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RESULTS FROM A DYNAMIC MODEL OF CARGO FLOW MANAGEMENT OF A NETWORK AIR CARRIER

We discuss a dynamic model for managing network traffic flows of a network air carrier based: (i) on a detailed analysis of the pre-existing freight traffic along the routes of the air carrier network in terms of the volume of cargo being transported and the fares for key destinations, and (ii) on the analysis of current data on the existing traffic of the network air carrier. We observe irregularity in the freight traffic and fluctuations in the demand and in the fares with respect of the different destinations.
JEL: C6; R42; L93

Introduction

Research on flows in networks increases steadily in the last years (Ford Jr., Fulkerson, 2010; Newman, Barabasi, Watts, 2006; Vitanov, Vitanov, 2016, p. 108-114; Vitanov, Vitanov, 2018, p. 1277-1294). Much attention in this research is devoted to the issues of network modeling of air traffic, e.g., (i) shape of airline networks are measured by means of the methods of the social network analysis (Alderighi, Cento, Nijkamp, Rietveld, 2007, p. 529-549); (ii) networks of airports are studied (Opsahla, Agneessensb, Skvoretz, 2010, p.

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245-251); (iii) the concentration of the network air carriers on certain hubs is evaluated (Scholz, von Cossel, 2011, p. 62-70; Burghouwt, 2007). In (Gallego, Iyengar, Phillips, Dubey, 2004), a deterministic linear programming model was proposed that is based on the selection of the management of the customer choice for the case of airline carrier's network. In connection with this in (Lytvynenko, 2011, p. 83-88) the selection of a common set of activities and tools of economic and organizational nature was studied for the implementation of the process of re-engineering business processes at freight airlines and in (Lurkin, Garrow, Higgins, Newman, Schyns, 2017, p. 228-246) network planning model predicting the profitability of airlines has been discussed on the basis of multi-criteria solutions, including decisions on equipment acquisition and a route selection model for distribution of the total demand for various routes. A comprehensive analysis of the references mentioned above has revealed the absence of any effective mechanisms for implementing a freight carrier's network management system based on logistics. This fact led some of us to study additional models of the network carrier traffic flows (Voitsehovskiy, Gabrielova, Grygorak, 2017, p. 69-74; Voitsehovskiy, 2017, p. 50-55) and the study below is a continuation of the studies in these articles. Let us note here that we shall not describe in details below the long mathematical equations connected to the used model (interested reader can see such equations, e.g., in (Gallego, Iyengar, Phillips, Dubey, 2004; Voitsehovskiy, 2017, p. 50-55). Instead of this on the basis of the available data and computer simulations based on the model equations we shall present briefly our findings.

Data and results

The task of managing airline freight traffic of an airline network is an example of the problem of mathematical modeling of transportation networks. The dynamic model of the network carrier's air cargo flows assumes a higher dimension, continuous variables, fixed demand and transportation prices, and the cargo is considered as a part of the flow. Before making any calculations, it is necessary to conduct a detailed analysis of freight traffic along the routes of the network airline carrier. We have taken as a basis the volumes of freight transportation and fares of the former leader on the aviation market in Ukraine – Aerosvit Airlines as the initial data array. By analyzing data of Aerosvit Airlines for the period 2008-2012[8], the following observations are made.

1. During the above period, more than 65,000 shipments have been completed, out of which we have selected shipments between the cities of Almaty, Kiev, New York, Beijing and Tbilisi. The sample used for the analysis below accounted for about 14 thousand shipments. The traffic volumes of Aerosvit Airlines between the cities of Almaty, Kiev, New York, Beijing and Tbilisi for 2008-2012 are shown per week in Figure 1.
2. The largest traffic volumes were accomplished along the destination Kiev – New York, and yet the majority of these cargoes were transported in the opposite direction at a rate

[8] "AeroSvit" PJSC. Regular information (2017). Available at: https://smida.gov.ua/db/emitent/report/year/show/122213.

of 2-2.5 USD/kg, whereas by a direct flight a certain amount of cargo was delivered at rates ranging from 3 to 6 USD/kg. This is explained by the different traffic flows. The final rates of Aerosvit Airlines for transportation of goods between the points Almaty, Kiev, New York, Beijing and Tbilisi for 2008-2012 are shown on a weekly basis in Fig.

3. Considerable discrepancies in fares are also observed for the route Kiev- Beijing, as the direct flight fare is USD 1.5-2 / kg, whereas the return fare is USD 4-5 / kg.
4. Along the route Kiev-Almaty much larger amount of cargo is transport in the comparison to the cargo flow on Almaty-Kiev flights. However, by analyzing the fares in the direction of Kiev-Almaty, it should be noted that they fluctuate within the range of USD 1.5 to USD 2/kg, whereas in the opposite direction they are slightly higher and vary from USD 2/kg to USD 6/kg.
5. We note that the freight traffic and the amount of the fare for transportation in the direction of Kiev-Tbilisi in direct communication are considerably greater as compared to the opposite direction.

We have used the above data in the implemented models as described in [9,12,13] and we have performed series of computational experiments. As a result of these experiments we note that the models are capable to supply information about: systematize the process of cargo flow traffic management by the network air

1. Maximization of transportation revenue, exclusive of storage costs. Within the process of solving the problem, it is decided which cargo needs to be urgently shipped, and the cargo is to be dispatched to the carrier for storage.
2. It is also possible to reject the carriage of certain goods. It is believed that there is a specific demand for each period, for each cargo category and for each pair of airports. We note that a cargo category is to be understood as an abstract category of division into parts, which is embedded in a set. A three-dimensional table is generated, where each cell is considered as an element of this set, namely, urgent shipments, non-urgent shipments and that for each and every period.
3. There is a certain demand that the airline is capable to satisfy, i.e., it systematizes the process of cargo flow traffic management by the network air capable of providing transportation, and it may also refuse to carry out transportation.
4. The dynamic model decides what kind of cargo will be transported by a network air carrier, on the grounds of the capabilities, priorities, restrictions of the capabilities of the airline as regards delivery. The model selects those units of cargo that generate the highest revenue and require the lowest storage costs, while the restrictions indicate that the airline is not able to accept a cargo greater than the demand thereof plus those units of cargo that are left for storage at the airport. Those units of cargo that have been left for storage are picked up by the airline while the new ones are left for storage.

Figure 1

Carriage volumes of Aerosvit Airlines between the cities of Almaty, Kiev, New York, Beijing and Tbilisi in 2008-2012 by weeks, in kg. The filled circles are for the corresponding week of the year (when cargo was delivered)

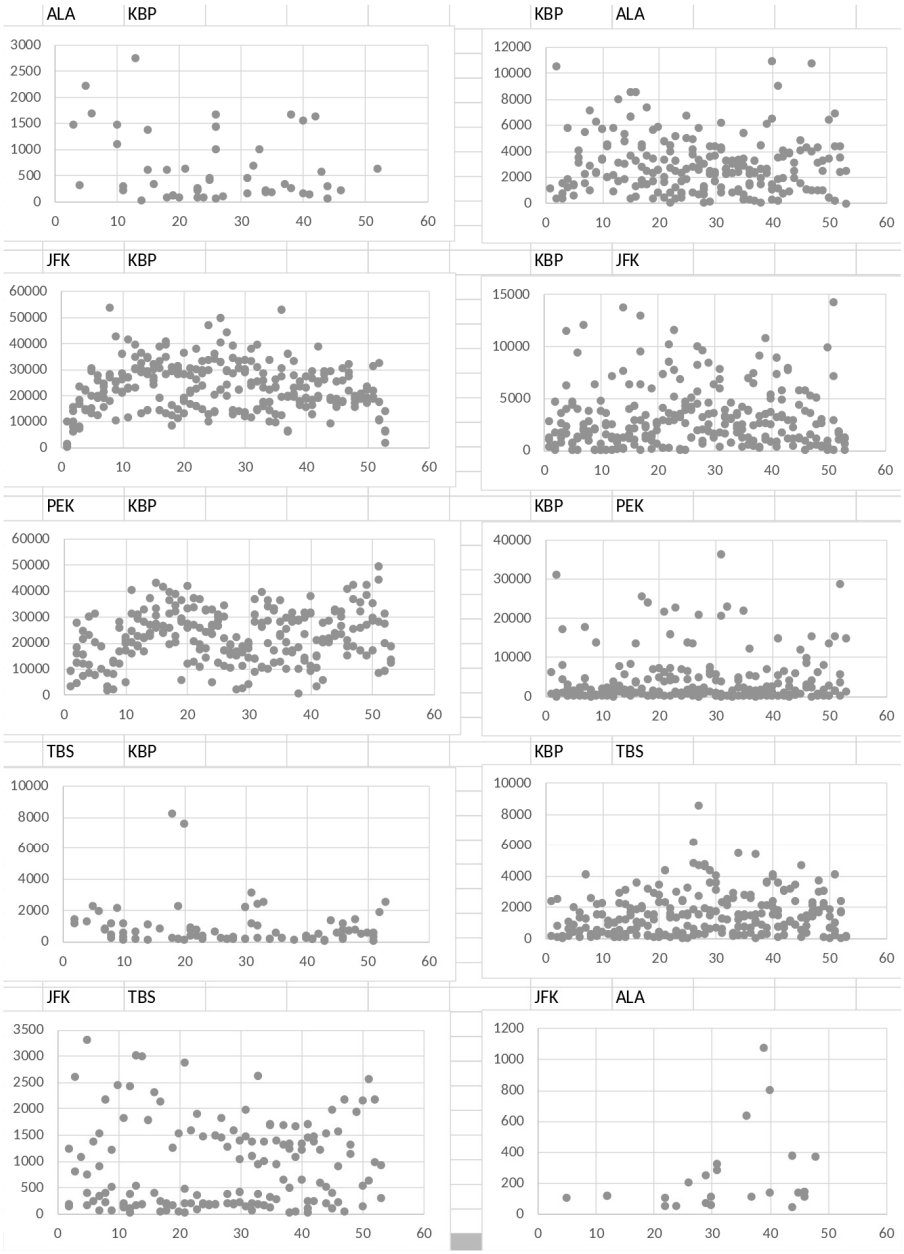
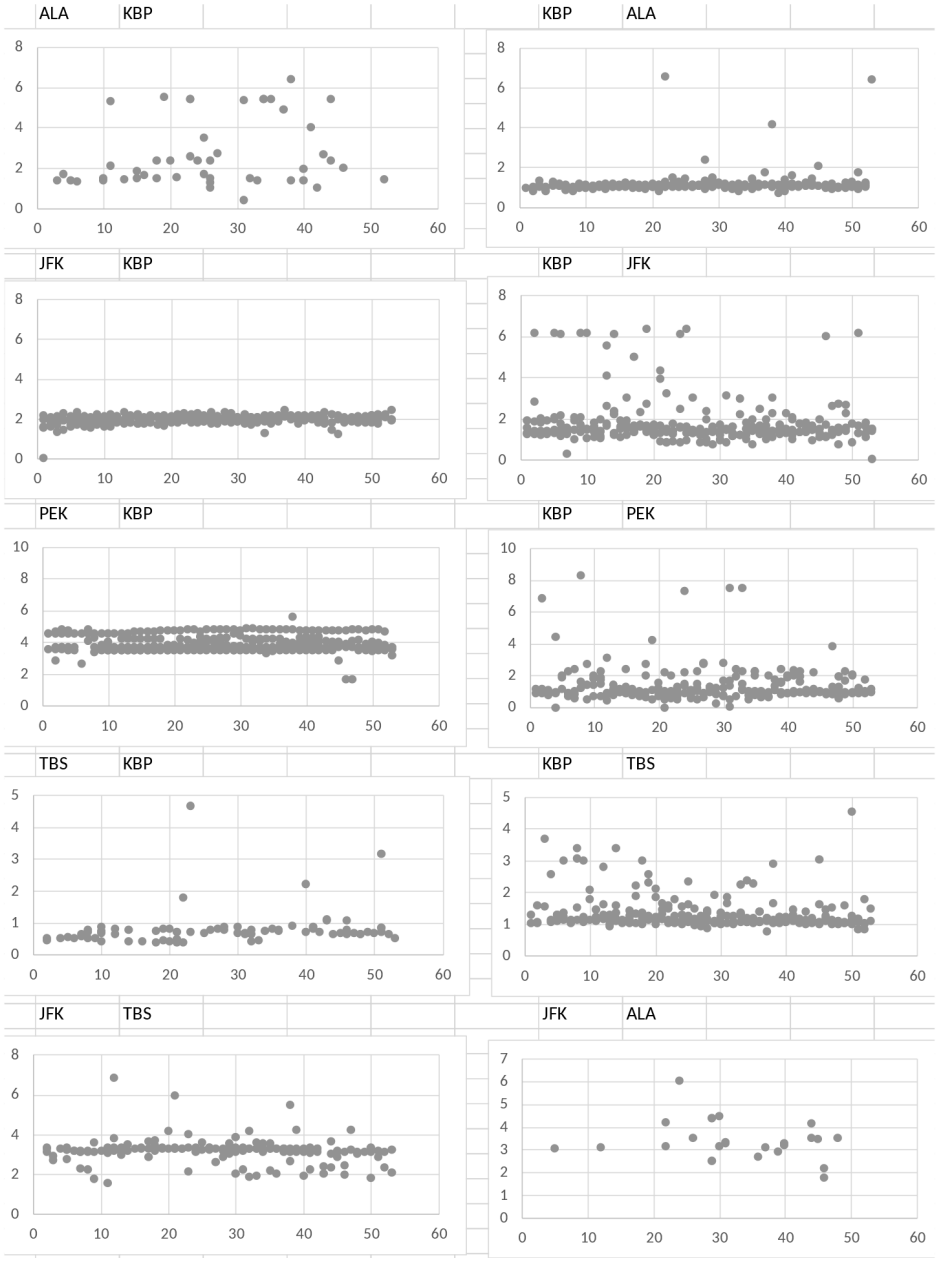


Figure 2

Tariffs of Aerosvit Airlines for the carriage of goods between the cities of Almaty, Kiev, New York, Beijing and Tbilisi in 2008-2012 per week, in USD/kg. The filled circles are for the corresponding weak of the year when cargo transport was delivered



5. Additional restrictions to the model are: the usual balance, the period of time, type, kind and category of cargo, intermediate airports. The usual balance within a network accounts for the fact that the cargo is transported from one airport to another and may not remain at an intermediate airport at all. The cargo is considered continuous, it may not be divided and left for storage; the essence of the restrictions is mathematically such that it is possible to take and transport a part of the cargo and leave another part into a warehouse. At each intermediate airport, through which the cargo will be transported, there should be a balance as to how much cargo has been brought, plus that left in storage. As per the departure and arrival airports, what was transported should be more than what was stored, that is, what is transported today should be more than what was left yesterday left, as today what was left yesterday should be transported together with today's carriage.
6. Transportation is considered for each category individually, there are syllabic restrictions, that is, it is impossible to leave more storage capacity. Once the cargo is taken for carriage, it may be divided into parts, and then all cargo flows are merged together at the destination point.

As a final remark, we note that because of the complexity of the airline cargo flows no effective mechanisms exist for systematization of the process of cargo flow traffic management by the air network. At the same time, the practical need for such is indisputable. A detailed analysis of freight traffic along the routes of the national network of air carriers of Ukraine shows irregular cargo flows, fluctuations in demand and tariffs in various areas, both in historical retrospect and in the current period of time. Our numerical experiments show that the models and considerations from (Gallego, Iyengar, Phillips, Dubey, 2004; Voitsehovskiy, Gabrielova, Grygorak, 2017, p. 69-74; Voitsehovskiy, 2017, p. 50-55) (i) capture key aspects of cargo flow traffic management in the ordinary course of operation of the airline, and (ii) can contribute to the systematization of the process of cargo flow traffic management by the network air carrier.

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