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Long-Distance Airport Substitution and Air Market Leakage: Empirical Investigations in the U.S. Midwest

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Abstract

Following airline mergers and network reorganizations aimed at reducing operational costs, consolidated air services at large hub airports have encouraged air travelers to forego use of their smaller local airports to access large hub airports offering superior air services farther away. In this study, we investigate airport leakage in areas of Wisconsin and Michigan served by small airports, where air travelers may leak to neighboring large hubs. Using a proximity-based service area definition, we identify three airports experiencing leakage, to apply a hierarchical logit airport choice model that accounts for air service characteristics and access distance for travelers coming from these airports' service areas. Results show that a similar mean number of flight legs at both the local and substitute (large hub) airports will encourage leakage at Dane County Regional and Gerald R. Ford International, indicating that adding direct flights alone will not be sufficient to combat leakage. Comparable access distances to local and substitute airports have opposite effects on the local markets of Gerald R. Ford International and Milwaukee Mitchell International Airports – promoting leakage at the former but discouraging it at the latter. Furthermore, proportional increases in airfares at local airports lead to uneven losses of markets in investigated service areas. Overall, our study provides empirical evidence of long distance airport "leakage" in parts of the U.S. Midwest, and how its implications can be used by small airports seeking to further understand and respond to travelers' airport choices within their local markets.

Keywords: interregional airport substitution, airport leakage, long-distance airport choice, U.S. Midwest.

Introduction

Air travelers often forego their small local airports and drive long distances across regional and state (and national) boundaries to depart from large hub airports, that offer superior air services such as direct, more affordable and frequent flights (*1–3*). With airline mergers and hub reorganizations that aim at lowering operational cost, the disparity in air services between small and large airports has grown, thereby putting large hub airports in a better position to attract passengers from far away (*4, 5*). Air travelers' choice of distant large airports over their small local airports is known as airport "leakage" (*2*), and has direct consequences on these small airports. Passenger losses can lead to service degradations that include increasing fares and reduced services, which further exacerbate local air market loss, eventually resulting in a vicious cycle of airport leakage (*6*). The local economy of regions served by small airports may also experience losses in potential revenue due to employment and tourism reductions (*6*). For instance, it was estimated that Wisconsin's economy could have gained over 233 million USD in revenue, 600 jobs and dozens of new flights if travelers had chosen their local airport of Milwaukee Mitchell International Airport (MKE) instead of leaking to Chicago airports (*7*). On an international scale, transborder leakage to U.S. airports is believed to cost the Canadian economy 2.4 billion USD in output and 9,000 jobs annually (*8*).

Long-distance airport substitution has been investigated through studies that mainly account for air service characteristics at local and distant hub airports (also known as substitute airports) such as airfare, airport access cost, flight frequency and availability of direct flights (*1, 2, 9–16*). In studies based on surveys, traveler specific characteristics such as trip purpose, access to car, age, income, travel frequency, frequent flyer membership and previous airport experience have been incorporated (*2, 10*). Some studies have also accounted for airport service quality such as on-time performance and types of aircraft (*17, 18*).

The purpose of this study is to use a large dataset of air ticket purchases towards better understanding interregional airport leakage and its drivers using a discrete choice model. Previous choice model-based studies have been limited by surveys mostly conducted at airports or via mail that strongly restricts both the amount of data (despite its high quality) collected and diversity of itineraries on which passenger information is gathered. More importantly, the lack of coordinated funding among various planning institutions for collecting data on long-distance travel across neighboring regions has generally prevented an integrated megaregional study (*19*).

This study takes a step towards addressing the above challenges by using millions of air tickets purchased by travelers whose residential ZIP codes are known, and departed from 27 airports in parts of the U.S. Midwest to hundreds of domestic destinations over the period 2013 up to 2018. This air ticket data is supplemented with other publicly available aviation data to build our model of long-distance airport leakage. We establish a "service area" definition in which we assign each airport a local market consisting of a group of ZIP codes closest to it. This definition of "service area" is a simple proximity-based configuration rather than an estimate of "airport catchment." We assume "leakage" takes place when a traveler from the service area of a small/medium airport departs out of a large hub serving a different service area. After determining the proportion of such travelers that abandoned their local airport, we identify three small/medium-sized airports that lost at least a quarter of their local markets and examine the drivers of leakage using a hierarchical logit (HL) model.

Literature Review

Around the year 2000, before major airline mergers, travelers were estimated to travel up to 75 miles to access airports that offered lower fare due to the presence of low cost carriers (*15, 16*). Subsequent studies then showed that air travelers drove in excess of 200 miles to out-of-region large hubs (*2, 20*). As the air travel industry underwent significant changes over the following years – leading to stark differences in air services among neighboring regions, it was estimated that up to 85.1% of air travelers facing connecting itineraries at their local small and medium airports leaked to large hubs up to 300 miles away (*1*).

The drivers of airport leakage have mainly been studied through discrete choice models and market share models. The majority of studies that employed choice models are pre-major airline mergers based on surveys of few hundred air passengers at a single location over a short period of time (*2, 11, 12*). Despite the limitation in number of passengers and itinerary plans surveyed, such studies, in addition to accounting for air service characteristics (airfare, flight frequency and availability of direct flights), often incorporate valuable information such as travel purpose, income, frequent flyer membership, and flying experience of travelers which are important in explaining the propensity to "leak" (*2*). Market share models, on the other hand, use publicly-available, aggregate data to investigate air passenger traffic leakage (*1, 9, 20*). These studies have shown that leakage at smaller airports could potentially become irreversible without external intervention as long as competing large airports with superior air services keep attracting more passengers.

The problem of airport leakage is not one that merely concerns air travelers and small airports, but also the entire region served by these small airports. Air services are known to stimulate regional economic development through tourism and employment opportunities (*21–23*). Airport sponsors such as cities and sub-state governmental authorities worldwide re-invest airport revenues towards maintaining and expanding air services (*4, 24*) and as such, loss of local market through airport leakage deprives regions of potential economic growth. Furthermore, prolonged leakage leads to depressed demand at local airports, leaving airlines little choice but to reduce air services and increase fares (*6*) – paving the way for more leakage. In order to combat this detrimental effect, small airports have been using different marketing and incentivization strategies, such as waiving airport fees to persuade certain carriers into adding nonstop services, improving airport amenities; and extensive awareness campaigns (*5, 7)*.

With the availability of a substantially larger data set reporting itineraries on millions of travelers originating from parts of the U.S. Midwest, we build on previously published long distance airport choice model studies. By incorporating variables such as airport access cost (in terms of distance), airfare, flight frequency and number of flight legs, which are well-established determinants of leakage according to the literature thus far, we present hierarchical logit (HL) models that provide further insight into these drivers. Our results offer small airports additional evidence of airport choice behavior in their intended markets and targeted knowledge to combat airport leakage.

Data

Study Area

We focus on the U.S. Midwest centered around Chicago, which includes parts of Illinois, Indiana, Iowa, Michigan, Minnesota and Wisconsin. Chicago is a well-known multiairport system (MAS) consisting of O'Hare (ORD) and Chicago Midway (MDW) International Airports, attracting passengers from a large surrounding area, crossing state boundaries (*25, 26*). The chosen area includes MKE that recently launched a market retention campaign called "Choose MKE" which is aimed at reducing leakage to Chicago and earned the airport (along with its rebranding efforts) international recognition at the Airports Council International – North America Marketing and Communications Conference in November 2019 (*27, 28*). Among the study airports, MKE is also the only medium sized airport in the category of small/medium hubs that lost at least a quarter of its local market between 2013 and 2018 due to leakage according to the ticket purchases data used in this study.

Table 1 gives a summary of the study airports explored initially, including the International Air Transportation Association's (IATA's) three letter codes and the Federal Aviation Administration's (FAA's) airport category (*29*).

UIN, although was forecasted to remain as a Non-primary Commercial Service (CS) by the FAA in the National Plan for Integrated Airport Systems for 2019-2023 (*30*), qualified for Non-hub primary according to its 2018 enplanement. A map of the study airports is given in Figure 1.

Evident from Figure 1, the MAS of Chicago is in an ideal central position to attract market from afar in all four directions.

Main Data – ARC Market Locator

Itineraries of air travelers departing from the 27 study airports for the period January 2013 through December 2018 are acquired from the Airlines Reporting Corporation's (ARC's) Market Locator dataset. The Market Locator data is a sample of air tickets purchased through travel agencies (both traditional brick-and-mortar and online) and contains complete information on: month and year of purchase; origin-destination (O-D); route; and ZIP code under which the credit card used to purchase the ticket(s) is registered. Because tickets purchased from travel agencies/third parties are far more likely to be for personal travel, we assume that most credit card ZIP codes would be travelers' home addresses rather than those of companies. However, the dataset has some limitations. First, it is likely to contain a much higher proportion of leisure travelers over business travelers as business travelers are more inclined towards purchasing tickets directly from airlines rather than third-party agents. Second, itineraries on Southwest Airlines and several other low-cost carriers are not included. Annual number of travelers (upon initial departure/excluding connections) reported in the Market Locator data ranges from 2% up to 3.8% of total annual enplanements for large hubs except MDW and DTW, and 3.7% up to 9.8% for the remaining airports.

Supplementary Data

In order to compute airport access distance and establish our proximity-based service areas, primary and secondary road shapefiles for each of the six study states are downloaded from the U.S. Census Bureau, Department of Commerce (*31*). The geographic coordinates of the ZIP codes' centroids integrated into the road networks are extracted from the publicly available data source "opendatasoft" (*32*) while those of airports are acquired from IATA's airport database (*33*) and OpenFlights (*34*).

For air service variables such as airfare, flight frequency, available seat, market mile and nonstop miles flown, we use the Airline Origin and Destination Survey (DB1B) Ticket and Market data, and Air Carrier Statistics (Form 41 Traffic) – T-100 Domestic Segment (All Carriers) on the bases of quarter and final destinations (*35, 36*). Information regarding annual enplanement is obtained from the U.S. Department of Transportation – FAA (*37*).

Data Cleaning, Filtering, and Processing

ARC Market Locator Dataset

To limit our model scope to domestic travel, we first remove itineraries with international final destinations. Anomalous records whose origin does not match the first airport in the "routing" field and/or showing zero passengers are also removed. After cleaning, 4,666,310 usable records that consist of travelers coming from over 4,600 ZIP codes in the six study states remain. In some cases, more than one traveler is recorded on the same itinerary. This practice of reporting multiple passengers that purchase the same itinerary plan on a single record is common among agencies (including the FAA) that report samples of total air tickets sold, allowing for dataset compression (*38*). We "uncompress" this data into individual itineraries in order to construct our disaggregate passenger level model.

The distance between every ZIP code and each of the study airports is then computed in ArcGIS, ArcMap 10.4.1, using the primary and secondary road shapefiles as well as geographic coordinates representing the centroids of ZIP codes and airports. We then label all ZIP codes closest to a certain airport as the "service area" of that particular airport as shown in Figure 2. "Chicago Multi-Airport Region (CHI)" stands for the MAS of ORD and MDW that serves the metropolitan area of Chicago and its suburbs (*39*).

The uncolored ZIP codes in Figure 2 have no itinerary record associated with them after data processing.

Throughout the study region from 2013-2018, the data shows that 76% of air travelers traveled less than 80 miles to their chosen airport, 17% traveled between 80 - 200 miles, 5% traveled between 200 - 300 miles, and the remaining 2% traveled over 300 miles. The majority of passengers that traveled less than 80 miles consist of travelers originating from ZIP codes of the heavily populated Chicago MAS that departed from either ORD or MDW; travelers from Minneapolis that chose MSP; and passengers from Detroit that accessed DTW. The mean extra distance traveled by leaking passengers is 79 miles, and the 75th percentile – 120 miles. On average, around 300 different U.S. domestic airports are represented as final destinations on the tickets per quarter.

In Figure 3, we present the six-year airport choice distribution at 15 service areas. Service areas in which over 90% of market used local airport (IND, STL, DSM, and all four large hubs) are not included. Furthermore, service areas served by the five smallest Non-hub primary airports of RHI, IMT, ESC, MKG and UIN are excluded as these airports experienced market losses close to 100%.

From Figure 3, the strong attraction of ORD (bright green) is evident across this expansive study area. There is also at least one large hub that competes with the local airport in each service area.

We choose MKE, GRR and MSN as service areas to be modeled according to the criterion set at the beginning of the study (small/medium hub losing at least 1/4th of local market). MKE is heavily contested by ORD which is 73 miles away, and very slightly by MSP at 344 miles. MSN is contested by MKE and ORD which are 84 and 134 miles away respectively while GRR is contested by DTW and ORD at 147 and 200 miles.

Supplementary Data

The Market Locator data is supplemented with DB1B and T-100 records on the basis of "quarter" and "origin-final destination". The DB1B ticket and market data are matched to extract air service variables such as airfare, market miles as well as nonstop miles flown.

Other variables such as flight frequency, available seat and enplaned passengers per quarter for all reported destinations are extracted from the T-100 dataset, while number of flight legs is directly computed from the Market Locator data using route details provided.

Leakage

In Figure 4, we illustrate the proportion of leaked travelers at the three service areas chosen for modeling. The black continuous line cutting the ZIP codes in Wisconsin serves as the border between service areas MSN and MKE.

From Figure 4, GRR successfully attracted market within its immediate vicinity better than both MSN and MKE, but throughout its service area, MKE outperformed both GRR and MSN by retaining more local market. The eastern half of GRR's identified service area, towards DTW, appears to have experienced significant leakage to DTW. Travelers from that region must drive substantial distances to reach GRR and thus, many drive a little farther to access DTW instead. Furthermore, travelers that originate from ZIP codes that are midway between DTW and GRR are likely to choose between these two airports based on flight services alone, without considering (the comparable) ground access times. For instance, travelers from Lansing, MI would drive approximately one hour to GRR, and 1.3 hour to DTW. These travelers are likely to tolerate an additional 0.3-hour drive to access DTW's more expansive air services, as confirmed by the intensity of leakage shown in Figure 4.

With regards to MSN, leakage was more intense at the border between MKE's service area and Illinois, as travelers from those areas would drive nearly the same distances to MKE or ORD (instead of MSN). The same pattern is also observed in the service area of MKE, although at a lesser intensity – travelers on the border of service area MKE and Illinois leaked to ORD.

Approach

Modeling Market Leakage through Passengers' Airport Choice

Discrete choice models have been used to model not only airport choice but also: airport and airline; airport and access mode; departure and arrival airports; airport, airline, and access choice; and departure airport, airline, flight and access mode choices altogether (*40–46*).

We use HL models in which the decision to leak (or not to leak) is made first, followed by airport choice. Thus, we assume a sequential decision process is practiced by travelers.

In Table 2, we summarize candidate model variables that are initially explored and tested for multicollinearity.

Multicollinearity

In the presence of collinear explanatory variables, parameters calibrated by discrete choice models tend to be erroneous and poorly estimated (*47, 48*). In order to prevent this, we use variance inflation factor (VIF) to test collinearity among candidate variables. VIF, which is expressed in Equation 1, quantifies by how much the standard error of a predictor/explanatory variable's coefficient is inflated in the presence of collinearity in comparison with model fitted with no collinearity.

$$VIF_j = \frac{1}{1-R_j^2} \quad (1)$$

Where $VIF_j =$ the variance inflation factor of the j^{th} variable and

R_j^2 = the goodness of fit obtained by regressing the j^{th} predictor on the remaining regressors.

VIF can detect linear dependence among multiple variables even when pairwise correlations are small (*49*). A VIF exceeding five or at most ten is an indication that there is strong collinearity. These upper limits have also been suggested in other studies (*50, 51*). Thus, we assess and qualify candidate variables shown in Table 2 based on this recommended maximum VIF.

HL Model Specification

We specify a model for airport choice decision at service areas GRR, MSN and MKE. The choice set per service area is decided based on three airports that collectively account for at least 95% of the local market. As such, service area GRR is served by the local airport GRR and substitutes DTW and ORD with a combined market share of 98%. Similarly, service area MSN is served by MSN, MKE and ORD with a combined market share of 96%, and service area MKE is served by MKE, ORD and MSP at 98%.

Figure 5 presents the proposed model structure and choice set for each service area. In specifying utility expressions, we first fix airfare's coefficient across alternatives by assuming that travelers place the same value on money irrespective of their choice. However, we allow parameters associated with total flight frequency, distance to airport and mean number of flight legs to vary across alternatives, analogous to how utilities of different travel modes are specified (*52*). This approach is realistic as travelers are likely to be aware of the quality of service provided at all airports and place different weights on certain factors at local and substitute airports differently. For instance, the typical traveler (there will be exceptional cases, especially among high income frequent holiday travelers (*10*)) is unlikely to leak to a substitute airport in search of only a more suitable schedule unless a direct flight or a lower fare is offered and thus, is expected to value flight frequency at substitute airports less than at local.

The parameter associated with distance to airport also varies across alternatives because we expect travelers to be more sensitive to ground travel delays in shorter trips, i.e. while traveling to their local airport, in contrast to trips to distant substitute airports.

We also allow the coefficient associated with mean number of flight legs to vary across alternatives as our data processing includes all kinds of routes and does not explicitly account for travelers that leak to catch direct flights instead of using a connecting itinerary that starts at their local airport.

The model specification is given in Equations 2 – 4.

$$U_{t,q,Local}^{SA-j} = c_{Local} + \beta_1 . d_{Local} + \beta_2 . \bar{l}_{q,Local}^{j} + \beta_3 . t_{q,Local}^{j} + \beta_4 . \bar{f}_{q,Local}^{j} + \varepsilon_{Local} \quad (2)$$

$$U_{t,q,Sub1}^{SA-j} = c_{sub1} + \beta_5 . d_{Sub1} + \beta_6 . \bar{l}_{q,Sub1}^{j} + \beta_7 . t_{q,Sub1}^{j} + \beta_4 . \bar{f}_{q,Sub1}^{j} + \varepsilon_{Sub1} \quad (3)$$

$$U_{t,q,Sub2}^{SA-j} = \beta_5 . d_{Sub2} + \beta_6 . \bar{l}_{q,Sub2}^{j} + \beta_7 . t_{q,Sub2}^{j} + \beta_4 . \bar{f}_{q,Sub2}^{j} + \varepsilon_{Sub2} \quad (4)$$

Where $U_{t,q,Local}^{SA-j}$ = the utility derived by traveler t coming from service area SA that flies from local airport $Local$ to final destination j during quarter q via any route,

c_{Local} = alternative specific constant for local airport $Local$,

$\beta_1 \dots \beta_7$ = estimated parameters,

d_{Local} = distance (in hundreds of mile) from traveler's ZIP code centroid to local airport $Local$,

$\bar{l}_{q,Local}^{j}$ = mean number of flight legs from local airport $Local$ to final destination j via all routes during quarter q,

$t_{q,Local}^{j}$ = total number of flights (in hundreds) available from local airport $Local$ to final destination j via any route during quarter q,

$\bar{f}_{q,Local}^{j}$ = mean market fare (in hundreds of USD) from local airport $Local$ to final destination j considering all routes during quarter q,

$U_{t,q,Sub1}^{SA-j}$ = the utility derived by traveler t coming from service area SA that flies from substitute airport $Sub1$ to final destination j during quarter q via any route,

c_{Sub1} = alternative specific constant for substitute airport $Sub1$,

d_{Sub1} = distance (in hundreds of mile) from traveler's ZIP code centroid to substitute airport $Sub1$,

$\bar{l}^{j}_{q,Sub1} =$ mean number of flight legs from substitute airport $Sub1$ to final destination j via all routes during during quarter q,

$t^{j}_{q,Sub1}$ = total number of flights (in hundreds) available from substitute airport $Sub1$ to final destination j via any route during quarter q,

$\bar{f}^{j}_{q,Sub1} =$ mean market fare (in hundreds of USD) from substitute airport $Sub1$ to final destination j considering all routes during quarter q,

$U^{SA-j}_{t,q,Sub2}$ = the utility derived by traveler t coming from service area SA that flies from substitute airport $Sub2$ to final destination j during quarter q via any route,

$d_{Sub2} =$ distance (in hundreds of mile) from traveler's ZIP code centroid to substitute airport $Sub2$,

$\bar{l}^{j}_{q,Sub2} =$ mean number of flight legs from substitute airport $Sub2$ to final destination j via all routes during quarter q,

$t^{j}_{q,Sub2}$ = total number of flights (in hundreds) available from substitute airport $Sub2$ to final destination j via any route during quarter q,

$\bar{f}^{j}_{q,Sub2} =$ mean market fare (in hundreds of USD) from substitute airport $Sub2$ to final destination j considering all routes during quarter q and

$\varepsilon_{Local}, \varepsilon_{Sub1}, \varepsilon_{Sub2} =$ stochastic error terms.

We include error terms to account for unexplained variations that could result from traveler-specific factors such as socioeconomic characteristics which are not available in our model.

Results

In Table 3, we summarize parameters estimated for the model specified.

The coefficient of flight frequency for substitute airport is less than half of that for local at all service areas, suggesting that higher flight frequency at substitute airports is not a major driver of leakage. Similar flight frequency at both the local and substitute airports would result in more travelers choosing their local airport. This is mainly because the Market Locator dataset predominantly consists of leisure travelers who are expected to care more about airfare and airport access time, as opposed to business travelers who would be more concerned about timing (flight frequency) (*10*).

Regarding airport access, the coefficients on the distance to local and substitute airport (4.216 and -4.131 respectively) are comparable at service area MSN, such that when distances to both airports are equal, travelers have no strong preference for one airport over another except those which are captured by the remaining air service variables. For service area GRR, the coefficient values indicate that when distances (and all else) are equal, there is a preference for the substitute airport (DTW). This result reflects the leakage intensity at service area GRR shown in Figure 4, where we observe that more travelers from ZIP codes equidistant to GRR and DTW leaked to DTW. For service area MKE, distance to airport coefficient for the local airport (MKE) is smaller in magnitude than that for substitute airports, indicating that comparable access distances to local and substitute airports discourage leakage. This may have been induced by the inclusion of MSP which is quite distant from MKE at 344 miles away and chosen only by 2% of the local market. In order to investigate how the model parameters would change, we remove MSP from the list of substitute airports for service area MKE (including the 2% travelers that chose MSP) and estimate a new model with 96% of the total travelers that chose between MKE and the only remaining substitute – ORD. Although the coefficients change in magnitude, the changes are not significant, nor do they lead to different conclusions. This result also reflects the observations from Figure 4, where a smaller proportion of travelers from service area MKE bordering with Illinois appear to have chosen ORD over MKE compared to parts of service areas MSN and GRR which are equidistant to local and substitute airports.

With regards to mean number of flight legs, the coefficient at local is lower than the one at substitutes at service areas GRR and MSN (-2.119 vs -2.088 for service area GRR and -1.607 vs -1.591 for service area MSN) – a comparable number of flight legs at both the local and substitute airports results in greater utility (more preference) for the substitute airport. All other variables (airfare, access distance and flight frequency) accounted for, if the same number of flight legs is offered to a certain destination at both the small local and large substitute airports, we normally expect more travelers to derive higher utility from (and thus prefer) their local airport. Nevertheless, model results confirm the opposite, possibly indicating that air travelers generally have low opinion of these small airports. On the other hand, at service area MKE, the parameter estimated for mean number of flight legs at substitute is larger in magnitude than its counterpart at local which shows that travelers from service area MKE derive higher utility out of their local medium hub of MKE than ORD if the same number of flight legs is provided to a certain destination from both airports. This is particularly convincing since MKE, in comparison to GRR and MSN, is a well-serviced medium hub and travelers would generally have to find direct flights at ORD that are not offered at MKE in order to leak. These opposing findings show that effective market retention strategies should not be homogenously applied to different airports as also noted in a previous study (*53*). For instance, adding direct flights at MSN/GRR to destinations directly served by large substitute airports will be more effective only if awareness creation campaigns are carried out in order to reduce the favoritism towards distant large hubs. On the other hand, only introducing direct flights might be enough to combat leakage at the medium hub of MKE.

The effect of airfare is best presented through a sensitivity analysis which captures market share changes induced by increments in airfare at local airports. Keeping all other variables unaltered, we look at the effects of increased fare at local airports up to 40%, in increments of 10%. A 10% increase in airfare at the local airport leads to a dramatic market loss of 20.4% at service area GRR, but results in only 5.8% and 2.8% losses at service areas MSN and MKE respectively. These results show that a small increase in airfare at local airports can have very different impacts on the respective local markets. Greater increases in local airport airfare at service area GRR (i.e., beyond 10%), however, do not lead to further substantial market loss, as evident from the 28% market loss that results from a 40% increase in airfare. On the other hand, market losses at service areas MSN and MKE reach up to 39.1% and 28.5% respectively as airfares at the local airports increase by 40%.

Overall, model results show that the same number of flight legs at both the local and substitute airports promotes leakage at service areas MSN and GRR while discouraging it at service area MKE.

Comparable distances to both local and substitute airports lead to more travelers bypassing their local airport in service area GRR, but choosing their local airport in service area MKE. Furthermore, a small increase in airfare at the local airport leads to substantial market loss only at service area GRR, although greater increases eventually drive away considerable travelers from the two remaining service areas. Additionally, our findings show that higher flight frequencies at substitute airports do not appear to be the predominant driver of leakage.

While our study provides valuable insight into service variables affecting long distance airport choice, and its findings can be used as inputs by small airports towards retaining more market in parts of the U.S. Midwest, a more analytical “airport catchment” definition is required instead of the simple proximity based “service area” configuration to better capture destination based choice behavior. Furthermore, variables related to socioeconomic characteristics of travelers need to be incorporated in future modeling works.

Conclusion

This study assesses long distance airport substitution and leakage in areas served by three small/medium airports in the U.S. Midwest where air travelers have the option to drive out of region to large hub airports, using a dataset of air ticket itineraries that include presumed residential ZIP codes of these travelers. We use a proximity based “service area” configuration in which we assign groups of ZIP codes closest to a certain airport as the local market of that airport. We assume leakage occurs when travelers abandon their original service area and choose a substitute airport (generally a large hub) different from their local one. We supplement itinerary records with other publicly available air service information, and model airport choice for travelers originating from service areas served by GRR, MSN and MKE using a hierarchical logit model.

Application of the model confirms that comparable access distances to both the local and substitute airports at service area GRR encourage leakage, but discourage it at service area MKE. With regards to number of flight legs, more travelers from service areas GRR and MSN leak even when the number of flight legs at both the local and substitute airports is similar, possibly due to passengers' low opinion of these small local airports. However, at service area MKE, a similar number of flight legs at both the local and substitute airports results in less leakage, showing that adding direct services at MKE may be effective in combating leakage to Chicago. A sensitivity analysis of market share with respect to airfare indicates that service area GRR is at risk of losing substantial market if airfare is increased by 10% at the local airport of GRR. Higher increases in fares at local airports are required for the same substantial local market loss at service areas MSN and MKE. Finally, model results show that flight frequency does not appear to play a measurable role in leakage, mainly because the Market Locator dataset predominantly consists of leisure travelers that are not expected to value flight schedules as much as airfare and airport access time. Overall, our study provides the link between airport leakage and various air service variables based on a large and recent dataset, and its findings can be used as inputs by small airports and their sponsors towards understanding air travelers' airport choice in order to lessen leakage.

This paper documents the first exploration of this dataset towards understanding long-distance airport leakage, and there is much work ahead. In order to replace the "service area" definition, more research is needed – particularly empirically-based approaches that control for destination airports – to define geographic airport catchments. Second, other model specifications and explanatory variables will be explored. Third, models will be constructed to include the entire megaregion and others to understand general interregional airport leakage experiences throughout the US.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: K. W. Yirgu, A. M. Kim; analysis and interpretation of results: K. W. Yirgu, A. M. Kim; draft manuscript preparation: K. W. Yirgu; draft manuscript review and editing: K. W. Yirgu, A. M. Kim, and M. S. Ryerson. All authors reviewed the results and approved the final version of the manuscript.

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Table 1 Study Airports

Airport	**IATA code**	**State**	**FAA Airport Category** (*29*)	**Airport**	**IATA code**	**State**	**FAA Airport Category** (*29*)
Appleton International	ATW	Wisconsin	Non-hub primary	Chicago Midway International	MDW	Illinois	Large hub
Kalamazoo/ Battle Creek International	AZO	Michigan	Non-hub primary	Milwaukee Mitchell International	MKE	Wisconsin	Medium hub
Central Illinois Regional	BMI	Illinois	Non-hub primary	Muskegon County	MKG	Michigan	Non-hub primary
University of Illinois Willard	CMI	Illinois	Non-hub primary	Quad City International	MLI	Illinois	Non-hub primary
Central Wisconsin	CWA	Wisconsin	Non-hub primary	Dane County Regional	MSN	Wisconsin	Small hub
Dubuque Regional	DBQ	Iowa	Non-hub primary	Minneapolis-Saint Paul International	MSP	Minnesota	Large hub
Des Moines International	DSM	Iowa	Small hub	Chicago O'Hare International	ORD	Illinois	Large hub
Detroit Metropolitan Wayne County	DTW	Michigan	Large hub	General Wayne A. Downing Peoria International	PIA	Illinois	Non-hub primary
Delta County	ESC	Michigan	Non-hub primary	Rhinelander-Oneida County	RHI	Wisconsin	Non-hub primary
Fort Wayne International	FWA	Indiana	Non-hub primary	Southbend International	SBN	Indiana	Non-hub primary
Austin Straubel International	GRB	Wisconsin	Non-hub primary	Abraham Lincoln Capital	SPI	Illinois	Non-hub primary
Gerald R. Ford International	GRR	Michigan	Small hub	St Louis Lambert International	STL	Missouri	Medium hub
Ford	IMT	Michigan	Non-hub primary	Quincy Regional Baldwin	UIN	Illinois	Non-hub primary
Indianapolis International	IND	Indiana	Medium hub				

Table 2 Candidate Variables

Variable	Timeframe	Basis	Unit
Airport access distance*	-	ZIP code centroid to airport	mile/100
Total flight frequency*		“origin-destination” for direct flight, “origin-first stop” for connecting flight – all routes leading to final destinations considered	/100
Mean airfare		“origin-final destination” (all routes averaged)	USD/100
Mean fare per mile		“origin-final destination” (all routes averaged)	USD/mile
Mean number of flight leg(s)		“origin-final destination” (all routes averaged)	-
Total available seat	quarterly	“origin-destination” for direct flight, “origin-first stop” for connecting flight – all routes leading to final destinations considered	/100
Total enplaned passengers		“origin-destination” for direct flight, “origin-first stop” for connecting flight – all routes leading to final destinations considered	/100
Mean market mile flown		“origin-final destination” (all routes averaged)	/100
Mean non-stop mile flown		“origin-final destination” (all routes averaged)	/100
*also tried with log transformation to account for decreasing marginal rate of return			

Table 3 Model Estimates

	Service area					
	GRR		**MSN**		**MKE**	
	estimate	**Z**	**estimate**	**Z**	**estimate**	**Z**
β_4 (airfare)	-1.352	-73.38*	-1.288	-122.55*	-1.281	-106.41*
Alternative specific variables						
Local						
β_1 (distance to airport)	-4.290	-232.62*	-4.216	-178.54*	-2.992	-112.04*
β_2 (mean no. of flight legs)	-2.119	-63.87*	-1.607	-79.47*	-1.982	-117.99*
β_3 (total flight frequency)	0.105	21.62*	0.064	19.42*	0.093	32.42*
Substitute						
β_5(distance to airport)	-3.570	-181.15*	-4.131	-187.95*	-3.643	-162.79*
β_6 (mean no. of flight legs)	-2.088	-80.53*	-1.591	-102.90*	-2.080	-105.23*
β_7 (total flight frequency)	0.041	26.15*	0.031	44.99*	0.032	46.41*
Alternative specific constants						
c_{Local}	-0.943	-16.45*	-1.170	-35.70*	-3.740	-28.61*
c_{sub1}	0.701	30.84*	0.631	47.37*	-3.489	-29.04*
Observations	664047		1054995		1442682	
Cases	221349		351665		480894	
Log Likelihood (LL)	-116688.72		-281700.59		-253731.31	
Wald Chi Square	57180.43		60589.65		56697.07	

*significant at the 99% confidence level

Figure 1 Study airports.

Figure 2 Service area of study airports.

Figure 3 Airport choice distribution by service area.

Figure 4 Leakage intensity in service areas of Gerald R. Ford International (GRR), Dane County Regional (MSN), and Milwaukee Mitchell International (MKE) airports.

Figure 5 Hierarchical logit (HL) model structure for service areas of Gerald R. Ford International (GRR), Dane County Regional (MSN), and Milwaukee Mitchell International (MKE) airports.

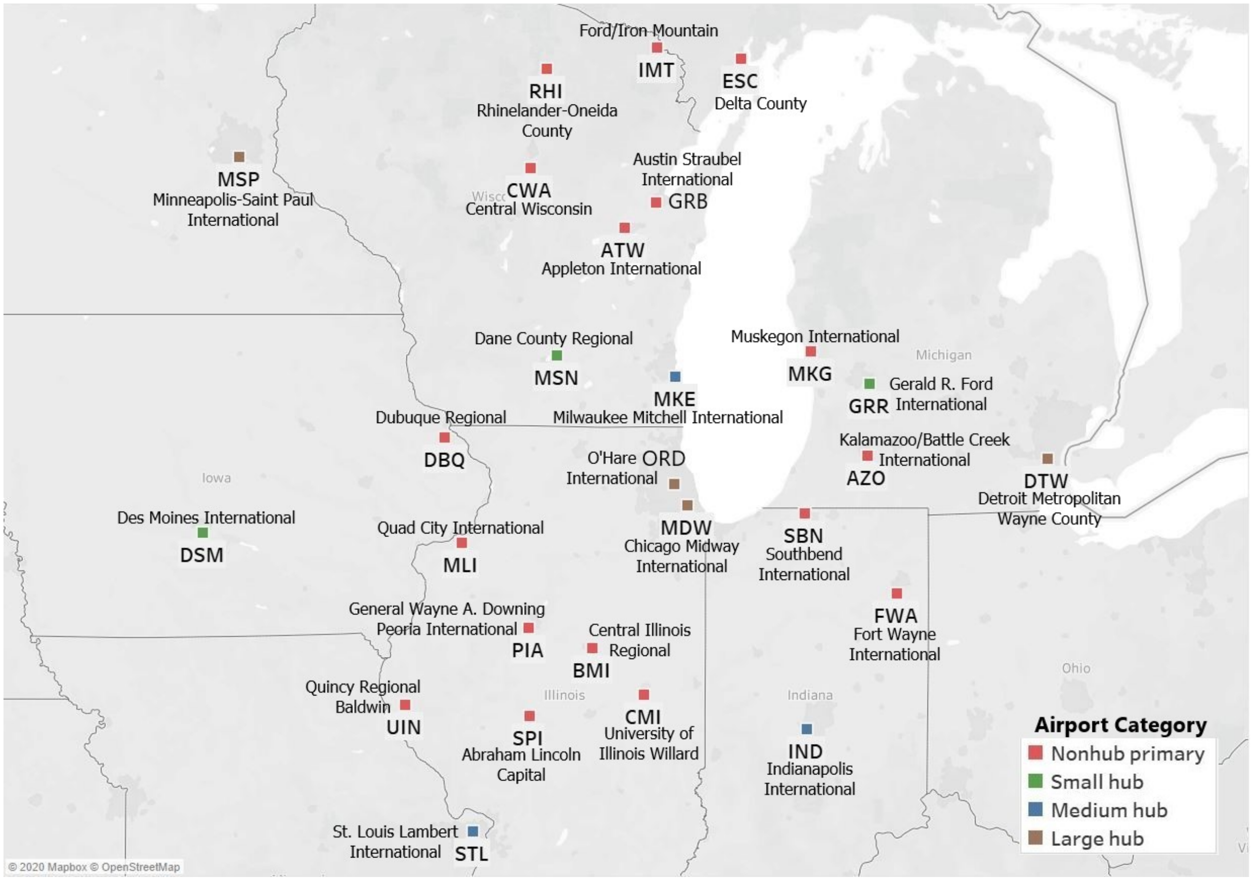

Ford/Iron Mountain
IMT
ESC
Delta County
RHI
Rhinelander-Oneida County
MSP
Minneapolis-Saint Paul International
CWA
Central Wisconsin
Austin Straubel International
GRB
ATW
Appleton International
Dane County Regional
MSN
MKE
Milwaukee Mitchell International
Muskegon International
MKG
Michigan
Gerald R. Ford International
GRR
Dubuque Regional
DBQ
Iowa
O'Hare International ORD
Kalamazoo/Battle Creek International
AZO
DTW
Detroit Metropolitan Wayne County
Des Moines International
DSM
Quad City International
MLI
MDW
Chicago Midway International
SBN
Southbend International
FWA
Fort Wayne International
General Wayne A. Downing Peoria International
PIA
Central Illinois Regional
BMI
Ohio
Quincy Regional Baldwin
UIN
Illinois
SPI
Abraham Lincoln Capital
CMI
University of Illinois Willard
Indiana
IND
Indianapolis International
St. Louis Lambert International
STL
Airport Category
Nonhub primary
Small hub
Medium hub
Large hub
© 2020 Mapbox © OpenStreetMap

Figure 1.

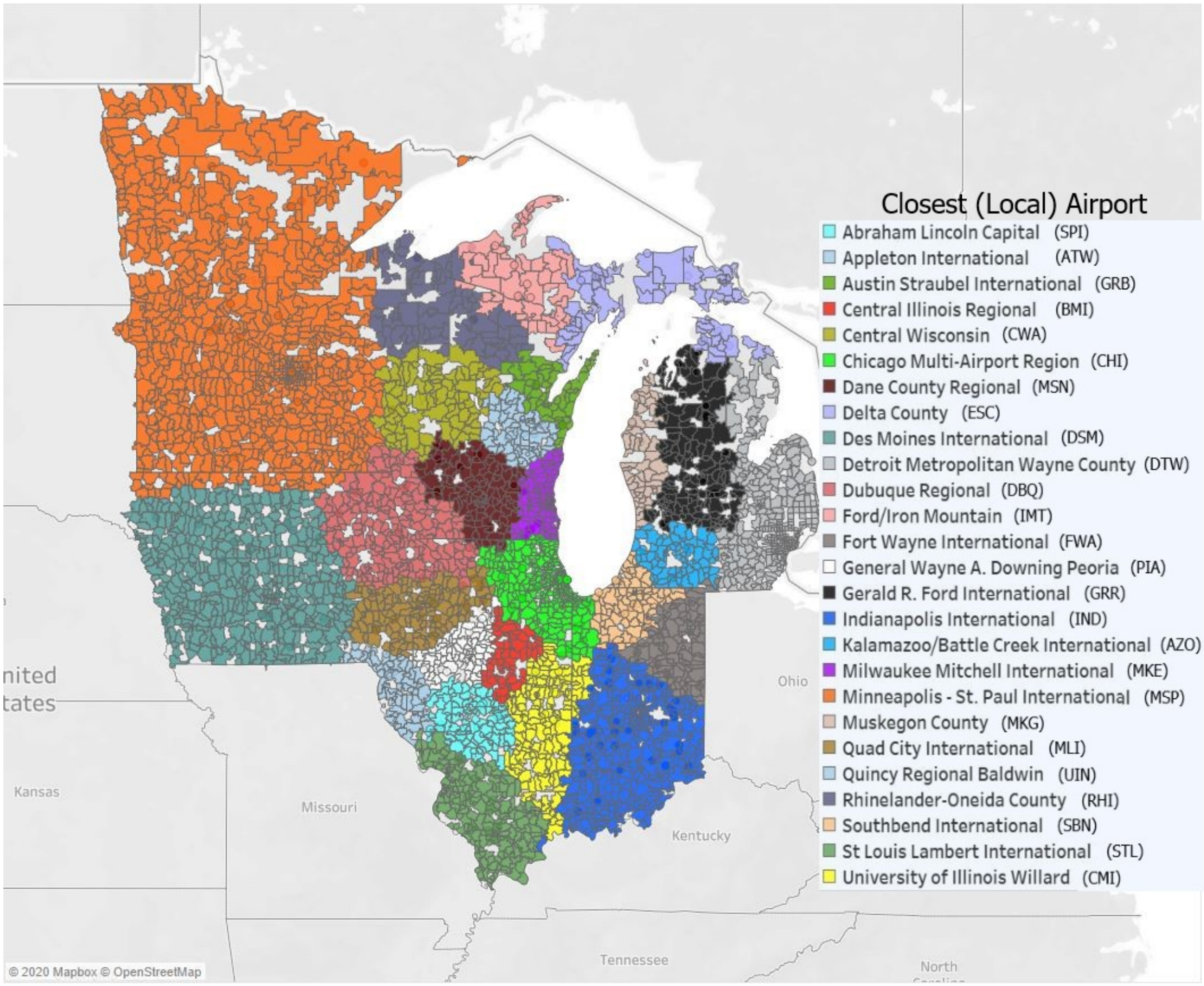
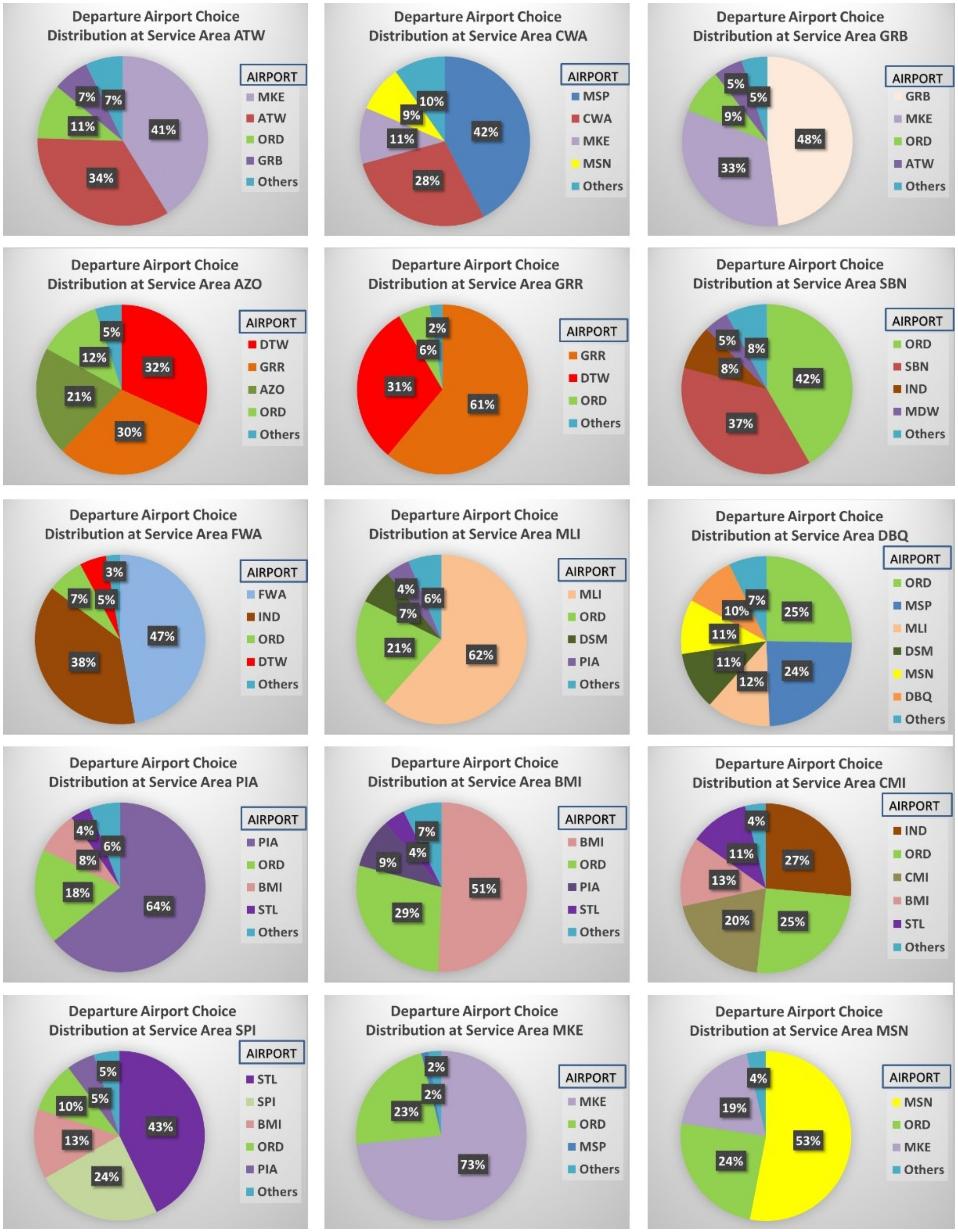

Closest (Local) Airport
Abraham Lincoln Capital (SPI)
Appleton International (ATW)
Austin Straubel International (GRB)
Central Illinois Regional (BMI)
Central Wisconsin (CWA)
Chicago Multi-Airport Region (CHI)
Dane County Regional (MSN)
Delta County (ESC)
Des Moines International (DSM)
Detroit Metropolitan Wayne County (DTW)
Dubuque Regional (DBQ)
Ford/Iron Mountain (IMT)
Fort Wayne International (FWA)
General Wayne A. Downing Peoria (PIA)
Gerald R. Ford International (GRR)
Indianapolis International (IND)
Kalamazoo/Battle Creek International (AZO)
Milwaukee Mitchell International (MKE)
Minneapolis - St. Paul International (MSP)
Muskegon County (MKG)
Quad City International (MLI)
Quincy Regional Baldwin (UIN)
Rhinelander-Oneida County (RHI)
Southbend International (SBN)
St Louis Lambert International (STL)
University of Illinois Willard (CMI)
Ohio
Kansas
Missouri
Kentucky
Tennessee
North
© 2020 Mapbox © OpenStreetMap

Figure 2.


Departure Airport Choice Distribution at Service Area ATW
AIRPORT
MKE
ATW
ORD
GRB
Others
7%
7%
11%
41%
34%
Departure Airport Choice Distribution at Service Area CWA
AIRPORT
MSP
CWA
MKE
MSN
Others
10%
9%
11%
42%
28%
Departure Airport Choice Distribution at Service Area GRB
AIRPORT
GRB
MKE
ORD
ATW
Others
5%
5%
9%
48%
33%
Departure Airport Choice Distribution at Service Area AZO
AIRPORT
DTW
GRR
AZO
ORD
Others
5%
12%
32%
21%
30%
Departure Airport Choice Distribution at Service Area GRR
AIRPORT
GRR
DTW
ORD
Others
2%
6%
31%
61%
Departure Airport Choice Distribution at Service Area SBN
AIRPORT
ORD
SBN
IND
MDW
Others
5%
8%
8%
42%
37%
Departure Airport Choice Distribution at Service Area FWA
AIRPORT
FWA
IND
ORD
DTW
Others
3%
7%
5%
47%
38%
Departure Airport Choice Distribution at Service Area MLI
AIRPORT
MLI
ORD
DSM
PIA
Others
4%
6%
7%
21%
62%
Departure Airport Choice Distribution at Service Area DBQ
AIRPORT
ORD
MSP
MLI
DSM
MSN
DBQ
Others
7%
10%
25%
11%
11%
24%
12%
Departure Airport Choice Distribution at Service Area PIA
AIRPORT
PIA
ORD
BMI
STL
Others
4%
6%
8%
18%
64%
Departure Airport Choice Distribution at Service Area BMI
AIRPORT
BMI
ORD
PIA
STL
Others
7%
4%
9%
51%
29%
Departure Airport Choice Distribution at Service Area CMI
AIRPORT
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CMI
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STL
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Departure Airport Choice Distribution at Service Area SPI
AIRPORT
STL
SPI
BMI
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PIA
Others
5%
5%
10%
43%
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24%
Departure Airport Choice Distribution at Service Area MKE
AIRPORT
MKE
ORD
MSP
Others
2%
2%
23%
73%
Departure Airport Choice Distribution at Service Area MSN
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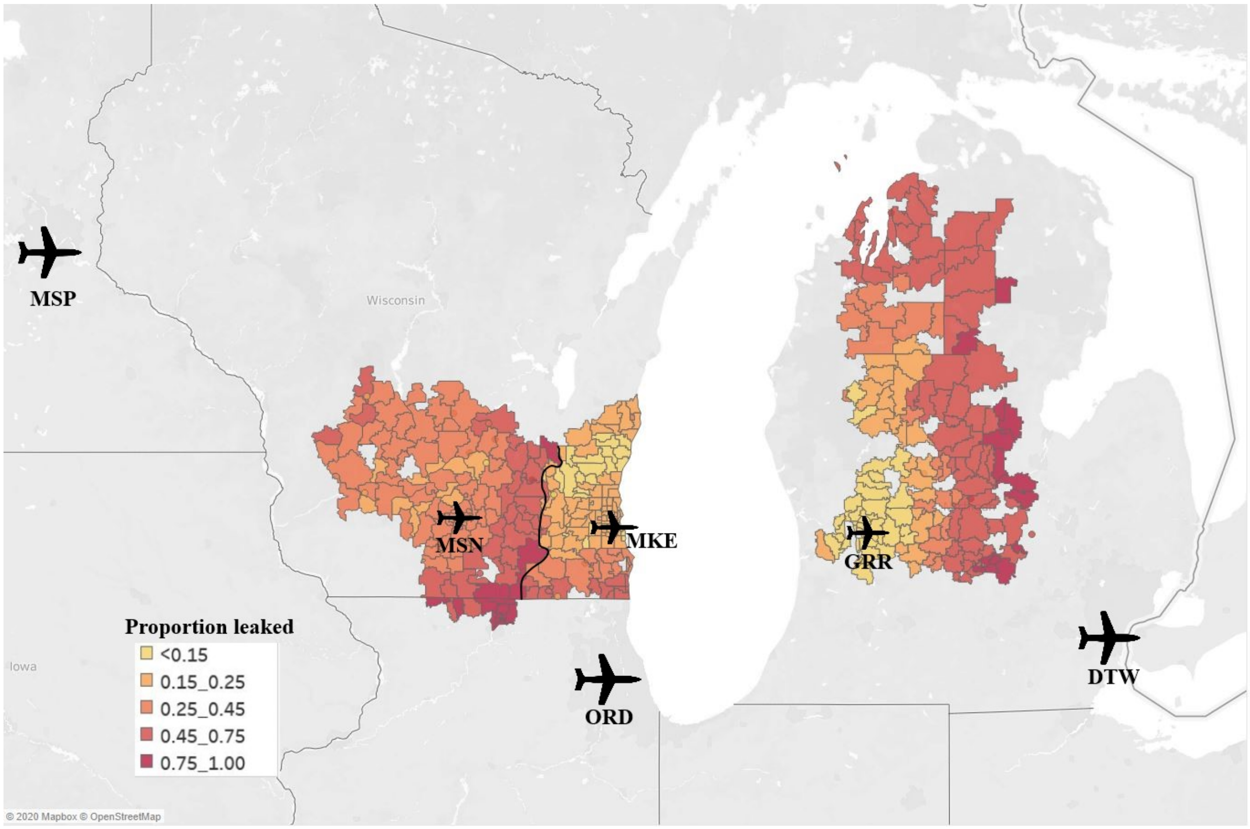
MSN
ORD
MKE
Others
4%
19%
53%
24%

Figure 3.


MSP
Wisconsin
MSN
MKE
GRR
Proportion leaked
<0.15
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0.25_0.45
0.45_0.75
0.75_1.00
Iowa
ORD
DTW
© 2020 Mapbox © OpenStreetMap

Figure 4.

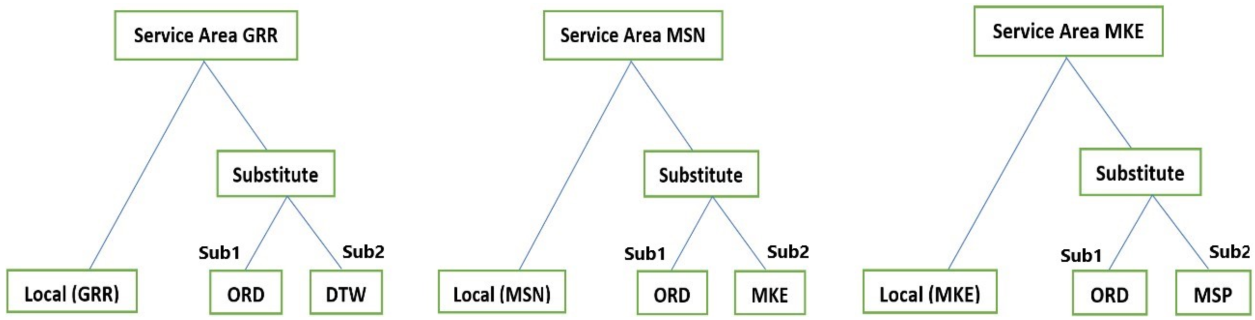
Service Area GRR
Substitute
Sub1
Sub2
Local (GRR)
ORD
DTW
Service Area MSN
Substitute
Sub1
Sub2
Local (MSN)
ORD
MKE
Service Area MKE
Substitute
Sub1
Sub2
Local (MKE)
ORD
MSP

Figure 5.