Connectivity and network robustness of European integrators
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Extended Abstract

The level of connectivity and the robustness of integrators’ network is a poorly studied topic in the academic literature. This is mainly due to the difficulties in collecting reliable data about freight-operated routes and the related freight capacity. Recent studies (Malighetti et al., 2019a, 2019b) firstly analyze the network provided by four major integrators, namely DHL, UPS, FedEx, and TNT, evidencing their differences and computing their level of connectivity in Europe and Asia by means of the most important connectivity indexes, such as network centrality and the shortest path length. Although their network strategy resembles the hub-and-spoke system of traditional carriers transporting passengers, some important differences emerge.

One of the major characteristics of integrators’ network is their apparent redundancy, as there are generally different alternative paths to connect two points of their network. Although this can be considered as inefficient from a network perspective, there are several advantages related to this redundancy. The itinerary of freight changes according to agreed delivery times, transportation costs and the integrators’ network load. If the critical factor is the delivery time, integrators are likely to route the freight via the quickest path between origin and destination. Oppositely, if integrators aim to reduce costs, they may rely on a more convenient path, unless they manage to deliver on time, thus employing cheaper airports or even several flight legs with one or more intermediate connections. In some cases, integrators may even decide to employ trucks to operate on part of the origin-destination path. Ultimately, there is the risk of overloading. When integrators’ network is overloaded, as in peak times close to the Christmas period (i.e. with the delivery of Amazon packages), redundancy may facilitate the delivery of freight. Redundancy is often associated with a negative aspect in networks. However, in the case of integrators’ network, redundancy is strictly related to network robustness, even if it involves greater operating costs related to the management of multiple-hubs, secondary hubs, and hub-bypassing routes.

In this paper, we aim to measure the robustness of the integrators’ network in Europe. Our hypothesis is that, in this respect, networks of the major four integrators (i.e., DHL, UPS, FedEx, and TNT) diverge, so outlying different strategies. To pursue our aim, we rely on the operated flights of the identified integrators in the week 11-17 June, 2019, directly downloaded from the Flightradar24 website, a flight tracking service that provides information about operated flights.

To evaluate the network robustness, we test how the level of connectivity of a network changes when a node is no more available. Specifically, we employ the measure of airport connectivity known as Shortest Path Length – SPL – (Malighetti et al., 2008; Redondi et al., 2011; Shaw and Ivy, 1994). SPL between two nodes $i$ and $j$ of a network ($SPL_{ij}$) is defined as the minimum number of steps needed to connect them. In the case of air transport networks, this measure corresponds to the minimum number of non-stop flights necessary to connect two airports ($i$ and $j$) belonging

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to the same network (Redondi et al., 2011). The higher $SP_{ij}$, the longer the detour to connect airport $i$ and $j$, in terms of number of flights, is. If two airports are not connected neither directly nor indirectly, $SP_{ij}$ is set to infinite.

Combining the SPL measure with information on the freight tons moved, we compute the overall connectivity of each integrator. By means of a simulation analysis, we explore the decrease in the overall connectivity (i.e., the connectivity loss) when a single node is no more available. Robustness index is finally obtained by weighting each node’s connectivity loss according to its freight capacity. The nodes with the higher impact on the connectivity index would be the most central airports in the network (i.e., hubs), and offering many high-capacity flights.

In terms of connectivity index, DHL registers the highest value with 68.36, followed by TNT (42.83), FedEx (36.38), and UPS (25.85). The most important hubs in integrators’ network lead to the highest loss of connectivity, ranging from -54% for TNT (Liege) to -92% for UPS (Cologne). Similarly, the robustness index identifies TNT as the most robust integrator, with a value of 87.3%. The least robust integrator results to be UPS (65.77%), while DHL and FedEx have similar values, equal to 80.4% and 78.6%, respectively. These values denote the different integrators’ network configuration. According to literature, hub-and-spoke networks are less robust with respect to dispersed point-to-point networks (e.g., Sun and Wandelt, 2018). Consistently, UPS, with a hub-and-spoke type network, and TNT, with a low market concentration, register the lowest and highest level of robustness, respectively.

However, when evaluating network performances, it is important to compare robustness with other crucial measures. In this study, we compare robustness with network efficiency (Latora and Marchiori, 2001), capacity-weighted average SPL, and available ton kilometers (ATK) per flight. Analyzing such measures, we provide interesting insights on integrators’ strategy. The results of this study have both market and managerial implications. The extent to which a network should be more (less) robust and consequently less (more) efficient strictly depends on the consumers’ requirements. Generally, robustness, especially after the recent crisis related to COVID-19, is considered as a pivotal characteristic of networks, needed to reduce delays or even avoid stops in industrial production. However, standard package delivery to customers of large online companies still evaluate as more important low prices rather than robustness. Each integrator should be able to organize its network according to consumers’ needs. To this extent, we provide a measure of robustness which can be utilized by integrators to improve their flexibility and strategic decision-making when assessing the importance of nodes and which airports to add (or remove) to (from) their network.

References


