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Hub-and-Spoke System in Air Transportation and Its Implications to Regional Economic Development
—A Case Study of United States

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Abstract: Considerable changes have taken place in commercial passenger air transport since the enactment of the 1978 Airline Deregulation Act in the US and the deregulation of airline networks that has occurred elsewhere. The commercial and operational freedoms have led most of the larger carriers to develop hub-and-spoke networks, within which certain cities or metropolitan areas emerge as key nodes possessing tremendous advantages over other locations in the air transport system. This paper examines the nature of hub-and-spoke operations in air transportation services, and the benefits that accrue to a city or geographical region that is host to an airline hub. In particular, it looks into linkages between the air service hub and local economic development. Four potential types of impact of airports on the regional economy are defined and discussed. As an example, the assessment of the economic impacts of Cincinnati-Northern Kentucky International Airport (CVG), a major Delta Airlines hub, is introduced.
Keywords: Hub-and-Spoke System; air transportation; regional economic development

1 Introduction

Over the past twenty years since the enactment of the Airline Deregulation Act, the major US domestic carriers have developed hub-and-spoke structures for their operations. These have been instrumental in helping to reduce the overall costs of air travel to the U.S. public and to increase the travel options that are available. This effect also means that the quantity and quality of air services vary quite considerably between cities in the United States. The pattern of air services supply can, therefore, have important implications for the geographical distribution of population and for the location and growth of industry. Goetz (1992) found that prior growth in the population and employment levels of metropolitan areas partly explained subsequently higher levels of air passengers per capita. In attempting to better understand these growth patterns over time, Irwin and Kasarda (1991) examined the changing "centrality" of American major airports from the Northeast/Midwest manufacturing belt to the South/West Sunbelt regions, similar to what occurring in industries and people.

Transport has long been seen as a strong positive influence on economic development (Bell and Feitelson, 1991; Button and Lall, 1999; Button et al., 1999; Button and Taylor, 2000; Debbage, 1999; Goetz, 1992; Irwin and Kasarda, 1991; Ivy et al., 1995; Van den Berg et al., 1996). The fact that a considerable proportion of airline passengers in the United States travel for business purposes also means a close relationship between business activity on the ground and airline networks in the skies. According to Bell and Feitelson (1991), an efficient transportation network serves two primary purposes in any urban hierarchy—it facilitates the movement of goods and services and it allows for the movement of key employees in a timely and reliable manner. Even with recent technological innovations that minimize the need for direct face-to-face contact, many economic sectors still rely heavily on direct contact with colleagues, suppliers, customers, and other key employees. Thus, an efficient air transportation network can be critical for knowledge-economy proclivities of the administrative and auxiliary sector that require frequent and direct contact with key personnel in other metropolitan markets, and disproportionately higher propensities to fly will be triggered (Debbage, 1999; Ivy et al., 1995). In fact, distance still seems to matter in current economy because knowledge is more easily exchanged as the level of shared experiences increases—a phenomenon that Nooteboom (1999) refers to as "cultural proximity". Cultural proximity can be enhanced by spatial proximity between firms, suppliers, and customers when the spatial, cognitive and cultural distances are minimized.

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Better understanding the nature of air transportation system and the role that air transportation and airports play in any urban agglomeration is critical because the 'accessibility through airports' issue has assumed an elevated role in answering the 'how' and 'where' of the geography of economic activity in the modern economy. This paper examines the nature of hub-and-spoke operations in air transportation services, and the benefits that accrue to a city or geographical region that is host to an airline hub, focusing on the potential linkages between the air service hub and local economic development.

2 Changes in the US Domestic Air Transportation and the Hub-and-Spoke Systems

Since the enactment of the Airline Deregulation Act of 1978, air transportation passenger volume has increased dramatically in the United States. By the year of 2000, US air passenger volume had reached a total of 677×10^6 passengers—an increase of nearly 243% on the comparable figures for 1978 (Bureau of Transportation Statistics of USA, 2005). These statistics suggest a radical shift in the absolute and relative geography of air passenger volume at US airports.

The new market conditions and resultant commercialism that accompanied deregulation, together with innovative managerial thinking, have been important in changing the ways that airline services are supplied. One important change has happened in the geographic structure of the air travel network itself, which is the growth of hub-and-spoke operations from the "linear" route structure in the prior-deregulation era. This system has led to greater flow efficiency and has led also to increase in connectivity for cities whose airports are directly involved in the hub-and-spoke configuration. Under the new structure, one or more cities are chosen by an airline as a regional collection points for passenger flow. The point is typically referred to as the hub, or hub city. A scheduled airline can feed into large airports, banks of flights that come from many different origins via spokes, and then consolidate passengers onto outward flights to a wide range of destinations. The major hub-and-spoke operators include American Airlines, United Airlines, Delta Airlines, US Airways, Continental Airlines, and Northwest Airlines. Hub-and-Spoke structure of American Airlines locates its four major hubs in the eastern half of the continental USA. Nashville, Tennessee, Raleigh/Durham, North Carolina seem to be strategically selected as the regional hubs to supplement the two national hubs at Dallas/Fort Worth and Chicago. American connections with the western half of the networks are mainly provided by the two national hubs.

The term "hub" has been used rather loosely in many of the air transport literatures. Many academic studies have thought a hub entails the carriers feeding three or more banks of traffic daily through an airport from 40 or more cities. The US General Accounting Office (GAO) assumed a concentrated hub to be an airport which was one of the 75 busiest in the nation in terms of emplacements and where one carrier accounted for at least 60% of emplacements or two carriers combined accounted for at least 85%. Airports falling into either category but not in the 48 contiguous states were excluded, as were those in cities with more than one airport.

From an operational perspective, when looking at concentration of airline activities, hubs are normally treated as airports—an integrated air transport interchange through which a single (occasionally two) carrier(s) operate(s) synchronized banks—or waves—of flights. In these, the hub-arrival times of aircraft, originating from cities at the ends of numerous spokes, are coordinated into a short time period. After the minimum interval necessary to redistribute passengers and baggage, an equally large number of aircraft depart to the spoke cities. This pattern is repeated several times during the day (Dennis, 1994a; 1994b; Graham, 1995; Hanlon, 1999).

The hub-and-spoke network is essentially a supplier-driven strategy, which maximizes the online (same carrier) connections available to a particular airline at the hub airport. For example, if only six point-to-point services are re-routed through a hub, the number of possible city-pair connections between the cities in the east and west served by the resultant 12-spoke network increases to 36-spoke. Furthermore, an exponential increase in possible connecting markets occurs as further spokes are added to the hub (Table 1). Thus, the hub-and-spoke configuration permits the construction of a network in which direct point-to-point flights are replaced with a much larger number of indirect connections.

Table 1 Growth in the power of a hub

Number of spokes	Number of connection markets	Local markets terminating at hub	Total city-pair markets
2	1	2	3
6	15	6	21
10	45	10	55
50	1225	50	1275
100	4950	100	5050

Dennis (1994b) identified two forms of hub, both aimed at serving the most marketable linkages. The first is the *hourglass* or *directional* hub in which aircraft from spokes in one region operate through a hub to other spokes which, broadly speaking, are located in an opposite direction. This arrangement avoids unnecessary backtracking and circuitous routings. The major U.S. east-west hubs, including Chicago, and Dallas/Fort Worth, were classed into this category. Here, the hub acts as the switching-point for a multiplicity of separate passenger flows. However, several directional hubs will be necessary if an airline requires serving all the major traffic flows. Delta Airlines, for example, operates a multi-directional hub at its main base, Atlanta, together with three east-west hubs at Cincinnati, Salt Lake City

and Dallas/Fort Worth.

Conversely, *hinterland* hubs link long-distance trunk or international routes with short-haul sectors, which feed passengers from the surrounding areas. In a sense, virtually all hubs are hinterland hubs because most directional hubs depend upon originating as well as connecting passengers.

The principal aim of an airline hub operation is to maximize the number of journey possibilities that can be accomplished using the airline's network. Thus, careful schedule becomes essential to link the greatest number of city pairs while minimizing the time that passengers spend on the ground. This involves creating a wave or bank, whereby a large number of aircraft arrive at the hub airport in a short space of time, followed by a similar wave of departures. This integrated arrangement of arrival and departure waves is sometimes referred to as a connection complex. Atlanta is the busiest single airline hub in the world, with around 600 departures per day by Delta Airlines in the 1990s. Despite the huge volume of activity which if uniformly distributed would still lead to one departure every 2 minutes, the flights are organized into connection complexes. Delta operates about 50–60 services in each wave. From the first flight arriving to the last departing, it takes a mere 90 minutes, and then the subsequent group of arrivals start coming in. Some 2500 city pairs are available within each complex, requiring a connection time from 35 minutes up to 90 minutes. More than 20,000 passengers interchange between Delta flights at Atlanta every day.

3 Primary and Secondary Economic Effects of Hub Airports

A hub airport has significant implications to travelers, as well as the local economy as a whole. In the U S, major airports are mainly owned by city and county authorities and they actually vie with one another to become hubs, the fundamental reason of which is the boost given to the local economy. It includes the immediate impact on incomes from increased employment as a result of creating new services or expanding existing services at the airport (primary effects), and the long-term effects from running the airport, as well as indirect multiplier effects due to the on-going flow of income that the airport's operation puts into the local economy (secondary effects). The importance local authorities place on hubs can be reflected in some of the investments they have made. For instance, in December 1991, an alliance between the State of Minnesota and the Minneapolis-St Paul city authorities put together a package of grant aid and loan guarantee for Northwest Airlines worth a total of US$838×10^6, in exchange for promises from the airline that it would maintain service levels at the hub and thereby safeguard local employment. Pittsburgh once spent US$870×10^6 on a new terminal complex to strengthen its role as a principal hub for US Airway (Hanlon, 1999). Investments like this show a lot of faith in the power of hubs to generate external effects on incomes and employment. This kind of strategy is not without risk since airport facilities cannot move in the same way as airlines can. There have already been cases of cities losing their hubs, e.g. Dayton, Ohio. Nonetheless the attractions of hubs appear to be great, at least to public owned airports.

Cincinnati-Northern Kentucky International Airport (CVG) is a major Delta Airlines hub. Delta Airlines, jointly with subsidiary Comair, was responsible for approximately 95% of the emplanements. About 22% of the emplanements and 32% of deplanements involved business travelers. It was estimated that the overall economic impact of the Airport in 1998 was over 69,000 jobs and US$3.9×10^9 in economic activity (Table 2), of which, US$2.1×10^9 was in the form of business sales and US$1.8×10^9 was in the form of earnings to Greater Cincinnati households (Center for Economic Education, 1999). Specifically, the impacts of three sources of airport-related activities are assessed, such as the day-to-day operations of the Airport and its tenants; construction activity at the Airport; and the people the Airport brings into the Greater Cincinnati region for business, convention, and leisure purposes.

Table 2 Economic impacts of Cincinnati/Northern Kentucky international airport in 1998

	Total impact on business sales (US$)	Total impact on household earnings (US$)	Overall economy (US$)	Employment (Jobs)
Airport operation	925688437	1267581623	2193270060	38244
Visitor	1166629081	513754779	1680383860	30648
Airport construction	11174645	4867832	16042478	191
Total	2103492163	1786204234	3889696397	69083

Source: Center for Economic Education, 1999

The day-to-day operations of the CVG's tenants play the largest role in the Airport's overall contribution to the local economy. Their expenditures have a "multiplier effect" because the Airport-related dollars are re-spent throughout the regional economy on labor, goods, and services in a wide variety of industries. This re-spending of Airport-related dollars creates higher levels of regional output, income, and jobs. Direct expenditures of Airport tenants to local businesses were US$488×10^6 in 1998. The direct business expenditures by Airport tenants create an additional indirect effect on the Greater Cincinnati economy. This indirect effect was estimated at US$437×10^6, which gave a US$926×10^6 of the Airport's total regional business sales impact. Airlines accounted

for most of the economic impact on business sales, at 79% or US$732×10^6. Rental car companies created the second largest impact on business sales, accounting for 8% of the total. In 1998, the total economic impact of Airport operations on regional household earnings was US$1.3×10^9. This impact included US$621×10^6 in direct compensation expenditures to Airport employees and US$647×10^6 in indirect compensation expenditures. Tenants at the Airport directly employed 15,241 employees. The indirect impact of employment was slightly over 23,000 jobs, for a total employment impact of 38,244 regional jobs. Again, airlines accounted for most of the economic impact on employment, at 73% or nearly 28,000 jobs. Air cargo companies created the second largest impact on employment, accounting for 10% of the total or 3,800 jobs. Airline support organizations ranked the third, with 9% of the employment impact and 3300 jobs.

The Cincinnati/Northern Kentucky International Airport brings a large number of people into the Greater Cincinnati region every year. Nearly 11×10^6 passengers deplaned at the Airport in 1998. Of these, 70% boarded another plane for a connecting flight. The remaining 30% stayed in Cincinnati, either to return home from a trip, to visit on business, to attend a convention, or for leisure purposes. In 1998, direct expenditures by visitors were US$816×10^6, while the total impact on regional business sales was nearly US$1.2×10^9. In 1998, the household earnings impact mostly from visitors to the region via the Airport totaled US$514×10^6. Visitors to Greater Cincinnati via the airport directly and indirectly supported 30,648 regional jobs. Visitors' expenditures on hotels and lodging created the largest regional impact, totaling US$683×10^6 and 11,400 jobs. Expenditure on food and beverage was the second largest source of impact, with a US$456×10^6 impact and 9,075 regional jobs created and sustained (Center for Economic Education, 1999).

4 Tertiary Effects of Hub Airports

The tertiary effects of hub airports, modern economy and air services as a location factor, stem from the economic stimulus benefiting a local or regional economy as firms and individuals, particularly high-technology companies, are attracted to the locale due to the fact that a major hub airport and high-quality air transport are available. Generally, the kind of businesses for which air service is an important location consideration are: those whose operations are widely dispersed geographically, e.g. a large multinational organization; those whose highly specialized and technology- or knowledge-based activities require a diverse network of suppliers, clients and associates; and those manufacturing low-bulk, high-value products. The highly skilled and highly paid employment generated by businesses like these enhance the multiplier effects on local economy.

Button and Taylor (2000) suggest that "new economy" activities, such as information technology, biotechnology, electronics, and management services, are playing crucial role in a region's economic development. Ivy et al. (1995) argued that modern large corporations are complex entities. The integrated nature of divisions and subsidiaries makes it essential that various activities or functions of individual entities have different location requirements. Administrative and auxiliary activities are less influenced by wage rates and site location costs, and adequate transportation, information, and communication infrastructures are some of the more salient location criteria for firms performing higher order corporate functions.

There is evidence that, while air transportation is used by all categories of business, it has become particularly important for those engaged in what is termed new economy activities (Button and Lall, 1999). These potentially geographically mobile types of industry had been estimated to account for some 9.6% of the US labor force in 1998 (3.6×10^6 more than a decade earlier). About 90% of this employment was in metropolitan areas with 70% of the total in 50 of the 321 Metropolitan Statistical Areas. Button and Lall compared the situation at three non-hub airports (Nashville, Indianapolis and Milwaukee) with the major airline hubs of Cincinnati and Pittsburgh, and suggested a positive correlation between hubs and development. They also confirmed that the direction of causation was from air service availability to employment growth in an analysis how US hub airports with international gateways correlate to "new economy" employment levels in the local economy. Similar study on hi-technology employment in hub airport markets was also conducted by Button et al. (1999).

Irwin and Kasarda (1991) examined the empirical relationships that existed between airline networks and overall employment growth rates in 104 US metropolitan areas between 1950 and 1980. They argued that accessibility levels have changed constantly as new transportation innovations (e.g., jet engine) have reshaped the competitive advantage of the US spatial economy. They also suggested that in the post-World War II era, air transportation substantially reduced frictional constraints to long-distance economic interaction to the point that new location advantages were created for some metropolitan areas. They concluded that "changes in air transportation have altered the competitive advantages of metropolitan areas, and not the reverse", particularly in markets that are centrally located relative to existing airline networks.

Ivy et al. (1995) argued that changes in air service connectivity can lead to corresponding changes in administrative and auxiliary employment levels. They demonstrated that 'significant statistical relationships exist between changes in connectivity and professional employment' (Ivy et al., 1995). Debbage and Delk (2001) confirmed that statistically significant links exist between air transportation and economic development, particularly as measured by the ability of certain metropolitan areas to generate employment opportunities in

those sectors of the economy that stimulate unusually high propensities to fly due to the crucial importance of face-to-face contact and direct collaboration. As administrative and auxiliary-related jobs and industries shifted away from the traditional manufacturing centers of the Northeast and Midwest to the South and West in USA, the air transportation network appeared to experience a similar geographic shift as it broadened into a more deconcentrated air transportation network system. They suggested that while there is a dramatically different geography of both employment and air passenger volume by place, the two variables were closely linked over time. Air passenger volume behaves much like airline connectivity in mimicking the administrative and auxiliary employment hierarchy of the largest metropolitan markets of the United States and the connections between the two variables appear to be remarkably stable over time. The interdependence between the change in air service connectivity or passenger volume and the change in total administrative and auxiliary employment of the metropolitan areas has been evident. In fact, changes in air service connectivity serve as both a stimulus (supply-related) and response (demand-related) variable. On the one hand, increase in air service connectivity can make a place more attractive to companies wishing to locate a facility; and on the other hand, increases in professional employment and passenger volume can increase the demand for air service connectivity.

There is an increasingly widely accepted notion that economic growth, once started in a region, becomes self-sustaining and may accelerate. There has been empirical evidence that infrastructure investment can act as a catalyst for higher economic growth in an area; essentially it can act as a kick-start mechanism (Aschauer, 1990). The major new air services may act, therefore, to set in progress a much larger and longer development process in a region—the perpetuity effects of hub airports affecting the dynamics of an area.

5 Conclusion

Although agglomerative or highly clustered urban markets were traditionally intended to minimize transportation and labor costs, Porter (1998) has argued that contemporary metropolitan cluster advantages now “rest on information, transaction costs, complementarities, and incentives as well as ‘public’ goods that result from both public and private investments”. It was suggested in this paper that airports are part of Porter's ‘public goods’ equation because many airports are operated and managed by quasi-public airport authorities, and they can often amplify the competitive advantages of large metropolitan markets. Thus, from a macro, national perspective, proximity to an airport hub has important structural advantages for the local economy. Holding and expanding a hub airport in a city can generate unparalleled benefits to the economic development. The benefits may be short term, directly related to the construction or expansion of the hub facility; or long term, associated with running and operating the hub airport. These benefits can be extremely important to a local economy in terms of employment, income and, for local government, taxation revenue. Even more importantly, to be a hub city can be a significant stimulus for long-term local economic growth, since it enables the locale to attract firms and individuals having strong propensity in relying on air transport services. While most forms of business activity now involve considerable use of transportation infrastructure, new economy firms make particularly intensive use of air transport. These companies require considerable interpersonal contacts which are only possibly kept through high quality air transport. From a local development perspective it is often those types of firms that form the basis for continuing economic growth because they are usually geographically mobile and represent a major growth sector of the modern economy.

High-technology jobs and other administrative and auxiliary-related jobs have grown considerably in the region of major hub activities. It has been shown that, by various studies, the link between jobs and airport services at hub cities flows from the air transport input to the creation of employment and not the other way round. Airports have been a chief agent in creating jobs in hub-hosting areas. By initially attracting undertakings to an area in sufficient numbers, airport development can lead to the crossing of important thresholds in terms of economies of scale, scope and density. In particular, in the context of 'new economy', high-technology activities, an area can acquire a vital knowledge base that fosters local development and makes the region quasi-independent of others. The regional economy can feed on this to further its high-technology activities and hence to accelerate its growth.

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