How transfer flights shape structure of the airline network

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For many decades, the gravity models have been successfully applied in many different contexts for analyzing socio-economic flows of varying types. The well-known examples include: migration, consumer spatial behavior, inter-city telephone communication flows, hospital-patient flow systems and the international trade. All these models predict or describe certain behaviors that mimic gravitational interaction as described in Isaac Newton's law of gravity. They assume that a flow between the two places is directly proportional to their importance (expressed in, e.g., population size, gross domestic product (GDP), or some attractiveness index) and is inversely proportional to the physical distance between them. Gravity models work particularly well in the systems where all the places are directly connected (i.e. where the underlying structure is the complete graph). International trade network is a typical example of such a system. In opposite to the above example, most transport networks involve a series of intermediate stops, which are, themselves, generators of originating and terminating traffic. In such networks, especially for large distances, it may happen no direct connection from the location i to the location j. In these cases, the potential, but not realizable, flow predicted from the gravity model, is realized by the increase of the other subsequent flows among the successive links of a path from i to j. Obviously, this scenario must lead to the observed flows among some places, which differ from the expected ones. It means that, in the case of airline networks, the standard gravity model can not be directly used to estimate weights of the existing connection flights. Here, we analyze the gravity model in the world passenger air-transport network. We show that in the standard form the model is inadequate to correctly describe the relationship between passenger flows and typical geo-economic variables that characterize connected countries. We propose a model of transfer flights which allows to exploit these discrepancies to discover hidden subflows in the network. We illustrate its usefulness by retrieving the distance coeffcient in the gravity model which is one of the determinants of the globalization process. Finally, we discuss the correctness of the presented approach by comparing the distance coeffcient to several well known economical events.

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