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Exploiting a Natural Hub: Turning a Stopover into a Destination

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Abstract

In the mature aviation system of today, it is difficult to establish new hubs that focus solely on transfer traffic. This paper identifies a new type of hub—a natural tourism hub—one at which an airline and the surrounding metropolitan area can simultaneously benefit from a transportation hub and accompanying tourist destination, respectively. The study aims to identify existing airports for these stopover locations that are located on highly trafficked international flight routes. Using Iceland as an example, this country's success in optimizing its stopover location to promote tourism and gain airline passenger demand is examined. The analysis is carried out by implementing a k-means clustering algorithm on total distance added for stopover locations, as well as flight leg symmetry to identify existing airports that are geographically located in an optimal stopover path for international routes across the Atlantic and Pacific oceans, and between Europe and East Asia. Airports in the clusters that minimize total added distance are then observed, and the clusters are ordered based on how symmetric the two flight legs of a stopover journey at an airport in that cluster tend to be. In addition, three airports near the top of this list are analyzed as potential stopover locations. In using this algorithm, not only is it possible to forecast which hubs may become major tourist destinations, but also to identify how airlines can shape people's perception of their location as a tourist destination.

As demand for service in the transportation industry has grown considerably, there has been a shift in focus toward economies of scale. Airline carriers began research on optimizing airport locations to use their transportation network as an advantage over competitors (*1*). Hub-and-spoke (HS) networks emerged from this research, presenting the concept of hub locations that offer efficient passenger routing. Instead of a fully connected network in which point-to-point routes are offered for all origin destination paths, the HS model directs flights through major hub locations that branch off to the different destinations (*2*). Research has shown that utilization of such a model helps reduce service costs, increase passenger frequencies, and reduce uncertainty in demand (*1*). As such, airlines are largely concerned with optimizing such hub locations so as to fully exploit these opportunities for economies of scale.

There are various aspects to consider when determining a hub location. In the continental United States, characteristics such as demographics, climate, and economics all affect the probability of a city hosting a hub airport. One of the most important factors, however, is the city's geographic location (*3*) and the presence of a lot of people with relatively high incomes (*4*). In already competitive airline markets, many healthy hubs are already established; globally and domestically the networks are well covered with options to get between an origin and destination through multiple potential hubs. With every increase in hub location, travelers have more choices among airline carriers and routings they can take to connect to their destination, creating a more competitive environment. New entrants need to offer a better or cheaper product, or a different kind of one to succeed (*5*). An approach is proposed by which new entrants can compete with entrenched airline carriers by borrowing the hubbing concept but using it not to maximize passenger loads but instead to offer a new destination for stopover travel. In this paper, an alternate perspective to hub location identification is offered such that it is possible to forecast markets that can ultimately be successful.

The starting point is the perspective of identifying natural hubs that can be used as a stopover location. A natural hub is defined as a location near the paths of highly trafficked international flight routes. A stop at such a hub would not drastically affect the flight route between origin and final destination. The criteria for a hub such as this are similar to those of a traditional hub in that economic, demographics, and climatic factors affect the hub's success. However, it is slightly different with regard to geographic criteria in that this kind of hub's focus is connecting nations. Not only that, it is promoting its location as an intermediary destination for those traveling internationally. Previously, destination airports for existing tourist locations were attractive for

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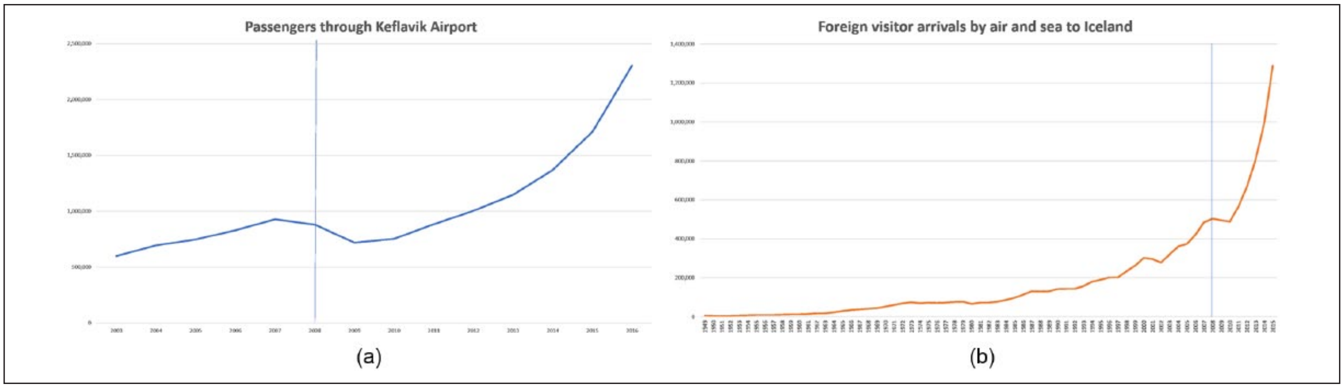

Figure 1. Increase in passengers through KEF from 2003 to 2015 (*a*) and increase in foreign visitors by both air and sea arrival to Iceland from 1950 to 2015 (*b*), both denoting when the financial crisis occurred.

hubbing given the many customers generated (*3*). In this approach, the focus is shifted from the final destination to the connecting destination as a way of promoting tourism. By pulling customers through the hub using a stopover policy, it is possible to change the perception of the location and it begins to be seen as a tourist destination.

This paper will first discuss how Iceland successfully used its location to promote a stopover policy that generated millions of new passengers. It would have been very difficult for airline professionals to accurately forecast the success of both Keflavik International Airport (KEF) and Iceland's tourism industry using traditional time-series models based on the airport's history of passengers or enplanements. A model is offered that identifies airports in an optimal geographic location for hubbing and it will show how the development of these hubs can be forecasted. Finally, three airports are identified particularly and their similarities with Iceland and potential for a successful stopover policy are discussed.

Iceland as a Natural Hub

When the financial crisis hit in 2008, Iceland was affected significantly. Between 2000 and 2008, the finance sector in Iceland had grown rapidly. Due to the large influx of foreign funds, at one point the three largest banks in Iceland held nearly 10 times more than Iceland's economy (as measured by Gross Domestic Product). Thus, when the financial crash occurred, there was a major banking crisis, the housing market collapsed, and there was increased unemployment. The Icelandic Krona collapsed by 60% by the end of 2008 (*6*). To help improve Iceland's failing economy, the Icelandic Tourist Board pushed marketing initiatives to promote Iceland as a tourist destination (*7*). From this came the stopover policy that Iceland's major airline, Icelandair, promoted at the main airport, KEF. This policy allows for up to seven nights of free layover for transatlantic flights. Icelandair connects 27 cities in Europe with 12 cities in North America (*8*).

Since the promotion of this stopover policy, Iceland's tourist economy has boomed. Tourism has increased from 18.8% in 2012 to 31% in 2015, such that it is now the country's top industry (*7*). It contributes nearly 5% to the country's gross domestic product and, as of 2014, 12% of the labor force of Iceland is employed in the tourist industry. Additionally, as seen in Figure 1*b*, air arrivals to KEF have tripled since 2008 (*9, 10*). In 2016 more than 5 million passengers traveled through KEF, in comparison with fewer than 1 million in 2008 (Figure 1*a*).

There are a few key features of Iceland that allow this model to work so well. The most notable is Iceland's geographic location. KEF is 2,600 miles from New York City and 1,200 miles from London, putting it about midway between the two. In addition, stopping at Iceland only adds 322 extra miles, a low number relative to a transatlantic flight (*10*). KEF is also well located within the largest city in Iceland, where almost two-thirds of Iceland's total population live. Thus, the city is well suited to accommodate tourists with regard to staff, amenities, and activities. Furthermore, the local airlines place strong emphasis on growing the surrounding area for tourism. Icelandair Group runs Icelandair Hotels and tour operator Iceland Travel (*7*). WOW air, which was founded in 2011 and also implements a stopover policy, provides online flight, hotel, and car booking services to its customers, a unique offering that has helped grow the airline (*11*). Through exploiting its geographic location, Iceland has effectively changed travelers' perceptions of the nation from somewhere they probably would not have considered visiting to one of it being a major destination (*8*).

Model for Identifying Optimal Natural Hubs

Data Source

This section of the paper focuses on identifying geographically optimal airports for stopovers. Locations of major world airports (airport codes, latitude values, longitude values) were obtained from the OpenFlights Database (*12*). The initial goal was to identify hubs that could serve as feeders to

Figure 2. Map of world hubs (*a*) and the flight paths identified (*b*).

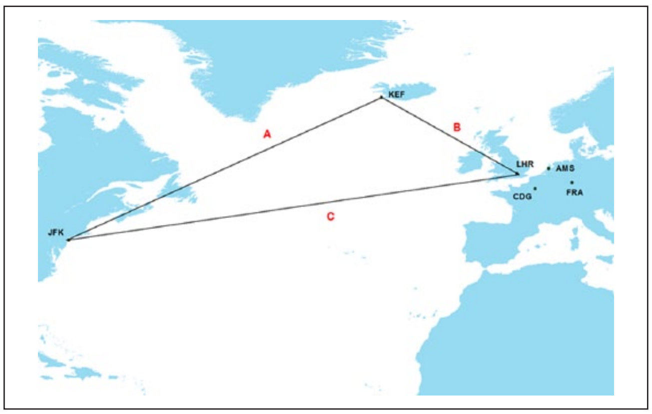

Figure 3. KEF stopover diagram.

the potential geographically optimal stopover airports. The top 16 hubs in the world by total passenger traffic in 2016 were identified (*13*). These hub airports, plotted in Figure 2*a*, are: Singapore (SIN), New York City (JFK), Amsterdam (AMS), Shanghai (PVG), Frankfurt (FRA), Istanbul (IST), Dallas–Fort Worth (DFW), Paris (CDG), Hong Kong (HKG), Los Angeles (LAX), London Heathrow (LHR), Tokyo (HND), Chicago (ORD), Dubai (DXB), Beijing (PEK), and Atlanta (ATL).

From these 16 hubs, three major "flight paths" were identified, as seen in Figure 2*b*: Atlantic, EuroAsia, and Pacific. The Atlantic path comprises all flights with origins in North America (LAX/DFW/ORD/ATL/JFK) and destinations in Europe and the Middle East (LHR/AMS/CDG/FRA/IST/DXB) for a total of 30 origin region to destination region (O–D) pairs. The EuroAsia path comprises all flights with origins in Europe and the Middle East (LHR/AMS/CDG/FRA/IST/DXB) and destinations in Asia (SIN/HKG/PVG/PEK/HND) for a total of 30 O–D pairs. Finally, the Pacific path comprises all flights with origins in Asia (SIN/HKG/PVG/PEK/HND) and destinations in North America (LAX/DFW/ORD/ATL/JFK) for a total of 25 O–D pairs. Throughout the analysis "flight paths" are identified as these three sets of O–D pairs.

Variable Generation

Observations of interest in this study are potential stopover airports in a given flight path. In creating the dataset all airports west of the easternmost hub and east of the westernmost hub on a given flight path were removed. For example, in the Atlantic path all airports west of JFK and all airports east of LHR were removed. The cutoff points for all three flight paths are expressed in Figure 2*b*.

For each of the potential stopover airports in the three flight paths two different distance variables for every O–D pair were generated: added distance and leg symmetry. For each potential stopover and O–D pair in a given path, "added distance" was calculated as the difference between making a stopover at an airport (A and B) and flying directly between the O–D pair (C); added distance is thus $A + B - C$.

For each airport in a given path, "leg symmetry" was calculated as $|A - B|$, the absolute value of the difference between the distances of the legs of a stopover. Thus, the leg symmetry for the stopover, KEF, depicted in Figure 3 for the O–D pair JFK–LHR, was calculated. JFK to KEF (A) is 2,593 miles and KEF to LHR (B) is 1,180 miles, so the symmetry is 1,413 miles.

However, there are 29 other O–D pairs on the Atlantic flight path, so the added distance and leg symmetry for making a stopover at KEF for those pairs was calculated as well (e.g., ATL to FRA, LAX to AMS, etc.). Then, the total added distance and total leg symmetry for the 30 O–D pairs were calculated and the results totaled. Thereafter, for every potential stopover in the dataset the same process was used—the O–D pairs depend on the flight path that the potential stopover airport is located in. Finally, every observation has two variables: total added distance and total leg symmetry.

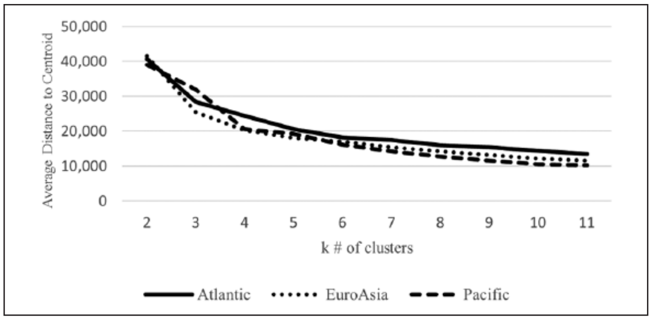

Figure 4. Average distance to centroid by k number of clusters.

$$\text{Total Added Distance} = \sum_{\#\text{O-D PAIRS IN PATH}} A + B - C$$

$$\text{Total Leg Symmetry} = \sum_{\#\text{O-D PAIRS IN PATH}} |A - B|$$

Throughout this study, distances between two airports were calculated using the geodesic distance between a pair of points on the surface of the Earth, with an accurate ellipsoidal model of the Earth (*14*). It is understood that true flight paths do not follow the direct measures as calculated by this method. However, it is felt that this calculation serves as a close approximation.

Model and Results

The procedure used to identify geographically optimal hubs is k-means clustering. *k*-means clustering attempts to group observations together based on feature similarity according to *k* number of clusters, where *k* is a number that is chosen a priori (*15*). The clustering was based on two variables throughout the analysis: total added distance and total leg symmetry. Three separate k-means procedures for each of the flight paths identified were run, in which the individual observations were potential stopover airports.

To find the k parameter, the elbow point method was used (*16*). This measures the average distance between all observations and the cluster centroid to which they are assigned based on the k number of clusters. The elbow point is the point at which the average distance levels off, or in simpler terms, the point at which adding more clusters offers little more explained distinction between the clusters. Figure 4 shows the elbow point plots for the three different paths. Ten was chosen as the value for *k* across the analysis as it seems to level off at that point for all three paths.

In the identification procedure, symmetry and added distance are generally minimized. An ideal stopover should not be too far out of the way of a typical path between hubs, as calculated by the "added distance" variable. Furthermore, it is generally preferable to passengers when the leg lengths of the two legs on a stopover are close to equal, because a break in the middle of a trip is generally better than a stopover very close to either the origin or destination. This conclusion was made after observing the success of KEF in promoting stopovers as the airport is approximately halfway across many transatlantic flights.

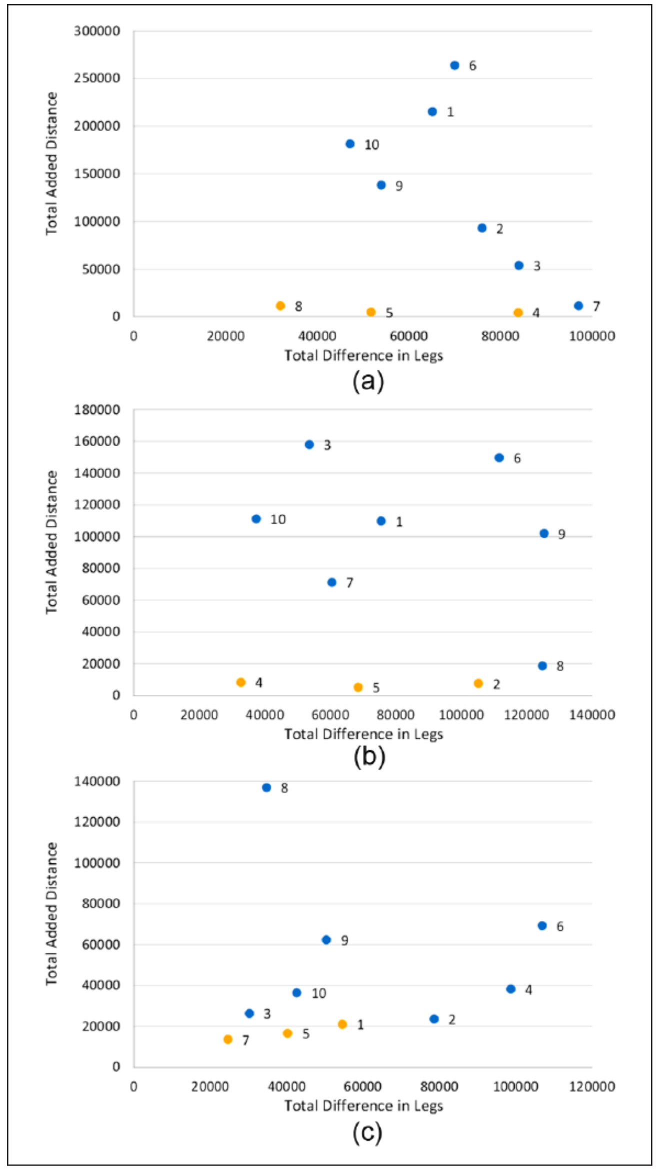

Figure 5. K-means centroid plots for the Atlantic (*a*), EuroAsia (*b*), and Pacific (*c*) flight paths. Selected clusters for analysis are highlighted in yellow.

After running k-means procedures on the three different flight paths, the cluster centroids were plotted to gain a sense of the distribution of the clusters related to the two variables of interest. Figure 5 plots these centroids for the Atlantic (*a*), EuroAsia (*b*), and Pacific (*c*) flight paths, respectively. For the analysis, it is more important to minimize total added distance than total leg symmetry. Therefore, for each of the flight

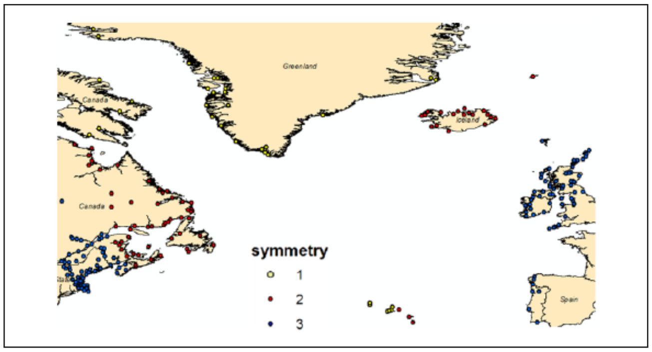

Figure 6. Geographically optimal clusters for Atlantic flight paths.

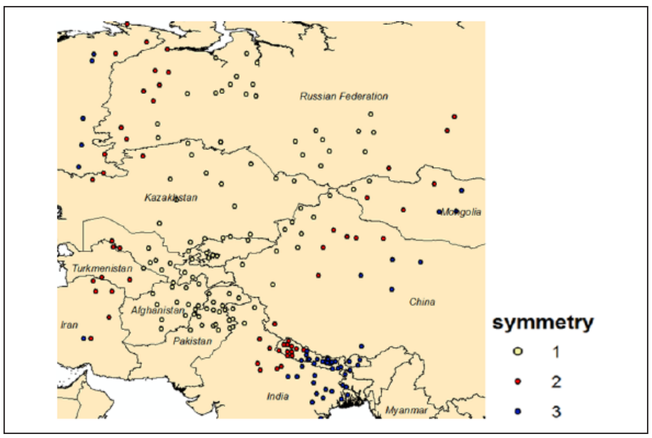

Figure 7. Geographically optimal clusters for EuroAsia flight paths.

paths the three clusters that minimize total added distance are reported, and they are ordered according to their level of leg symmetry, 1 being the most symmetric and 3 the least symmetric. In Figure 5*a*, it can be seen that clusters 8, 5, and 4 minimize total added distance and at the same time have progressively lower levels of total leg symmetry. Therefore, those three clusters were chosen as the "geographically optimal" clusters for stopover airports and ordered according to symmetry, so that 8, 5, and 4 become clusters 1, 2, and 3 for the Atlantic path. Following a similar procedure, clusters 4, 5, and 2 were chosen to become clusters 1, 2, and 3 for the EuroAsia flight path, as seen in Figure 5*b*. Finally, clusters 7, 5, and 1 were chosen to become clusters 1, 2, and 3 for the Pacific flight path, as seen in Figure 5*c*.

The optimal airports with cluster identifiers (based on symmetry) have been mapped for the Atlantic (Figure 6), EuroAsia (Figure 7), and Pacific (Figure 8) flight paths respectively. In Figure 6, it can be seen that Cluster 1 is centered on Greenland and Northeast Canada and Cluster 2 contains airports in Iceland, Newfoundland, and Nova Scotia. With regard to the Atlantic flight path, Cluster 1 contains 34 airports, Cluster 2 has 74, and Cluster 3 has 142. In Figure 7,

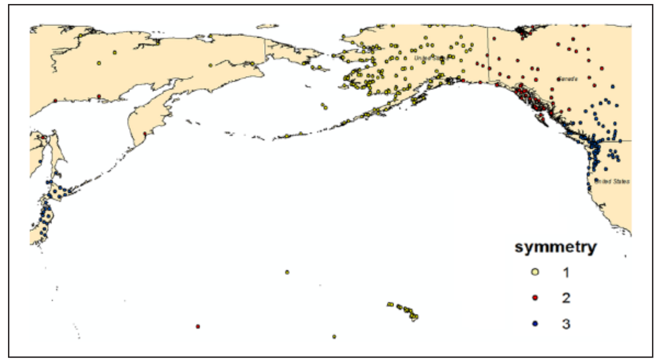

Figure 8. Geographically optimal clusters for Pacific flight paths.

it can be seen that Cluster 1 is centered on Kazakhstan, Pakistan, Afghanistan, and Russia and Cluster 2 is more sparsely concentrated in Iran, India, and Western China. For the EuroAsia flight path, Cluster 1 contains 103 airports, Cluster 2 has 55, and Cluster 3 has 53. In Figure 8, it can be seen that Cluster 1 is centered primarily on Alaska and Hawaii, whereas Cluster 2 is mainly in Yukon Territory, Canada. With regard to the Pacific flight path, Cluster 1 contains 178 airports, Cluster 2 has 64, and Cluster 3 has 112.

The quantitative analysis in this section has identified airports that can be reached over many hub to hub journeys across major flight paths without adding much distance to the trip. Furthermore, these clusters are separated by the level of symmetry that the two legs (before and after the stopover) exhibit. Although this analysis is by no means complete, it offers a picture of which airports can be accessed with ease by many passengers flying between these hubs as stopovers as an alternative to one long-haul flight between the hubs.

Model Limitations

This study on geographically optimal airports for stopovers considers only distance-based measures for optimality. It does not consider the existing infrastructure, population features, or the desirability of the airport locations for potential stopover tourists. Some of the most symmetric optimal airports that have been identified in this analysis would be highly unfeasible for stopover journeys for a variety of reasons. For the Atlantic flight path, most of the optimal airports in the most symmetric cluster are located in Greenland, which does not contain the infrastructure necessary for a large tourism industry at the moment. Furthermore, with regard to the EuroAsia flight path, many of the most optimal and symmetric airports lie in politically unstable countries such as Pakistan, Iran, and Afghanistan, which would be unattractive for many potential tourists. Extensions of the study should consider clustering potential stopover airports based on demographic, economic, and political variables as well as distance variables.

Natural Hub Profiles

Transatlantic

With regard to the Atlantic flight path, the airport highlighted, Saint John's International Airport (YYT) in Saint John's, Canada, falls into Cluster 2 in the analysis. With a metropolitan population of over 200,000, the city and surrounding area offer the infrastructure and a coastline environment that could support an increased level of tourism. The airport is well positioned to serve transatlantic flights as it currently serves Dublin, Ireland in 4 h and 30 min and London in 5 h (both nonstop flights operated by WestJet). Furthermore, it serves several major North American cities such as Toronto, Montreal, Orlando, and Tampa (17). YYT is positioned in a very similar level of symmetry as KEF, which as has already been noted has gained success as a stopover airport. YYT is roughly 5 h to Europe and 3 h to many east coast airports and KEF is 5 h to North America and roughly 3 h away from the many European airports that it serves.

Based on figures from 2016, the province of Newfoundland and Labrador (the Saint John's metro area contains nearly 50% of the province's population) has experienced a modest growth in tourism at a rate of 4.1% from air passengers (*17*). Furthermore, accommodation occupancy remained steady at 50.2% for the year with an average hotel stay costing roughly \$139, which is nearly average for the entire country of Canada (*18*). As of March 2017, the unemployment rate in Saint John's stands at 8.9%, over two percentage points higher than Canada's unemployment rate of 6.7%. The local economy in Saint John's is highly sensitive to the performance of the oil industry, which has been somewhat volatile in the past few years (*19*). The local economy might benefit from developing the airport and city as a stopover destination for transatlantic flights. This could tighten the labor market at the same time diversifying it away from a volatile industry.

EuroAsia

The airport considered for the EuroAsia flight path is Tribhuvan International Airport (KTM) in Kathmandu, Nepal. This airport is part of Cluster 3 for symmetry. Although some airports in Nepal fall into Cluster 2, KTM is the only international airport in Nepal, and the only airport with a runway large enough for such airplanes. Additionally, KTM is very closely located to Cluster 2. Currently, KTM serves about 3 million passengers a year, with international flights to South Asia and the Middle East. Its only current connection with Europe is through IST. Thus, if KTM can incentivize more travelers, they have the potential to create more connecting flight paths.

Kathmandu is the capital city of Nepal and, as such, it is the largest metropolitan area in the country. It is a beautiful area in the Himalayan region, hosting palaces, mansions, and gardens. The location has a subtropical climate, allowing for year-round warm weather. In addition, tourism is an important industry for Nepal, contributing largely to income levels in the city. Thus, both the city and the airport have aligned incentives to increase tourism to the area, which may be done through a successful stopover policy.

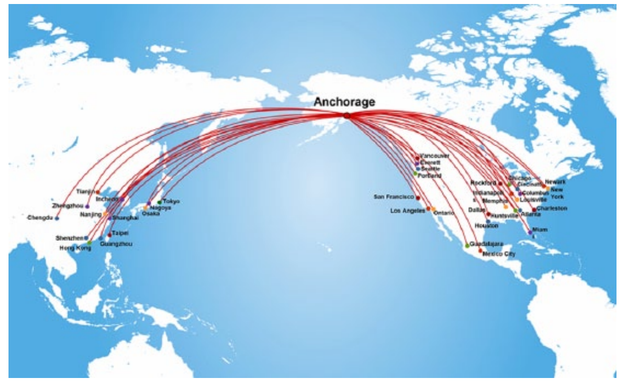

Figure 9. Passenger and cargo routes served by ANC (passenger routes only to North American regions).

Transpacific

With regard to the Pacific flight path, the airport chosen for consideration is Ted Stevens Anchorage International Airport (ANC) in Anchorage, Alaska. This airport falls into Cluster 1 of the analysis, meaning it is conveniently situated between major airports in North America and Asia. As a preliminary observation, the features of ANC were compared with those of KEF. ANC currently has three runways, one more than KEF. This suggests that ANC can cope with a similar capacity to KEF. Additionally, ANC currently has about 2.5 million passengers passing through annually. Before heavily promoting its stopover policy in 2009, KEF dealt with a similar number of passengers, around 2 million annually. Now, in 2016, KEF moves more than 6 million passengers through its airport annually (*10*). This shows how ANC has a large margin of growth given it can implement a successful stopover policy. In addition, just as with Reykjavik, Anchorage has the largest population in Alaska, allowing for the infrastructure and manpower to handle increased tourism.

When the current routes ANC serves were considered, there were only flights for passengers to locations in North America. However, when looking at its cargo routes, ANC clearly uses its geographic location for a competitive edge in cargo transport (*20*). The map in Figure 9 showing the cargo locations ANC serves looks similar to what it might be expected an optimal hub location would look like. Thus, it gives the impression that ANC would be very successful in implementing this policy. In looking at why ANC does not currently offer international travel, it can be seen that the increased airplane range for nonstop flights and the opening of the airspace after 1989 dramatically reduced the demand at ANC for international passenger traffic. Thus, even though ANC does not currently offer international flights, the airport and the surrounding city are very much interested in creating passenger demand. Given the creative spin and competitive edge that a stopover policy offers, implementing this at ANC could be an excellent way of increasing demand for the airport and, as a result, increasing tourism and boosting the economy in the surrounding area.

Conclusion

Airport locations that are geographically optimal for hubbing for international flights were identified using k-means clustering based on total added distance and total leg symmetry. The analysis may be used to successfully forecast the future growth of airports along high-activity international flight paths. These airports were grouped based on paths located in the Atlantic, Pacific, and EuroAsia flight routes. Given the many airports identified, however, future work could be to utilize features other than geography, such as economy, weather, and population, to further filter out the airports most suitable for implementing successful stopover policies. Given the novelty of this idea, it will be interesting to see how popular it becomes and which airports can successfully implement the policy.

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