World Journal of Information Technology
Print ISSN: 2959-9903
Online ISSN: 2959-9911
DOI: https://doi.org/10.61784/wjit3129

SELECTING ONWARD CONNECTING CARRIERS BEYOND A SINGLE HUB WITHIN AN AIRLINE ALLIANCE

Wei Ge*, Kai Wang
School of Management, Nanjing University of Posts and Telecommunications, Nanjing 210000, Jiangsu, China.
**Corresponding Author: Wei Ge*

Abstract: Regional exclusivity within an airline alliance pushes member carriers to look for cooperation outside the alliance, and the choice of a carrier for the onward connecting segment therefore calls for quantitative judgement. This paper deals with the case in which the onward network radiates from a single beyond hub. Member and non-member carriers are placed in one candidate set; the post-cooperation market share predicted by the quality of service index (QSI) is used as the demand ceiling of each path; and total post-cooperation revenue is maximised. A mixed integer programming model is built with constraints on share, path demand, logical linkage, capacity and path coverage, and it is solved for a China–Europe market in which a large Chinese airline serves seven European beyond points through London Heathrow. All seven paths are covered, 36,591 passengers are carried after cooperation, and total revenue reaches CNY 39.31 million, which is the synergy value created by this round of partner selection. Alliance partners remain the strongest candidates in the case, while non-alliance partners can supplement alliance cooperation on some paths.
Keywords: Air transport; Airline alliance; Partner selection; Quality of service index

1 INTRODUCTION

Airline alliances are the most highly organised form of cooperation in international air transport. Star Alliance, SkyTeam and oneworld connect the individually limited networks of their members into a global product system through code sharing, reciprocal frequent flyer recognition, shared lounges and coordinated hub waves. Writing when alliances were still new, Oum and Park argued that they were not a transitional phenomenon but a long-term arrangement that links continental markets through super-hubs [1]. Brueckner took the economics of code sharing further and showed that the value of an alliance comes from complementary segments and the integration of product attributes rather than from pooling capacity [2]. For an individual carrier, membership matters less for the destinations it adds than for the reach it gives its international product: partner segments before and after the flight carry that product into markets the carrier does not serve itself.

Alliances, however, are not the only channel. They are regionally exclusive: a new member is normally expected to work first with fellow members, an arrangement that lowers coordination costs inside the alliance but also narrows the room for cooperation outside it. In recent years members have increasingly worked with mass-market and other non-member carriers beyond the alliance framework, and these arrangements now sit alongside the mainstream alliance model as a supplement. A concrete decision follows: once the feeder segment and the target route are fixed and passengers must be carried onward in a beyond market, who should operate the onward segment, a partner inside the alliance or a carrier outside it?

The question amounts to comparing partner value under different product attributes. The onward carrier changes the bundle the passenger buys: the reach of the sales network, the convenience of the connection, the efficiency of airport coordination and the continuity of frequent flyer benefits. Different bundles bring different shares and different revenues. Judging by alliance membership or by past relationships cannot by itself secure a sound choice, and evaluating the options route by route by hand becomes unworkable once the number of candidate combinations grows.

Earlier work supplies parts of an answer but not a connected one. Studies of share forecasting settle the question of how many passengers cooperation can bring, yet most of them stop at the forecast and never put it inside a selection decision. Studies of alliance networks usually minimise network or fleet-utilisation cost and take the partner set as a given group of members, so members and non-members never enter the same pool. For the single-beyond-hub case there is still no optimisation model that can be used directly in decisions and whose constraints fit the existing forecasting methods.

This paper works on that gap. Member and non-member carriers share one candidate set; the post-cooperation share predicted by QSI sets the demand ceiling for each path; total post-cooperation revenue is the objective; and a mixed integer programming model is built with constraints on carrier selection, passenger allocation, logical linkage, capacity and path coverage. The model is solved for a China–Europe market in which a large Chinese airline reaches European beyond points through London Heathrow, both to test that it can be solved and to explain what it returns. Compared with a network that spans several hubs, the decision here involves only path and carrier and therefore no hub choice; the multi-hub case is left to a separate paper.

2 LITERATURE REVIEW

© By the Author(s) 2026, under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0).

Three strands bear on this problem: the economic effects and stability of alliance cooperation, methods of forecasting market share, and hub network design together with partner and path choice.

The first strand asks why alliances exist and how the gains are divided. Besides the analyses of alliance motives by Oum and Park and of code-sharing economics by Brueckner [1-2], Chinese work has concentrated on organisation and mechanism. Chen and Xu discussed what makes up an airline's market share on a route and which factors move it, giving later quantitative work a conceptual frame [3]. Zheng and Wang described alliance stability as a dynamic cooperative game and showed that a member's decision to stay depends on the allocation rule rather than on the size of the total payoff [4]. Cong et al. studied network decisions under revenue sharing and tied network design to the distribution of revenue [5]. Mi looked at the organisational forms and preconditions of international route joint ventures [6]. What these studies share is a view of the alliance as a whole and an interest in the terms among members; none of them asks how a single member should choose between an inside and an outside partner.

The second strand is share forecasting, where QSI is the most widely used tool. It scores product attributes — sales network, frequent flyer programme, transfer service and airport coordination — and converts the weighted score into a share. Zhao et al. adapted QSI forecasting to the alliance setting and brought alliance-induced attribute changes into the prediction [7]. Hu et al. proposed a multi-layer QSI for optimising alliance networks [8]. Chen et al. raised forecasting accuracy with a PSO-BP neural network [9], and Deng et al. used a long short-term memory network to capture the time-series behaviour of share [10]. Work outside China has also linked product attributes to share through QSI. The strand delivers reliable forecasts, but the forecast normally stays at the level of evaluation and seldom enters a selection model as a constraint or a parameter.

The third strand joins hub networks to partner and path choice. Hub location and flow allocation have been modelled together since O'Kelly's quadratic integer programme [11]. Ernst and Krishnamoorthy gave a mixed integer linear formulation and exact algorithms for the multiple allocation p-hub median problem [12], and Alumur and Kara reviewed the family of hub location models [13]. In China, Yan and Ma optimised aircraft routeing based on transhipment under route joint ventures and turned cooperation into specific segment combinations [14]. This strand offers mature network tools, but its objective is usually network cost, product attributes do not enter the share, and the question of whom to cooperate with is not a decision dimension of its own.

Between them the three strands cover the ground: alliance studies explain the motives and the division of gains, share studies deliver a forecast of the post-cooperation share, and network studies supply the framework for location and allocation. The link that joins them is still missing, namely how the forecast can constrain a revenue-oriented partner selection model and how members and non-members can be compared inside one candidate set. This paper supplies that link. The QSI forecast becomes the demand ceiling of each path, carrier selection is written as a 0-1 variable, and forecasting and selection close inside a single model.

3 ONWARD CONNECTING CARRIER SELECTION BEYOND A SINGLE HUB

3.1 Problem Description

The model addresses the choice of carrier for the onward connecting flight. The target airline is assumed to have completed the feeder flight and the target route, and what remains is to choose the carrier for the onward market and the beyond points to be served. Taking the flights on the target route of that market as the object of optimisation, and allowing partners to be either alliance or non-alliance carriers, a route-product optimisation model is built to maximise the revenue of the target flights. The share change after cooperation is predicted with QSI, so that the synergy value of the partnership is maximised.

Three boundaries apply. The carrier, schedule and cabin of the feeder and target segments are fixed and lie outside the decision. Demand on each path is given by the O-D market and treated as deterministic, with no change in total demand before and after cooperation. Cooperation cost is represented by the cost of opening a path and involves no negotiation over joint-venture revenue sharing.

3.2 Parameters and Decision Variables

3.2.1 Model parameters

A: set of airlines, covering alliance and non-alliance carriers, $A = A_L \cup A_N$;
J: set of beyond points, that is, all the O-D pairs of the onward connecting paths;
$OpenCost_{ij}$: cost for airline i to open path j;
$Fare_{ij}$: average fare of airline i on path j;
$Cost_j$: seat cost of the target flight;
FQ: current frequency of the target flight;
Seat: number of seats of the aircraft type currently used on the target flight;
PLF: expected passenger load factor of the target flight;
QSI_{ij}: QSI value of airline i on path j;
$SaleNet_i$: sales network score of airline i used in the QSI;
$TransferSV_i$: transfer service score of airline i used in the QSI;
$AptCo_i$: airport coordination score of airline i used in the QSI;

FFP_i: frequent flyer programme score of airline i used in the QSI;
WeightS: coefficient of the sales network in the QSI; WeightT: coefficient of transfer service; WeightA: coefficient of airport coordination; WeightF: coefficient of the frequent flyer programme;
D_j: passenger demand of O-D market j;
$TotalQSI_j$: sum of the QSI values of all carriers currently operating in O-D market j;
M: a sufficiently large number.

3.2.2 Decision variables

$x_{ij} \in \{0, 1\}$: whether airline i operates path j;
pax_{ij}: number of passengers carried by airline i on path j after optimisation;
$NewQSI_{ij}$: QSI value of airline i on path j after optimisation. The new value equals the original value plus the change in QSI produced on that path:

$$NewQSI_{ij} = QSI_{ij} + x_{ij}(WeightS \cdot SaleNet_i + WeightT \cdot TransferSV_i + WeightF \cdot FFP_i + WeightA \cdot AptCo_i)$$

Revenue: total revenue of all airlines on all paths after cooperation. The difference between the post-cooperation and pre-cooperation totals is the synergy value. Because pre-cooperation revenue is fixed, the model maximises post-cooperation revenue, and the partner selection model is formulated as follows:

3.3 Partner Selection Optimisation Model

$$\max Revenue = \sum_{i\in A}\sum_{j\in J}\left(Fare_{ij}pax_{ij} - x_{ij}OpenCost_{ij} - Cost_j \cdot FQ \cdot Seat \cdot x_{ij}\right) \quad (1)$$

$$pax_{ij} \le D_j NewQSI_{ij}/TotalQSI_j,\ \forall i \in A, j \in J \quad (2)$$

$$\sum_{i\in A} pax_{ij} \le D_j,\ \forall j \in J \quad (3)$$

$$pax_{ij} \le Mx_{ij},\ \forall i \in A, j \in J \quad (4)$$

$$pax_{ij} \le FQ \cdot Seat \cdot PLF,\ \forall i \in A, j \in J \quad (5)$$

$$\sum_{i\in A} x_{ij} \ge 1,\ \forall j \in J \quad (6)$$

$$x_{ij} \in \{0, 1\},\ \forall i \in A, j \in J \quad (7)$$

Here the objective is total revenue. Constraint (2) requires that the passengers carried by airline i on path j do not exceed the QSI-predicted demand for airline i on that path. Constraint (3) keeps the total passengers on path j within the predicted demand. Constraint (4) is a logical condition: if airline i does not open path j, its passengers on that path are zero, with M a sufficiently large number. Constraint (5) bounds passengers by available seats. Constraint (6) requires at least one airline to open path j.

If management simplicity or negotiation cost leads the decision maker to restrict each path to a single carrier, constraint (6) is replaced by:

$$\sum_{i\in A} x_{ij} = 1,\ \forall j \in J \quad (8)$$

4 CASE STUDY

4.1 Case Data

The case data come from a field survey of a large Chinese airline. A SkyTeam member with a stable schedule on China–Europe routes, it operates the feeder and target segments in the case. The alliance partners considered for the onward segment are KLM (KL) and Alitalia (AZ), both SkyTeam members, and the non-alliance partner is British Airways (BA). The target market is the European beyond market reached through London Heathrow (LHR), with seven beyond points: Amsterdam (AMS), Rotterdam (RTM), Rome Fiumicino (FCO), Milan Linate (LIN), Venice (VCE), Lyon (LYS) and Paris Charles de Gaulle (CDG). These give seven onward paths and fourteen candidate combinations.

The vintage of the data needs a word. After 2019 the air transport market absorbed a series of external shocks, and capacity, fares and demand became far more volatile, so data from several of those years no longer describe a stable competitive relationship; taking recent cross-sectional data would let abnormal conditions drive both the calibration and the reading of the results. Historical data from before 2019 are therefore used, so that the model inputs reflect normal competition.

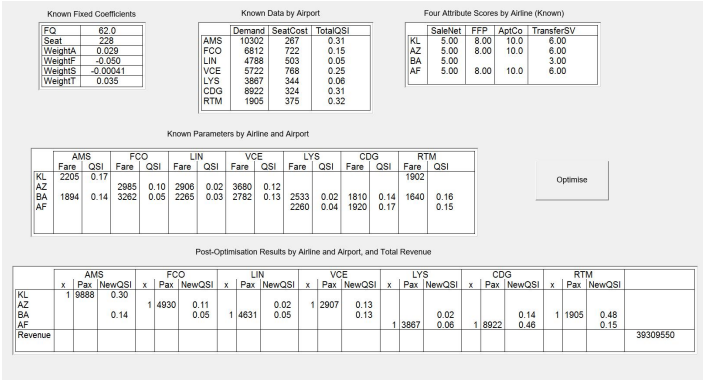


Figure 1 Fitted QSI Attribute Coefficients

The survey puts seat cost at roughly CNY 0.3–0.7 per kilometre, lower for larger aircraft and longer stages. All stages here are within 2,000 km and mostly C-class aircraft are flown, so the aircraft is taken to have 228 seats, the monthly frequency to be 62, and the cost of opening a path to be CNY 100,000. The QSI coefficients fitted to the survey data give the weights of the sales network, frequent flyer programme, transfer service and airport coordination, as shown in Figure 1.

The other target-flight data required by the optimisation are given in Table 1.

Table 1 Target Flight Data

Airline	Arrival airport	Average fare (CNY)	Average seat cost (CNY)	O-D demand (passengers)	QSI value	Sales network score	Frequent flyer score	Transfer service score	Airport coordination score
BA	AMS	1894	267	10302	0.14	5	0	3	0
KL		2205			0.17	5	8	10	6
BA	RTM	1640	375	1905	0.16	5	0	3	0
KL		1902			0.15	5	8	10	6
BA	FCO	3262	722	6812	0.05	5	0	3	0
AZ		2985			0.10	5	8	10	6
BA	LIN	2906	503	4788	0.03	5	0	3	0
AZ		2265			0.02	5	8	10	6
BA	VCE	2782	768	5722	0.13	5	0	3	0
AZ		3680			0.12	5	8	10	6
BA	LYS	2533	344	3867	0.03	5	0	3	0
AF		2260			0.04	5	8	10	6
BA	CDG	1810	324	8922	0.14	5	0	3	0
AF		1920			0.17	5	8	10	6

Note: Data from the field survey of Airline M; AMS, RTM, FCO, LIN, VCE, LYS and CDG denote Amsterdam, Rotterdam, Rome Fiumicino, Milan Linate, Venice, Lyon and Paris Charles de Gaulle airports.

Whether a partner belongs to the alliance shows up in the four attributes of the QSI model. The scores in Table 1 were produced by the expert scoring method: specialists from the international affairs department of Airline M assigned them.

4.2 Solution Results

The model was solved on the AIMMS optimisation platform under an open partnership. Optimised total revenue is CNY 39.30 million. Had the two sides not cooperated, pre-cooperation revenue would be zero, so the synergy value of this partner selection equals the whole CNY 39.30 million. The results are listed in Table 2.

Table 2 Optimisation Results

Airline	Arrival airport	Selected for this path (1 = yes, 0 = no)	QSI value	Passengers carried
BA	AMS	0	0.14	0
KL		1	0.30	9888
BA	RTM	1	0.48	1905
KL		0	0.15	0
BA	FCO	1	0.19	4960
AZ		0	0.11	0
BA	LIN	1	0.05	4631
AZ		0	0.02	0
BA	VCE	0	0.13	0
AZ		1	0.13	2970
BA	LYS	1	0.06	3315
AF		0	0.04	0
BA	CDG	0	0.14	0
AF		1	0.46	8922

Note: In the selection column, 1 means the carrier is selected and 0 means it is not; QSI values are those after cooperation.

Table 2 shows that, after optimisation, the partner for RTM, LIN and FCO can all be the non-alliance carrier BA, while the remaining paths go to alliance members; together these choices carry 36,591 passengers. Alliance partners are still the strongest candidates, but on some routes a non-alliance partner is a useful supplement to alliance cooperation. The case thus supports the model and method proposed here as an aid to carrier selection.

5 CONCLUSIONS

This paper has dealt with onward connecting carrier selection beyond a single hub in an alliance setting: the post-cooperation share predicted by QSI sets the demand ceiling of each path, total post-cooperation revenue is the objective, alliance and non-alliance carriers sit in one candidate set, and cost is made up of a path-opening charge and a seat cost

measured by deployed capacity. Model size follows the number of candidate combinations, and branch and bound solves it directly.

The case yields three findings. First, alliance partners remain the strongest candidates: of the seven paths, most are served by the alliance carrier based at that airport, which is consistent with the natural advantage such a carrier holds in sales network, frequent flyer programme and airport coordination. Second, a non-alliance partner can be a useful supplement: in some beyond markets the attribute gain from an outside partner is enough to win the share comparison, and such cooperation should not be ruled out by the exclusivity of the alliance. Third, the model turns the question of whether to work with an outside carrier into a computable one, namely on which path, with which carrier, and for how much attribute gain.

Some limits remain. The model is single-hub and assumes deterministic demand, so the effect of demand fluctuation on the choice is not represented. Attribute scores come from expert judgement and the weights from an existing fit, and both will date as market structure and products change. Seat cost is converted at a uniform unit rate, so the non-linearity that stage length and aircraft type introduce is not captured. The model also selects carriers at path level and does not yet allow for the joint effect of product substitution and competition when several carriers share a path.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

This study was supported by the Humanities and Social Sciences Youth Fund Project of the Ministry of Education of China (20YJC630024).

REFERENCES

[1] Oum T H, Park J H. Airline alliances: current status, policy issues, and future directions. Journal of Air Transport Management, 1997, 3(3): 133-144.
[2] Brueckner J K. The economics of international codesharing: an analysis of airline alliances. International Journal of Industrial Organization, 2001, 19(10): 1475-1498.
[3] Chen W, Xu L. Market share of airline routes. Journal of Civil Aviation University of China, 2006, 24(2): 30-33.
[4] Zheng S, Wang H. Stability of airline alliances based on dynamic cooperative game theory. Systems Engineering — Theory & Practice, 2009, 29(4): 184-192.
[5] Cong X, Li S, Cui Y. Decision model for airline alliance networks under revenue sharing. Industrial Engineering Journal, 2014, 17(6): 103-110.
[6] Mi G. Development of joint venture models for international airline routes. Comprehensive Transportation, 2014, 36(11): 59-64.
[7] Zhao X, Zhu J, Ge W. Market share forecasting for international routes under airline alliances. Journal of Transportation Systems Engineering and Information Technology, 2018, 18(2): 33-39.
[8] Hu H, Zhu J, Ge W, et al. Optimisation of airline alliance networks based on multi-layer QSI. Journal of Wuhan University of Technology (Transportation Science and Engineering), 2016, 40(5): 880-884, 890.
[9] Chen X, Zhu J, Liu Y. Market share forecasting for alliance routes with a PSO-BP algorithm. Journal of East China Jiaotong University, 2020, 37(1): 61-69.
[10] Deng Q, Duan P, Qiu W. Route market share forecasting with a long short-term memory network. Journal of Shanghai University of Engineering Science, 2021, 35(1): 61-66.
[11] O'Kelly M E. A quadratic integer program for the location of interacting hub facilities. European Journal of Operational Research, 1987, 32(3): 393-404.
[12] Ernst A T, Krishnamoorthy M. Exact and heuristic algorithms for the uncapacitated multiple allocation p-hub median problem. European Journal of Operational Research, 1998, 104(1): 100-112.
[13] Alumur S A, Kara B Y. Network hub location problems: the state of the art. European Journal of Operational Research, 2008, 190(1): 1-21.
[14] Yan Y, Ma X. Aircraft route optimisation based on transhipment under route joint ventures. Journal of Beijing University of Aeronautics and Astronautics, 2023, 49(1): 115-127.