Airline Network Design

Yizeng Zhou
Tandon School of Engineering
New York University
Brooklyn, United States of America
yz8467@nyu.edu

Ruike Qiu
Tandon School of Engineering
New York University
Brooklyn, United States of America
rq2046@nyu.edu

***Abstract*—This study presents a model for small startup airline companies to design an efficient airline network.**

***Index Terms*—network, routing, small-scale**

I. Introduction

Airline industry is important to our daily life. In the recent years, there are more and more small startup airline companies who wanted to enter the market and compete with the giants. However, the existing research on airline network were mainly targeting big companies, which would add some unnecessary factors to the model. In this paper, we present a model mainly targeting small startup airline companies by minimizing the total distance to connect the network.

II. Related Research

The most popular existing model for airline industry is the hub and spoke model. According to [1], there are multiple variants of this model such as different number of hubs and spatial constraints. However, after we compared them carefully, we found that existing models don't fit well for small startup companies because of the unnecessary cost of hubs. Especially for multiple hubs network, the cost of having additional routes for connecting every hubs is too costly for small airline companies. For small companies, we think the best way to obtain more profits is to minimize the cost and eventually lower the ticket prices. The term "Southwest Effect" described in [2] by US Department of Transportation indicates that a new airline company entering the market with lower ticket price "usually enjoyed a near-monopoly in the community." As a result, our idea is to avoid long flights and prefer more short flights, and we will connect all cities by minimizing the total distances.

III. Model

$Indices$
$v = 1, 2...V$
$e = 1, 2...E$
$d = 1, 2...D$

$Constants$
i_e originate node of link e
j_e terminate node of link e
src_d source node of demand d
dst_d destination node of demand d
$cost_e$ cost of link e
M a large number

$Variables$
$active_e$ if the link e is used to build the network
$dactive_{dv}$ if the flow of demand d passed node v
x_{de} if demand d used the path consisting link e

$Objective$

$$minF = \sum_{e=1}^{E} active_e * cost_e$$

$Constraint$

$$\sum_{e=1, i_e=v || j_e=v}^{E} x_{de} = 1, v = 1...V, d = 1...D, src_d = v || dst_d = v$$

$$\sum_{e=1, i_e=v || j_e=v}^{E} x_{de} = 2, v = 1...V, d = 1...D, src_d \neq v \&\& dst_d \neq v$$

$$\sum_{d=1}^{D} x_{de} \leq active_e * M, e = 1...E$$

$$\sum_{e=1, i_e=v || j_e=v}^{E} x_{de} <= dactive_{dv} * M, v = 1...V, d = 1...D$$

A. Explanation

In our model, the link is undirected, so i_e and j_e is just used to get the vertices of link. There will be total $V * V - 1$ demands to indicate all cities need to be connected. The large number M is used to compute the binary variables, $active_e$ and $dactive_{dv}$. The main logic behind the first constraint is that if a node is the source or destination of the demand, then the number of active links for this demand around it should be just one(either outgoing for source node or incoming for destination node). For the second constraint, if a node is neither the source node nor the destination node, then there should be two active links for this demand, which one of them represents the incoming flow and the other one represents the outgoing flow.

B. Algorithm

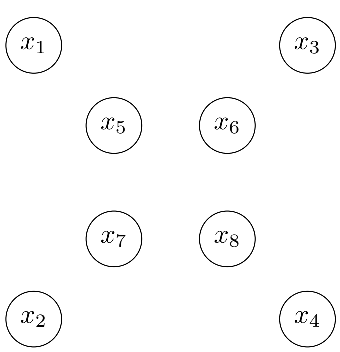
Our problem and model could be simplified as finding the minimum spanning tree of a given graph. We could solve it using Kruskal's algorithm [3].

- Sort all links with respect to cost, from lowest to highest, mark all nodes unvisited
- Remove the link with lowest cost, check if it will create a cycle in the network
- If so, discard it, if not, make nodes visited, and add the link to network
- Repeat step 2 if still nodes not visited.
- If no nodes left, stop.

C. Complexity

The algorithm's complexity is seperated into two parts, sorting the links which is going to take $O(E * \log E)$, and detect cycle using union find algorithm which is going to take $O(E * \log V)$, so this is going to take overall $\max(O(E * \log E), O(E * \log V))$

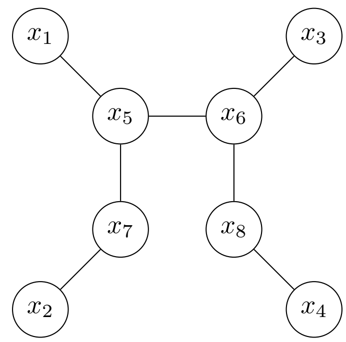
IV. Evaluation



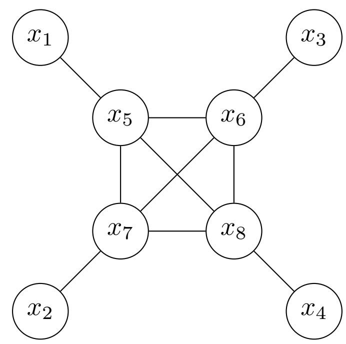
A. Comparison Study

We used a simple eight node network to do the comparison study, the hub and spoke model solution is already displayed in [1], which center four node are hubs, which would give us a result of 44, while our model will have a result of 30 by running in ampl.

B. Our model



C. Hub and Spoke model



D. Results

TABLE I
TEST RESULT

Model	Performance
Our model	30
Hub and Spoke	44

E. Real life example

We also computed the distance among top 11 cities in the US, and convert it into an ampl data file. Our model successfully build the network with the minimum distance. Fig.1 shows the result.

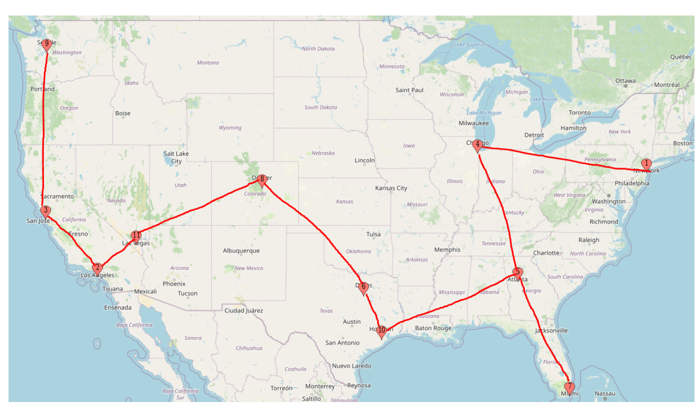


Fig. 1. Example of a figure caption.

V. Conclusion

The test result shows that our model outperform the hub and spoke model. This shows that our model indeed could help to solve airline network design problem for small startup airline companies. In the future study, we would like to focus on adding additional factors such as city population, staff cost, etc to improve our model. We also would explore the possibility of extending our model to intercontinental airline network.

References

[1] M. E. O'Kelly and H. J. Miller, "The Hub Network Design Problem: A Review and Synthesis," The Journal of Transport Geography, vol. 2, no. 1, pp. 31–40, 1994. doi:https://doi.org/10.1016/0966-6923(94)90032-9.

[2] R. D. Bennett and J. M. Craun, The Airline Deregulation Evolution Continues: The Southwest Effect. Washington, D.C. Office, 1993.

[3] J. B. Kruskal. On the shortest spanning subtree of a graph and the traveling salesman problem. Proceedings of the American Mathematical Society, 7:48-50, 1956.