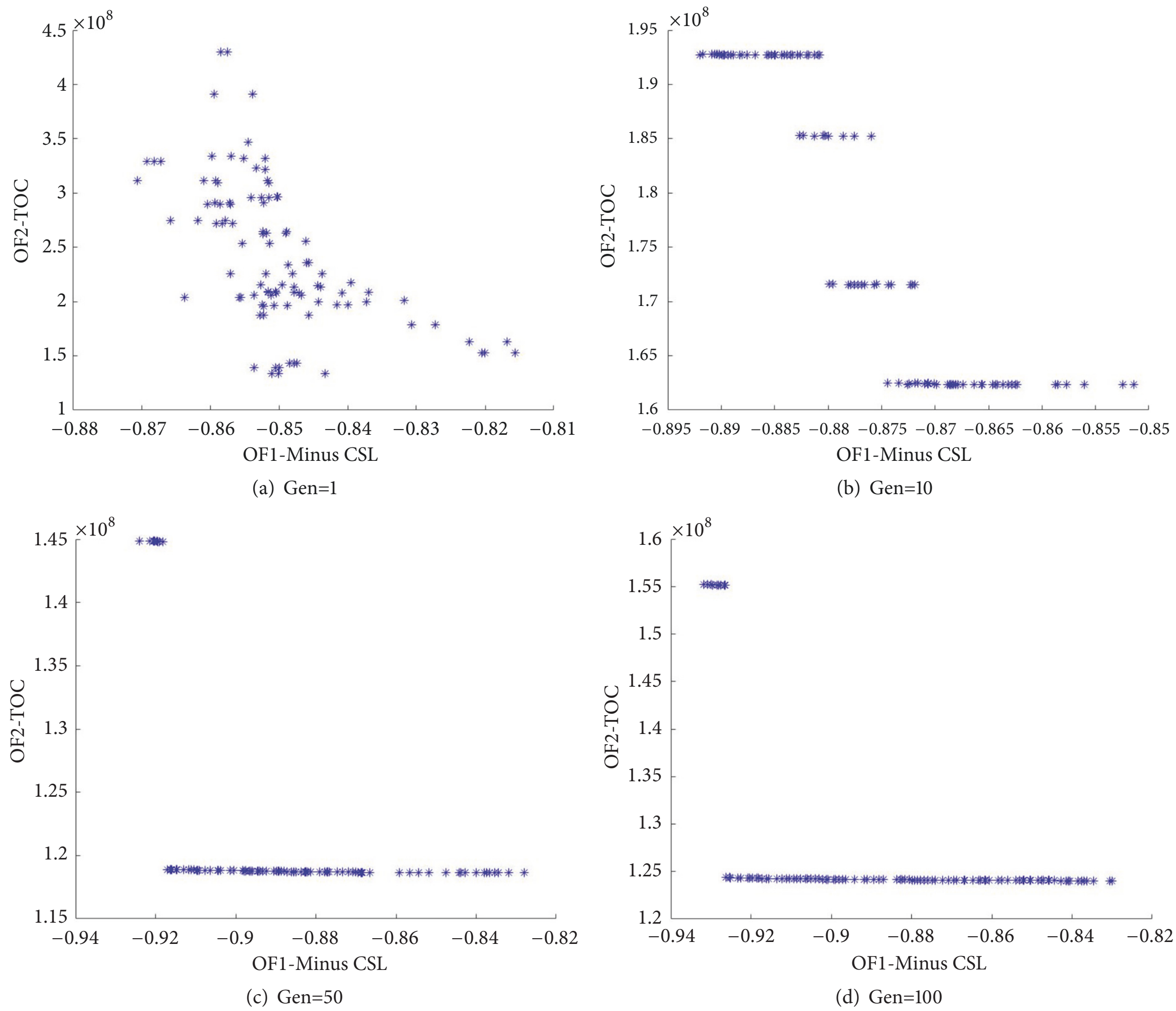


Figure 6: Pareto Front in the population of 100. Gen is the number of total generations. CPU time from (a) to (d) are 8.70s, 76.77s, 297.52s, and 508.42s, respectively.

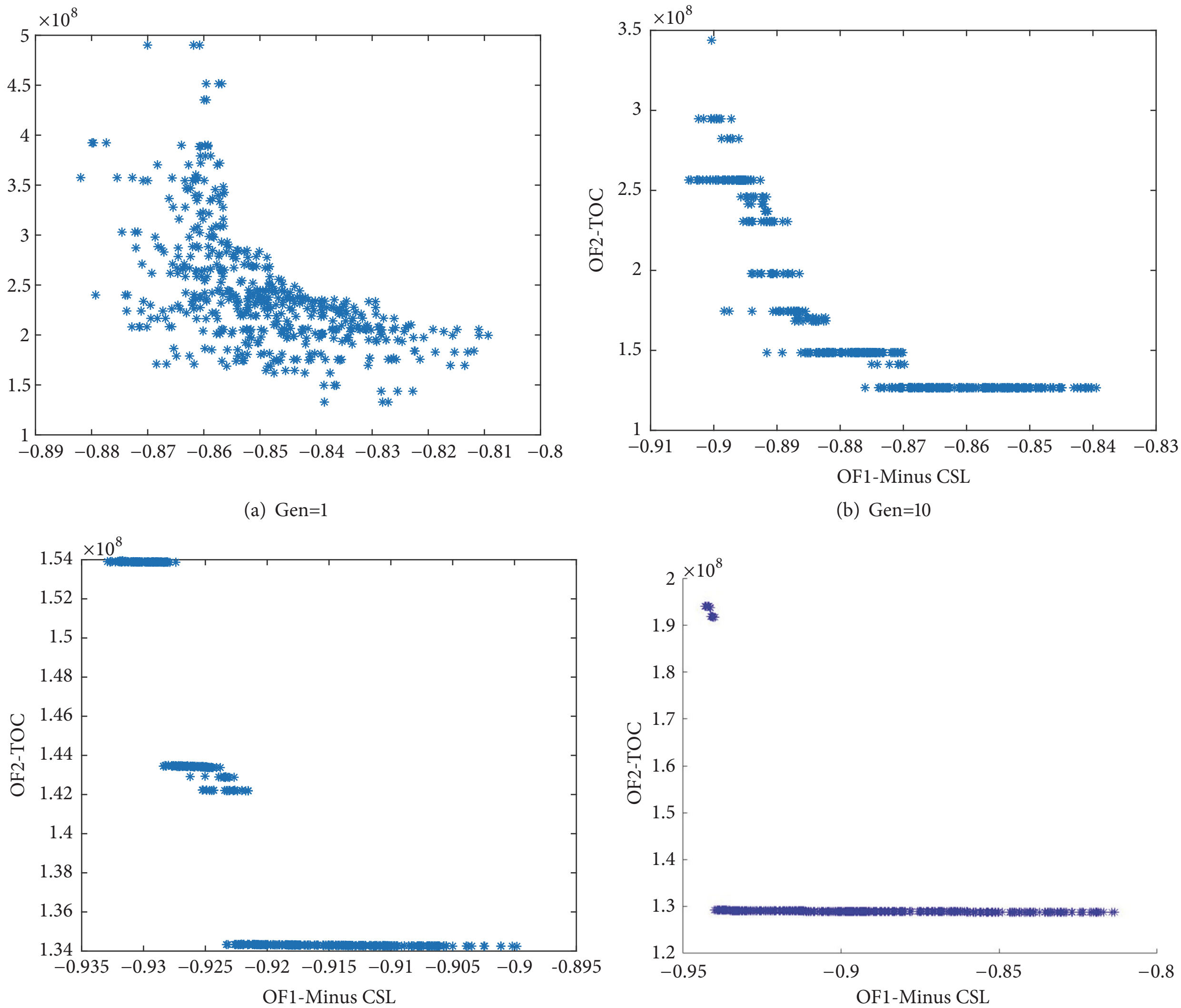
Table 4: Original value of the objectives of the case.

Objective	Initial Value
TOC	£ 219,290,000
CSL	46.00%

each kilometre is 5,900 pounds/km. Therefore, applying these imaginary data into the equations (1) and (2), we can obtain the initial value of two objectives of the enterprise as shown in Table 4 and then input the original numbers into the software for optimisation.

7.2. Results. With the various inputs of population size (i.e., 50, 100, 500, and 1000) and the number of total generations (i.e., 1, 10, 50, and 100), Figures 5, 6, 7, and 8 can be obtained for the Pareto Front in each context.

Each of Figures 5, 6, 7, and 8 illustrates that with the increase of the number of total generations, Pareto Front is growing to be mature and converged and, apparently, it is best when the number is 100. In addition, when fixing the number of total generations at 100, compared to the results of a different number of population sizes, it also implies a different number of final total fitness evaluations. In the case of population size 50, the maximum number of generations is 100 and therefore the number of fitness evaluations is 50x100 = 5000; when population size is 100, the number of fitness evaluations is 100x100= 10000; when population size is 500, the number of fitness evaluations is 500x100 = 50000; and when population size is 1000, the number of fitness evaluations is 1000x100=100000. Meanwhile, the observation to these four figures (i.e., Figures 5(d), 6(d), 7(d) and 8(d)) leads to the best selected outcome on the objectives TOC and Minus CSL (shown in Figures 8(d) and 9), which also has implied the higher computational effort. In this case, we can obtain the good compromise solutions in the fitness evaluations of 100000. The detailed data can be seen in Appendix B on the web page we created [67]. Extracted from Pareto Front, four good compromise solutions indicate the diverse advantages



(a) Gen=1 (b) Gen=10

(c) Gen=50 (d) Gen=100

Figure 7: Pareto Front in the population of 500. Gen is the number of total generations. CPU time from (a) to (d) are 76.12s, 823.68s, 2182.93s, and 4581.32s, respectively.

for the improvement of TOC or CSL, which can be seen in Figure 10.

Figure 10 shows that each good compromise solution gets a considerable promotion on each of the two aimed objectives. Compared to the initial network, from GCS1 to GCS4, each solution runs with the reduction of TOC by 33.17%, 43.85%, 51.70%, and 56.75% and an average increase of CSL by 105%. On the other hand, the lowest TOC can be reached in GCS4 with a tolerable loss of CSL in contrast to the other good solutions (e.g., loss of 0.75% compared to GCS1). Therefore, it is evident that Good Compromise Solution 4 is the best preferred solution to the decision maker in the experiment, so its details in terms of location of selected CDC and allocation of each BS and PS (i.e., connections between BS, PS and CDC) are visually present in Figure 11. For specific data it can be seen in Appendix B on the web page we created [67].

Figure 11 shows the entire optimised network for the imaginary company that (a) indicates the locations of selected CDCs, (b) and (c) respectively disclose the links between assigned BSs, PSs, and CDCs allocated to, and (d) shows the finally entire optimal network which can support the logistics of both items A and B with the TOC of 94,850,000 pounds and CSL of 93.85%. Such a solution can help the enterprise of the case deals with tourism logistics of both items A and B while reducing TOC by 56.75% and increasing CSL up to 93.85% from the original 46%.

8. Conclusion

This paper develops an MOO-CFLP model for the optimisation of tourism logistics network and presents a computational case for the application. First of all, both of items A and B of tourism logistics are focused that can simultaneously

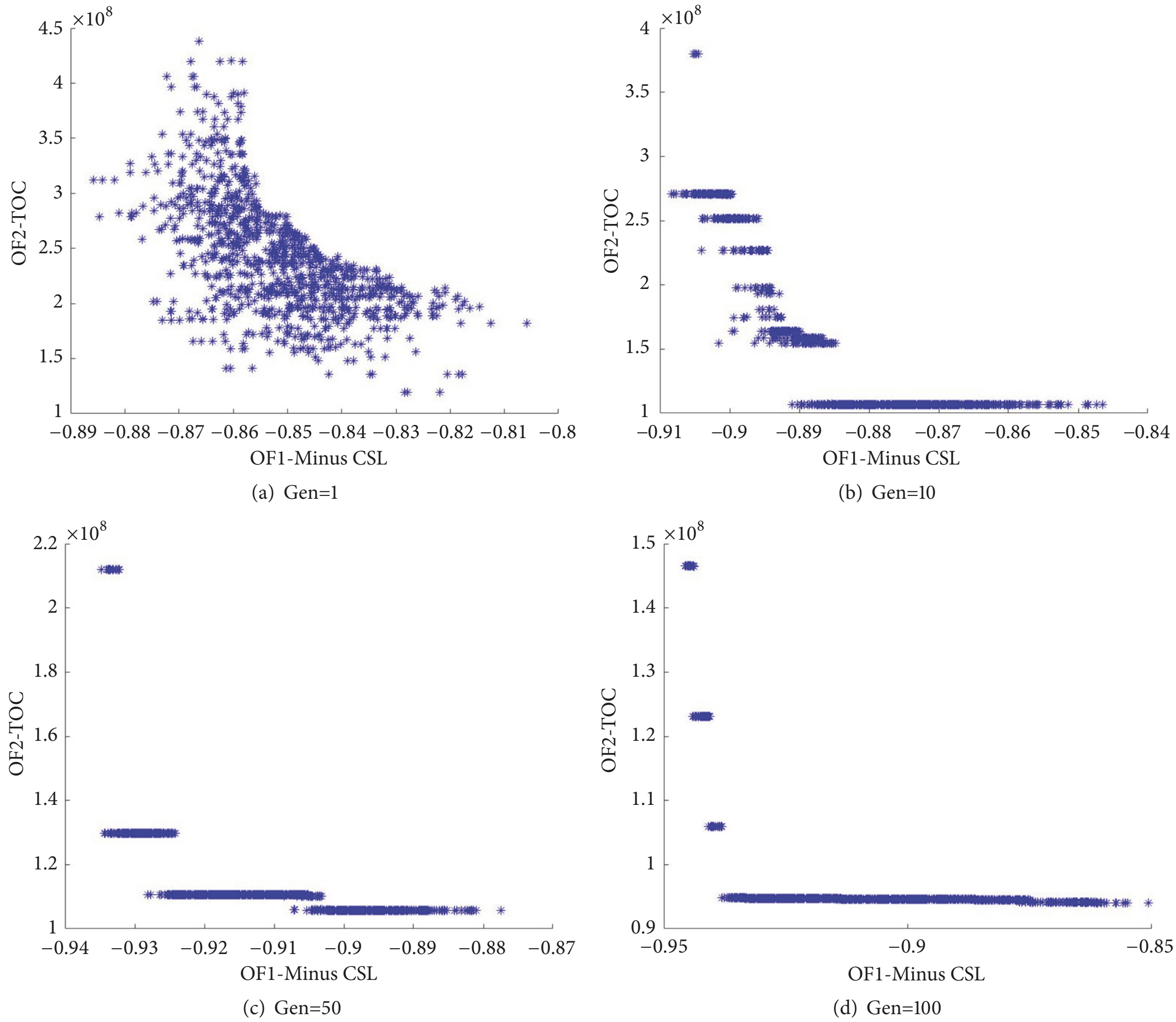


Figure 8: Pareto Front in the population of 1000. Gen is the number of total generations. CPU time from (a) to (d) are 224.46s, 2540.31s, 11199.90s, and 24304.86s, respectively.

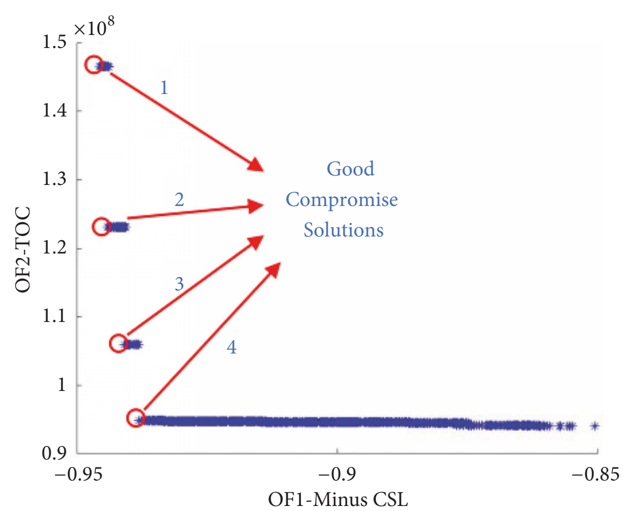


Figure 9: Good compromise solutions for the case.

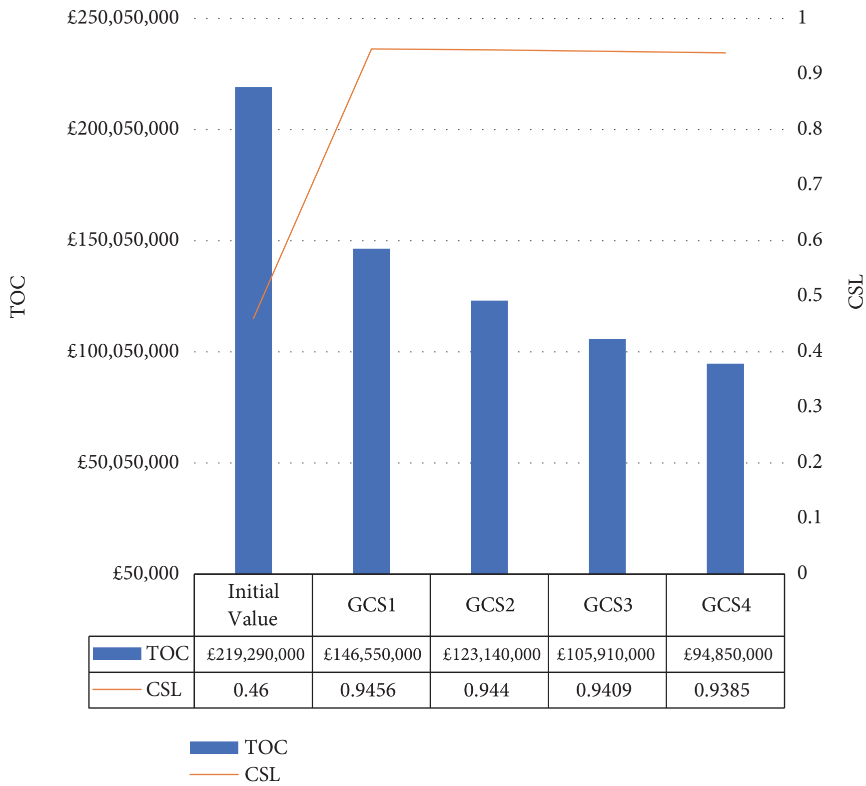


Figure 10: Comparison between the initial case and good compromise solutions. GCS1 is Good Compromise Solution 1, GCS2 is Good Compromise Solution 2, GCS3 is Good Compromise Solution 3, and GCS4 is Good Compromise Solution 4.

contribute to the improvement of travel experience of tourists and the optimisation of the logistics activity of tourism agency. Then, we propose a simple framework to enable tourism logistics company to deal with the logistics of both items A and B where three elements are needed and named as Basic Site (BS), Production Site (PS), and Collection and Distribution Centre (CDC). In addition, we prove that there is only the materials flow of items B in the linkage between CDCs, followed by the establishment of a tourism logistics MOO-CFLP model with the objectives of TOC and CSL.

With a set of imaginary data for the illustrative case, NSGA II approach is used to solve the model established in the paper. The consequences of the computations indicate that it reaches the best maturity and convergence with the population size of 1000 and 100 generations. More importantly, the results of the optimisation using the model proposed in the paper present nondominated solutions with the clarification of the solutions of location and allocation in tourism logistics network, enabling a significant reduction of TOC and considerable growth of CSL for tourism logistics services.

With contrast to the present tourism logistics-related studies, this paper fills the gap of tourism logistics network planning and conducts the research in a quantitative way. While compared to the current multiobjective CFLP models, the distinctions of our model are that for the optimisation of both TOC and CSL, the uncertainty of demand has been incorporated into the model, CFLP of tourism logistics network has been handled, and the subject matters coped with are both items A and B which is the most different point.

Overall, this paper provides a mathematical technique for managers and researchers who are interested in the optimisation of tourism logistics network with considerations of uncertain demand. However, in this study there is an assumption and a limitation for the model, which are related to Vehicle Routing Problem and the boundary of tourism logistics activity. In this regard, further studies on the transformation of the assumption and limitation to be a part of the model such as being parameters or constraints are recommended at the first place, and comparing the different state of the art evolutionary multiobjective algorithms with statistical significance tests with the NSGA2 is also recommended.

Notations

$V_{bs} = \{1 \ldots i\}$: Set of Basic Sites

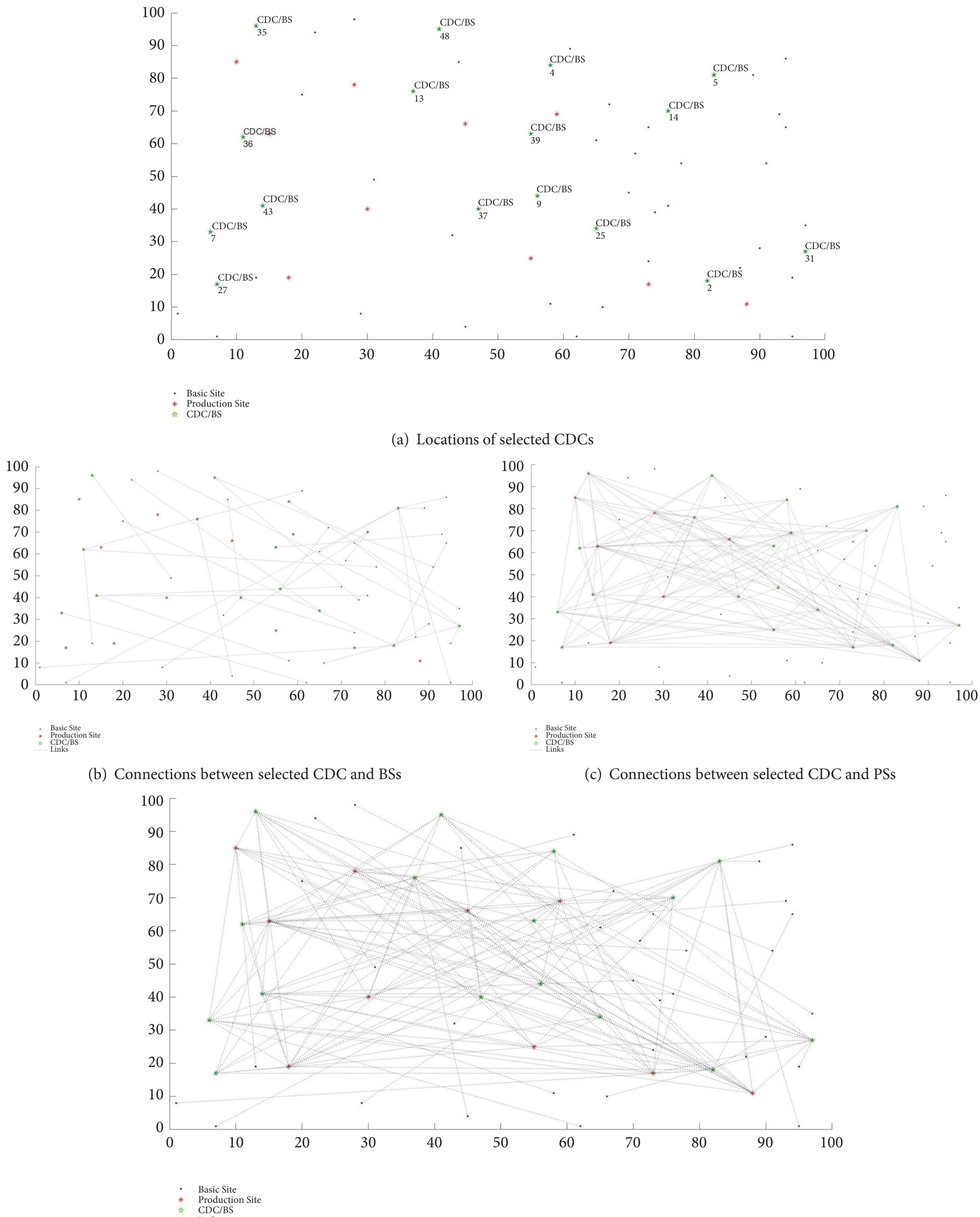
$V_{cdc} = \{1 \ldots j\}$: Set of potential CDCs, equivalent to V_{bs} as a CDC is selected amongst BSs

$V_{ps} = \{1 \ldots k\}$: Set of Production Sites

${ddpt^A}_i$: Average demand of items A during a periodic time in BS_i, $i \in V_{bs}$

${ddpt^A}_j$: Average demand of items A during a periodic time in CDC_j, $j \in V_{cdc}$

${ddpt^B}_i$: Average demand of items B during a periodic time in BS_i, $i \in V_{bs}$



(a) Locations of selected CDCs

(b) Connections between selected CDC and BSs

(c) Connections between selected CDC and PSs

(d) Final optimal network

FIGURE 11: Location and allocation of Good Compromise Solution 4.

$ddpt^B{}_j$: Average demand of items B during a periodic time in CDC_j, $j \in V_{cdc}$
n: Number of Basic Sites
m: Number of Production Sites
w: Required number of open CDC(s)
α^A: Periodic operational cost per capacity of items A
α^B: Periodic operational cost per capacity of items B
β: Periodic fixed cost for opening a CDC_j, $j \in V_{cdc}$
TC_{ij}: Transportation cost from BS_i to CDC_j, $i \in V_{bs}$, $j \in V_{cdc}$
TC_{kj}: Transportation cost from PS_k to CDC_j, $k \in V_{ps}$, $j \in V_{cdc}$
TC_{hj}: Transportation cost from CDC_h to CDC_j, $h \neq j \in V_{cdc}$
γ^{AB}: Periodic transportation cost of both items A and B per distance
γ^A: Periodic transportation cost of items A per distance
γ^B: Periodic transportation cost of items B per distance
$d^{bs}{}_{ij}$: Euclidean distance between BS_i and CDC_j, $i \in V_{bs}$, $j \in V_{cdc}$
$d^{ps}{}_{kj}$: Euclidean distance between PS_k and CDC_j, $k \in V_{ps}$, $j \in V_{cdc}$
$d^{cdc}{}_{hj}$: Euclidean distance between CDC_h and CDC_j, $h \neq j \in V_{cdc}$
S_{ik}: Capacity of supply of items A from PS_k to BS_i, $k \in V_{ps}$, $i \in V_{bs}$

Decision Variables

z_j: Equals 1 if potential CDC_j is chosen to operate, and 0 otherwise, $j \in V_{cdc}$, in response to RQ1
x_{ij}: Equals 1 if BS_i is allocated to CDC_j or $i = j$, and 0 otherwise, $i \in V_{bs}$, $j \in V_{cdc}$, in response to RQ2
y_{kj}: Equals 1 if PS_k is allocated to CDC_j, and 0 otherwise, $k \in V_{ps}$, $j \in V_{cdc}$, in response to RQ2
Q_{kj}: Optimal quantity of supply of items A from PS_k to CDC_j, $k \in V_{ps}$, $j \in V_{cdc}$, in response to RQ3
$bq^A{}_i$: Capacity of items A of BS_i, $i \in V_{bs}$, in response to RQ4
$q^A{}_j$: Capacity of items A of CDC_j, $j \in V_{cdc}$, in response to RQ4
$bq^B{}_i$: Capacity of items B of BS_i, $i \in V_{bs}$, in response to RQ4
$q^B{}_j$: Capacity of items B of CDC_j, $j \in V_{cdc}$, in response to RQ4.

Data Availability

All data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Supplementary Materials

The supplementary file includes the initial dataset of the illustrative case proposed in Section 7.1 of the paper, results of good compromise solutions selected in Section 7.2, and MATLAB code of NSGA II executed in Section 6. *(Supplementary Materials)*

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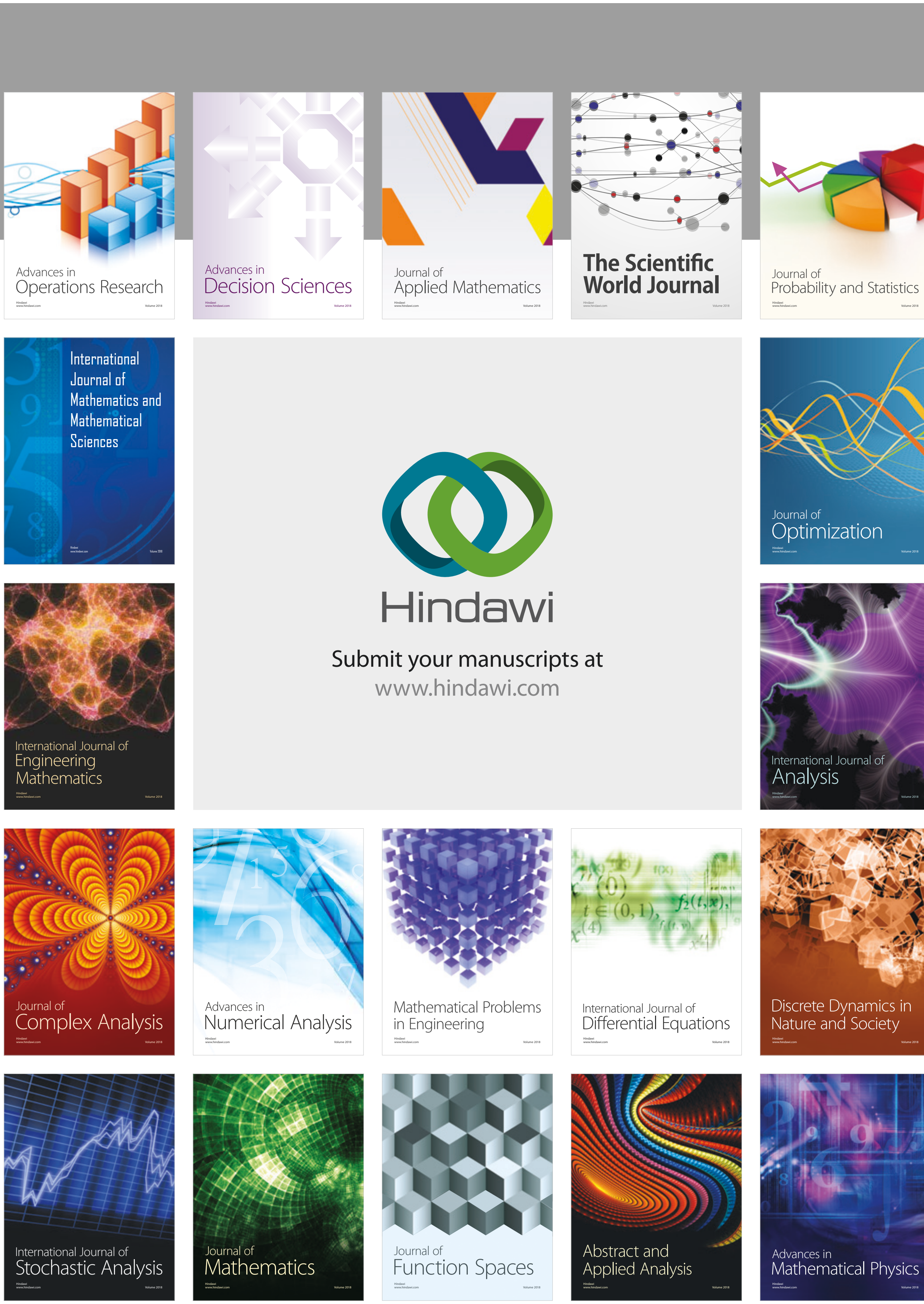
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