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A long drive: interregional airport passenger "leakage" in the U.S.

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***Highlights**

- We examine the literature (academic and in practice) on U.S. airport passenger leakage
- We focus on leakage from small and medium airports to large airports by personal vehicle
- Key points of focus to further the research on interregional airport leakage are identified
- Airport passenger leakage is a multimodal, inter-regional planning problem rather than solely an airport problem.
- Furthering the research depends on interregional data collection coordinated by cities, regions, and airports.

A long drive: interregional airport passenger "leakage" in the U.S.

Abstract

Airport passenger leakage is the phenomenon of air travelers foregoing their local airport to access large hub airports with better flight options and airfares. Interregional passenger leakage has not received extensive attention from the research community; this review was conducted in light of changes in the U.S. aviation system over the last 15 years. We examine the U.S. airport passenger leakage literature, focusing specifically on leakage from small and medium airports to large airports by personal vehicle. We emphasize the need for on-going data collection, to support advanced methodological applications and development. This allows for empirically-based definitions of airport catchment in an interregional context, and support airport planning and marketing activities. We also observe a need for more attention to integrated multimodal, interregional planning – specifically, understanding the air and ground connectivity of the interregional transportation system, particularly in the U.S. where public transport provision is largely absent interregionally.

Keywords: Interregional airport passenger leakage; interregional travel; airport passenger markets; airport passenger choice; airport competition; U.S. long-distance intermodal transport.

1. Introduction

Airport passenger "leakage" is the phenomenon of air travelers choosing to drive relatively long distances to access larger hub airports, bypassing their local airport. Air passengers "leak" across regions to take advantage of convenient flight schedules, lower airfares, and other amenities at the larger (substitute) airport – features that can override the added cost of driving longer distances. Interregional airport passenger leakage has been documented for decades from airports in small or rural cities (Kanafani & Abbas, 1987; Innes & Doucet, 1990; Grubesic & Wei, 2012; Wittman, 2014). However, in more recent years, there is evidence that airline mergers, alliances, and decisions to cut operational costs and increase efficiency (coined "capacity discipline") have reduced and degraded air services from small and medium-size airports. This has further resulted in these airports losing passengers to neighboring large airports (Sharkey, 2015; Ryerson, 2016b). But the subject of passengers "leaking" from a U.S. airport designated a small or medium hub (FAA, 2016) to large hub airports[1], often travelling well over 100 miles, has received less scrutiny from the research community. Despite airport competition and leakage being an issue worldwide, in this paper we focus specifically on the U.S. context in light of changes in the U.S. aviation industry.

Airport passenger leakage is a concern for airport operators, airlines, and ultimately, the traveler. Airport sponsors – typically cities or sub-state governmental authorities – have long sought to attract airlines to their airports, believing that air services stimulate regional economic development (Button & Taylor, 2000; Brueckner, 2003; Button, Doh, & Yuan, 2010; Green, 2007; Sheard, 2014). In fact, air service is viewed as so critical to a local economy that many airport sponsors throughout the world provide incentive packages funded by airport revenue to retain and build new service (Hihara, 2012; Malina, Albers, & Kroll, 2012; Ryerson, 2016a). Moreover, as passengers "leak" to an out-of-region airport, airlines will experience depressed demand at the local airport, leading to reduced flight schedules and higher fares. This vicious cycle is a detriment to passenger service, business development, and tourism at small and mid-sized cities.

[1] These airports make up roughly the top 30 U.S. airports, each handling over 1% of the country's annual passenger boardings.

This article's objectives are to: 1) identify the changing forces in both the U.S. aviation and surface transportation industries which make interregional airport passenger leakage a critical issue for researchers and decision makers, 2) review the methodological approaches that have been employed to assess leakage data, and 3) identify a research agenda to more comprehensively and rigorously understand leakage issues in the U.S. We target this review to researchers as well as industry practitioners looking to understand how airport passenger leakage has been studied in the past, in order to analyze future trends and impacts.

2. Changes in the U.S. aviation system facilitating airport passenger leakage

The first decade of the 21st century was characterized by a period of significant change in the U.S. aviation industry, resulting in growing mismatches between aviation demand and supply in proximate regions. The century began after a period of large-scale growth in flight departures (Goetz & Vowles, 2009). In contested markets airlines found that they could compete for passengers more effectively by adding targeted frequency, most notably by scheduling flights at times very close to those of their competitors (Borenstein & Netz, 1999; Wei & Hansen, 2005; Hanlon, 1989). Airlines purchased small regional jet aircraft seating 40-75 passengers to facilitate adding service frequency on key routes (GAO, 2014). However, the 2000s saw seven major U.S. airlines consolidate into three during a period of large variations in fuel price and economic recession. The newly merged airlines consolidated their networks and established fewer, more concentrated airline hubs, reducing flights on less profitable routes typically operated by small regional jets (Ryerson & Kim, 2013). Major airports situated in the largest cities (particularly in the Northeast corridor) and leisure regions such as Florida saw increases in their air service, while airports in smaller metropolitan areas (particularly the Rust Belt, Appalachia, Mississippi Valley, and parts of Idaho, Montana, and the rest of the Intermountain West) lost significant air service (Fuellhart, Ooms, Derudder, & O'Connor, 2016). In this era of "capacity discipline," airlines are mainly flying certain (profitable) routes and charging higher airfares due to reduced competition. This has resulted in widening discrepancies in flight frequency, number of destinations served, and airfares at airports with significant service versus those without (Brueckner, Lee, & Singer, 2013; Governing: the States and Localities, 2013).

Although there are many studies on air and rail competition, there have been fewer studies on the competition between air and driving (Levinson, Gillen, & Kanafani, 1998; Erhardt, Freedman, Stryker, Fujioka, & Anderson, 2007). While there are modes other than driving available for intercity travel (such as intercity bus, or less frequently, rail), private vehicle travel has the largest market share in the U.S. for intercity travel below 600 miles (Resource Systems Group, Inc., 2015). Given that the per mile cost of driving decreases as a trip becomes longer, many travelers that choose to drive much longer distances to access an airport with better services do not fully realize and accurately account for the true costs of driving (VTPI, 2016). Moreover, air service discrepancies may simply overpower these driving costs.

3. Literature review scope

We bind the scope of this review to include studies on passenger leakage from small- and medium-size airports to large out-of-region hub airports in the U.S., with particular focus on quantitative modeling applications. The U.S. context creates a clear demarcation of scope; population densities in the U.S. tend to be lower than in Europe and Asia, resulting in a general lack of intercity public transport options to airports. We identify a specific competitive scenario for long-distance air travelers: travelers replacing a connecting flight from a (small- to medium-hub) local airport to a neighboring region's large hub airport with ground travel by private vehicle (or long-distance bus service, where available). These travelers effectively choose their point of entry into the aviation system over a geographic region that extends well beyond regional boundaries. Definition of these scenarios serves to exclude the literature on: competition and complementary of high-speed rail and air transport networks (Lee & Chang, 2006; Clewlow, Sussman, & Balakrishnan, 2012; Chester & Ryerson, 2014; Coogan, 2012); airport access mode choice (Tam, Tam, & Lam, 2005; Jou, Hensher, & Hsu, 2011); the U.S. Essential Air Service (EAS) program for rural airports (Grubesic, Matisziw, & Murray, 2012; Cunningham & Eckard, 1987); U.S.-Canada transborder leakage (Elwakil, Windle, & Dresner, 2013); and finally, the dynamics of a smaller airport's low-cost carrier service drawing passengers from a larger airport (Vowles, 2001; Tierney & Kuby, 2008; Graham, 2013).

4. Airport catchments and passenger choice

4.1. Defining passenger market catchment areas

The definition of airport catchment and the determination of whether a passenger is leaking from one airport catchment to another are intrinsically linked. If an air passenger within one airport's catchment chooses an alternate airport in another region, this passenger is "leaking" from one airport market to another (Suzuki & Audino, 2003). However, defining an airport's catchment area is not a straightforward endeavor.

An airport market, or catchment, is generally described as the land area from which passengers are expected to use the services of that airport. This definition does not provide any information on the parameters of the catchment area itself; definitions differ widely in the literature and practice. For instance, Latvia's Riga International Airport defines its catchment as "the number of people living within an area in which people have approximately two hours of transport by bus, car or train to an airport." (Riga International Airport, 2009). Airports typically do not provide such clear definitions of their catchment areas. Researchers have employed numerous approaches that challenge the simplistic but most common method of "drawing concentric circles of travel distances around (the airport)" (Fröhlich & Niemeier, 2011). Lieshout (2012) employed a multinomial logit model using key variables known to influence airport choice (access time/cost, airfares, air travel time) to establish the catchment for Amsterdam's Schiphol Airport, while Fröhlich & Niemeier (2011) used stylized economic models of spatial competition to demonstrate overlapping airport catchment areas and therefore, the existence of competition. Suau-Sanchez et. al (2014) considered catchment to be a function of population density and airport connectivity, as opposed to a simple function of distance (Fuellhart, 2007).

The defining difference between a passenger "leaking" to a different market versus choosing between airports in a multiple airport system should be the passenger's true origin within one or multiple catchment areas, respectively. Consider Figure 1, which depicts airport catchment in a multiple airport system (MAS) – a set of significant commercial airports in a metropolitan region that may or may not be under the same ownership – versus interregional air passenger leakage (de Neufville & Odoni, 2003). Many MASs, such as those of the San Francisco Bay Area (SFBA), Washington/Baltimore, and Greater London, are heavily studied due to plentiful data availability. Data on airport and ground access choice within a MAS region is collected entirely under the jurisdiction of local government agencies such as metropolitan planning organizations (Shapiro, 1997). In interregional leakage, shown at the right in

Figure 1, air passengers considered to be within the catchment of one small or medium airport may choose to "leak" to a larger hub airport with more direct destinations, greater flight frequency, and lower airfares due to airlines' economies of density as well as more intense airline competition.

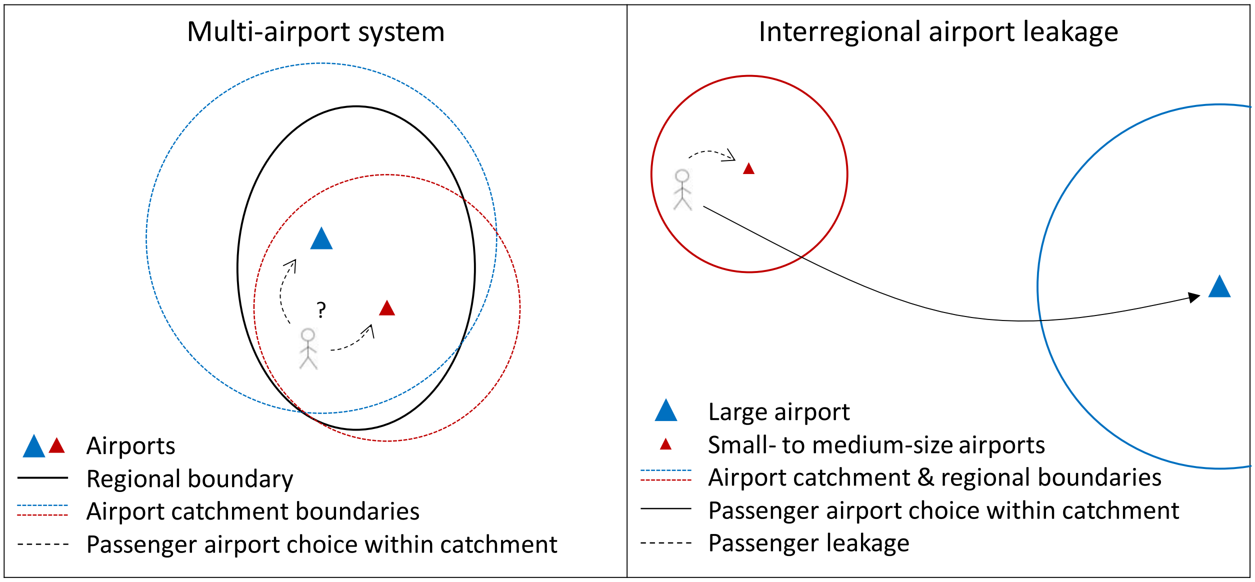

Figure 1 The geography of airport choice in a multi-airport system (MAS) versus interregional passenger leakage

4.2. Passenger airport choice in MAS

Why air passengers choose one airport over another has been heavily explored in multi-airport regions. One of the earliest studies demonstrated, using a multimodal logit model, that ground accessibility and flight frequency were the dominant factors driving airport choice in the Washington D.C. area (Skinner, 1976). More airport choice studies in multiple airport regions emerged in the 1980s facilitated by the availability of passenger airport choice data, collected by regional transportation authorities to document airport access trips in their jurisdictions (Ashford & Bencheman, 1987; Harvey, 1987; Windle & Dresner, 1995). Researchers focused on the impacts of ground access characteristics, including distance and traffic congestion (Innes & Doucet, 1990), rail transit availability (Figueiredo Monteiro & Hansen, 1996; Hansen, 1995), and differentials in air service supply (Cohas et. al. (1995). More complex model structures that could accommodate simultaneous choices combining airport, airline, and ground access mode choice followed, particularly for regions with plentiful data: SFBA (Pels, Nijkamp, & Rietveld, 2001; Basar & Bhat, 2004; Hess S. , 2004; Hess & Polak, 2006; Hess & Polak, 2010), London (Hess S. , 2005), and New York (Gupta, Vovsha, & Donnelly, 2008).

The results and findings from the above studies are varied; however, ground access time and flight frequency were commonly found to be the most significant determinants of airport choice. Some studies found that airport choice is most heavily influenced by ground access characteristics or accessibility (Pels, Nijkamp, & Rietveld, 2003; Ishii, Jun, & Van Dender, 2009) while Harvey's study (1987) found air services characteristics to be of greatest importance. Using a survey of passengers at Hong Kong International Airport, Loo (2008) found that the most important attributes defining airport attractiveness were airfare, ground access time, flight frequencies, and number of airlines.

The vast majority of the above work on MAS airport choice considers air and ground transportation service characteristics to be exogenous to passenger demand, with two notable exceptions[2]. Hansen (1995), by estimating logit models of airport choice and employing these in a supply-and-demand equilibrium analysis, demonstrated that passenger volumes and airport services in the SFBA had a positive feedback relationship. Pels, Nijkamp, and Rietveld (2000) developed a nested logit model of passenger airport choice, and used this in a model of airport and airline competition, using the same SFBA dataset.

Based on the MAS airport choice literature, the key variables found to influence airport choice are:

- **Variables related to the traveler:** travel group size; travel purpose (business or leisure); (ground) access travel time; airfare; availability of direct flights; flight frequency.
- **Variables related to the airport(s) and air service:** available ground transport options and cost (personal vehicle, transit, airport shuttle, etc.); airlines serving an airport, service frequencies and aircraft types; airport amenities (parking, retail, terminal experience, etc.).

[2] Models of air-HSR competition that account for supply and demand endogeneity are also found in the literature, notably (Adler, Pels, & Nash, 2010).

This review of airport catchment areas, and the modelling methodologies and explanatory variables used to understand MAS airport choice, provides a basic methodological background as we shift our attention to the related phenomenon of interregional airport passenger leakage.

5. Interregional airport passenger leakage

We cover the literature chronologically and in categories of academic studies and airport-driven studies, as the prevalence and types of studies performed on the subject follow historical changes in the U.S. air transportation system.

5.1. Academic studies

Studies from the 1980s and 1990s first documented the existence of airport passenger leakage, particularly at small airports located near urban regions with major hub airports (Kanafani & Abbas, 1987; Kaemmerle, 1991). Innes and Doucet (1990) evaluated residents' choices between three small airports with scheduled service in New Brunswick, Canada, using data on air service characteristics and travelers' decisions collected from travel agents in the region. Application of a multinomial logit model indicated that travelers highly preferred jet aircraft and direct travel, choosing airports farther away to obtain these services.

In the early 2000s, two studies used publicly available data to investigate airport passenger leakage. Suzuki and Audino (2003) used data from the Bureau of Transportation Statistics for 14 airport pairs throughout the U.S., where leakage was hypothesized to occur from the small/medium airport's expected catchment to a large airport up to 250 miles away. They estimated regression models demonstrating the existence of a two-way relationship between fares at the large hub airport and passenger volumes at the local airport. Fuellhart (2003) assessed passenger leakage to Baltimore-Washington International Airport (BWI) from in and around Harrisburg and Philadelphia. Although these cities are each served by their own airport, air passenger leakage was suspected to BWI from both, due to BWI's reputation for lower fares provided by low-cost carriers. The results suggested that air passengers were willing to drive an additional 70-90 miles for lower fares.

Also starting in the early 2000s were efforts to gather survey data on interregional airport choice, to support discrete choice modeling applications. A major data collection effort was undertaken for Des Moines International Airport (DSM) in Iowa (Suzuki, Crum, & Audino, 2003). DSM was very concerned about leakage of their passenger base to Kansas City International Airport, Minneapolis-St. Paul International Airport, and Omaha Eppley International Airport. The survey asked residents (via mailouts and an intercept survey at DSM) about their last trip from one of these four airports, and 317 viable responses were obtained. Multinomial logit models of airport choice indicated that travelers preferred airports with lower airfares, more non-stop services, and served by airlines with which the traveler collects frequent flyer miles. These models show that access time and flight frequency are insignificant, which is quite different from studies of MAS passenger choice. In line with previous studies, the authors found that leisure travelers were much more likely to leak than business travelers. In another study using the same dataset, Suzuki, Crum & Audino (2004) used a discrete choice model within an endogenous airport profit maximization model. The latter model captures how a change in airfare offered by an airline at one competing airport impacts passenger volumes for other airlines and other airports. The authors showed that most airlines will experience reduced revenues when one airline reduces their airfares at the leakage airport, due to competitive responses. Another study by Suzuki (2007) modelled interregional airport and airline choice as a two-step process, challenging the assumption that people have the capacity to fully evaluate and consider all possible (out-of-region airport) options available.

A study using ticket booking data from Wyoming looked at the proportion of air passengers that substituted a connecting flight from a local airport to a hub airport, with driving directly to the hub airport (Phillips, Weatherford, Mason, & Kunce, 2005). The results of a two-stage regression indicated that leakage is positively related to the additional fare paid for a connecting flight from the local to hub airport, and that greater driving distances to the hub airport reduce leakage. Using residential zip code data collected at the Harrisburg International Airport (MDT) parking lot exit, Fuellhart (2007) assessed the spatial characteristics of MDT's passenger catchment area. A large set of observations was collected, to model the number of airport customers at a zip code using linear regression. Overall, the results show a potentially strong influence of BWI's lower airfares on leakage from MDT's core market catchment area. Zhang and Xie (2005) used logistic regression to model the probability of using a local community airport versus more distant large airports. Using data collected from an air passenger intercept survey at the Golden Triangle Regional Airport in Mississippi, the authors found that airfare, flight schedules, distance to airports, and previous experiences with the local airport are major factors impacting the choice to drive to more distant airports. Blackstone, Buck and Hakim (2006) estimated probit models to assess the airport choices made by residents in the catchment area of Philadelphia International Airport (PHL), using phone survey data collected in 2000. The authors found that higher incomes increased the probability of having flown from Newark (EWR) or BWI, while if ground travel distance was an important consideration then the respondent was more likely to have flown from EWR, JFK, or PHL.

Concern with interregional airport passenger leakage is not confined to North America, as evidenced by a discrete choice modelling study of airport choice by passengers originating in the Campania region of southern Italy (de Luca, 2012). Although the study area is called a multi-airport region, only one of the three airports considered (Naples-Capodichino, or NAP) is located within Campania, while the two leakage airports primarily serve Rome. Stated preference data was collected via intercept surveys of Campania residents. The findings showed that the more trips an individual had made in the past, the more likely they were to travel through their closest airport (NAP). In addition, availability of a personal vehicle increased the likelihood of leaking to a Roman airport. Higher incomes also increased the likelihood of leakage to the Roman airports but only when better flight frequencies were offered. Another study looked at regional airports' loss of passengers to main airports in Norway (Lian & Rønnevik, 2011). The authors found that both fares and direct/connecting services impacted leakage levels but were not able to distinguish between the effects of these variables, as higher fares and connecting service were always prevalent at the regional airports.

A recent study focused on methods capturing the endogeneity between airfares and passenger volume shares for airport pairs with suspected leakage (Fu & Kim, 2016). The results confirmed the existence of airfare and passenger volume relationships between local and out-of-region hub airports, and that lower airfares at out-of-region airports have a greater impact on airport choices made by larger travelling groups.

5.2. Studies by airport authorities

The reality of passenger leakage, particularly as a response to "capacity discipline," is confirmed by the actions of airport authorities to estimate and mitigate passenger leakage. There are numerous examples to be found: among them include the 19 Florida Airport Air Service Profiles (Kimley-Horn &

Associates, Inc., 2012), a study for Savannah/Hilton Head International Airport (Leigh Fisher, 2012), and another for Edmonton International Airport in Canada (Edmonton Airports, 1998). These reports confirm the regularity by which leakage occurs from areas served by smaller airports to those with larger airports, at distances up to 200 miles (Kimley-Horn & Associates, Inc., 2012). Edmonton International Airport estimated that 750,000 Edmonton-area residents flew through Calgary International Airport annually, a hub airport 179 miles south of downtown Edmonton (Jang, 2010). Despite their ubiquity, these studies are typically limited to data descriptions; they do not include empirical modelling applications that may provide insights into the factors driving the passenger leakage – results that could inform the design of incentive programs attracting passengers back to local airports.

5.3. Synthesis of the literature

The literature suggests that leakage is a phenomenon worthy of attention from both researchers and practitioners. Overall, it has revealed that lower fares, greater flight frequency, better schedules, and direct services offered by airlines at large hub airports – in addition to passenger characteristics such as reason for travel (business or personal) and group size – are the main drivers of passenger leakage from regions served by small to medium airports. However, there remain some outstanding concerns: the range of added driving distances is large and not clearly defined (certainly there is no general consensus), and we do not thoroughly understand the drivers of out-of-region airport choice. The results available from numerous studies of MAS passenger choice do not directly address these issues, while the applied literature provides anecdotal treatments rather than statistically valid results.

The modeling techniques applied in both the numerous MAS and less-prevalent leakage studies (discrete choice models, game theoretic equilibrium models), in addition to a broader range of data visualization and network analysis models, are appropriate for continued investigation and tracking of interregional airport leakage. However, in order to do so, there are at least two key considerations to be made. Firstly, disaggregate traveler survey data (i.e., survey data collected at the individual person or household level) facilitating studies of interregional airport passenger leakage is typically not collected by government agencies. Researchers have collected this data themselves, often as part of projects funded by local airport authorities concerned about passenger loss. As a result, there have been a very limited number of these studies (Innes & Doucet, 1990; Suzuki, Crum, & Audino, 2003; Blackstone, Buck, & Hakim, 2006; de Luca, 2012). This lack of disaggregate data has not allowed for broader application of well-accepted quantitative methodologies, which in turn does not allow us to clearly demarcate the geographic boundaries of leakage. Without clear geographic (and therefore, governance) boundaries, data collection efforts are stymied; thus, the study of interregional airport passenger leakage is caught in a vicious feedback loop (Figure 2).

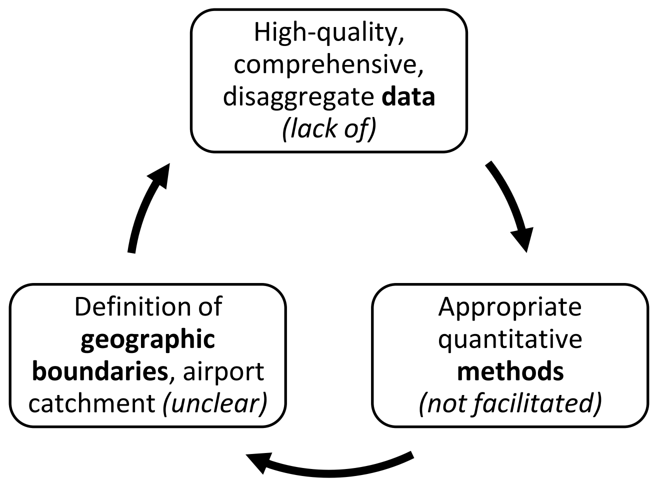

Figure 2 Vicious feedback loop in the study of airport market leakage.

Secondly, interregional leakage in the U.S. is mainly facilitated by private vehicle, as highways and air transport largely facilitate interregional travel in North America. This leads to two further implications. First, models of MAS passenger choice are not directly applicable to the study of airport leakage, as these models typically consider that airport ground access options are a driver of airport choice. Second, a region that experiences significant air passenger leakage is also seeing those air passengers driving on intercity highways (often an interstate freeway in the U.S.). These air passengers may potentially take a measurable share of volumes on freeways (Ryerson & Kim, 2018; in press), which have experienced huge growth since the 2008 economic downturn (Jin & Rafferty, 2017). As a result, there is incentive for state and federal DOTs to understand airport passenger leakage traffic on state and interstate facilities, and also give more attention towards understanding the connectivity and complementary of the intercity transportation system – particularly in the U.S. context where public transport provision is largely absent interregionally (although airport bus services are sometimes provided in heavy leakage corridors, such as Tucson to Phoenix International Airport). Increased co-operation between DOTs and airport authorities may encourage high-quality data collection (as per the first point) and more integrated, intermodal approaches to intercity transportation planning.

Table 1 provides a summary of the literature discussed in this section in chronological order.

Table 1 Studies on interregional airport passenger leakage.

Study authors (publication year)	Geographic scope	Approx. driving distances*	Methods used	Traveller survey data?	Data source **	Key findings
Innes & Doucet (1990)	Province of New Brunswick, Canada (3 airports)	94, 125, 133 miles between airports	Multinomial logit (airport choice)	Yes	SDC	Travellers highly prefer jet aircraft and direct travel
Suzuki & Audino (2003)	14 U.S. airport pairs	-	Log-linear regression (2SLS)	No	PA	Passenger volumes and fares at local and possible leakage (large) airport related
Suzuki, Crum, & Audino (2003)	Des Moines (DSM), leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	Multinomial logit (airport choice)	Yes	SDC	Passenger leakage exists to BWI
Fuellhart (2003)	Harrisburg, PHL, leakage to BWI (U.S.)	97, 100 miles	Linear regression	No	PA	Travellers prefer airports with lower airfares, more non-stop services
Suzuki et al. (2004)	DSM, leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	Nested logit (airport choice)	Yes	SDC	Airlines serving DSM should reduce airfares to increase demand (and profits)
Phillips et. al. (2005)	State of Wyoming (U.S.)	Avg. of 261 miles	Two-stage linear regression	Yes	SDC	More leakage with higher additional fare for connecting flight from local to hub airport; greater driving distances to hub airport reduce leakage
Zhang & Xie (2005)	Golden Triangle Regional Airport (GTR) leakage to MEM, JAN, BHM (U.S.)	170, 150, 80 miles	Logistic regression (of airport usage)	Yes	SDC	Factors influencing airport choice include: airfare, flight schedules, distance to airports, previous experiences with local (leakage) airport
Blackstone, Buck &	Philadelphia (PHL),	100, 94,	Probit model	Yes	SDC	Higher incomes increased

Study authors (publication year)	Geographic scope	Approx. driving distances*	Methods used	Traveller survey data?	Data source **	Key findings
Hakim (2006)	leakage to BWI, Newark (EWR), JFK (U.S.)	115 miles				probability of using EWR or BWI; higher likelihood of leaking if ground travel distance was important consideration
Fuellhart (2007)	Harrisburg, leakage to BWI (U.S.)	97 miles	Linear regression	No	SDC	BWI's lower airfares promote leakage from MDT's core market catchment
Suzuki (2007)	DSM, leakage to MCI, MSP, OMA (U.S.)	200, 250, 150 miles	2-step nested logit (airport choice)	Yes	SDC	Model demonstrates improved fit over Suzuki et al. (2004)
Lian & Rønnevik (2011)	Norway	84-850 miles	Logistic regression (binary airport choice)	Yes	PA	Fares and direct/connecting services impacted leakage levels; lower fares and greater car ownership enlarged catchment areas of main airports
de Luca (2012)	Campania Region: Naples, leakage to Rome airports (Italy)	131, 150 miles	Multinomial, cross-nested, mixed logit (airport choice)	Yes	SDC	Frequent flyers likely to use closest airport; increased likelihood of leakage with personal vehicle availability and higher incomes (but only when better flight frequencies available)
Fu & Kim (2016)	20 U.S. airport pairs	54-202 miles	Log-linear regression (2SLS)	No	PA	Lower airfares at hub airports have greater impact on airport choice of larger travelling groups

* Driving distances from local airport to large hub airport, unless otherwise indicated

** (PA = publicly available, or SDC = purchased/sponsored data collection)

6. Concluding remarks & future research needs

We have provided an examination of the literature on interregional airport passenger leakage – from small and medium airports to large, out-of-region hub airports – within the U.S. context. We have covered methodological approaches, data, and major findings of studies on this topic with respect to interregional passenger leakage by personal vehicle (the mode traditionally associated with leakage in the U.S.). This topic has seen limited attention in the literature, largely due to lack of data and unclear definitions of airport passenger catchment beyond regional boundaries. Given the direction of U.S. aviation, namely, a deepening bifurcation between large hub airports with many flights and small/medium airports with dwindling flight service (Fuellhart, Ooms, Derudder, & O'Connor, 2016), we expect that interregional airport passenger leakage will continue. Recent concerns with leakage have prompted operators of small and medium airports, in concert with local governments, to offer incentive programs to airlines to continue and/or grow their services (Ryerson, 2016b). Based on our review, we make some key research recommendations.

Firstly, we emphasize the need to collect data on intercity travel trends. Data would enable further modeling applications to interregional airport passenger leakage, the ability to provide empirically-based (and shifting) definitions of airport catchment, and stay abreast of changing trends in all these areas. Collected data might consist of survey data, passive data on travel patterns (i.e. intercity modal shares from anonymous cell phone data (Hui, Wang, Kim, & Qiu, 2017)), and others. Participation by local, state, and federal agencies – in addition to airport authorities – will be critical in gathering useful data. Application of discrete choice modelling methodologies should yield information such as demand elasticities (with respect to the key factors driving airport choice), critical distance, fare, and trip duration breakpoints, and value-of-time and willingness-to-pay estimates. These important values are largely absent from the limited literature on interregional leakage, despite that the key factors driving the choice to “leak” have been identified and quantified. These values are critical for precise targeting of the airline incentive programs mentioned above. Also important for the design of these incentive programs are equilibrium models focusing on the relationship between supply and demand, and airline competition. Although plentiful in the MAS literature, Suzuki, Crum, & Audino (2004) were the only authors to touch on airline pricing strategies and their implications in an interregional airport passenger leakage context. Future studies might explicitly look at airline strategies under competition with other airlines at the local leakage airport, at the large substitute airport, or both. Through data collection, we further highlight the need to revisit the definition of airport catchment. Rather than framing the interregional air passenger leakage problem as such, the definition of airport catchment should be revised to extend beyond regional boundaries, supporting multimodal transportation network planning at a mega-region level (Coogan, et al., 2010). Precise definition of air passenger market catchment is instrumental in identifying leakage and designing targeted measures to combat it.

Secondly, a region that experiences significant air passenger leakage is also seeing those air passengers driving on intercity corridors (often an interstate freeway in the U.S.). These air passengers may take a measurable share of volumes on freeways, which have also experienced huge growth since the economic downturn of 2008 (Jin & Rafferty, 2017). As a result, there is incentive for state and federal DOTs to understand airport passenger leakage traffic on state and interstate facilities. More broadly, we feel that there should be more attention towards understanding the inherent connectivity and complementarity of the intercity transportation system. This is particularly true in the U.S. context where public transport provision is largely absent interregionally, despite clear empirical evidence of mega-regions based on commuter travel patterns (Dash Nelson & Rae, 2016). We have historically treated air and highway transportation as separate and disparate systems, instead of taking an intermodal approach such as those in Europe and Asia (Allard & Moura, 2016). There exists explicit competition between driving and flying in particular corridors – choices that are driven by the intercity transportation services themselves, as well as urban form. Increased co-operation between DOTs and airport authorities may encourage high-quality data collection and more integrated, intermodal approaches to intercity transportation planning.

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Figure (including maps and photographs)

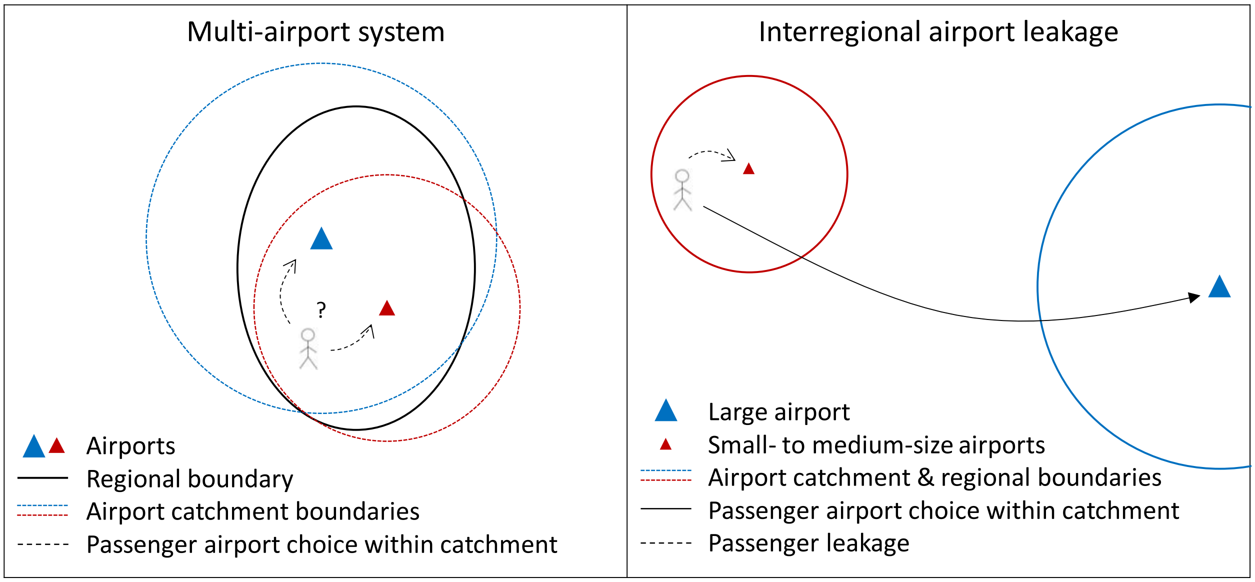

Figure 1 The geography of airport choice in a multi-airport system (MAS) versus interregional passenger leakage

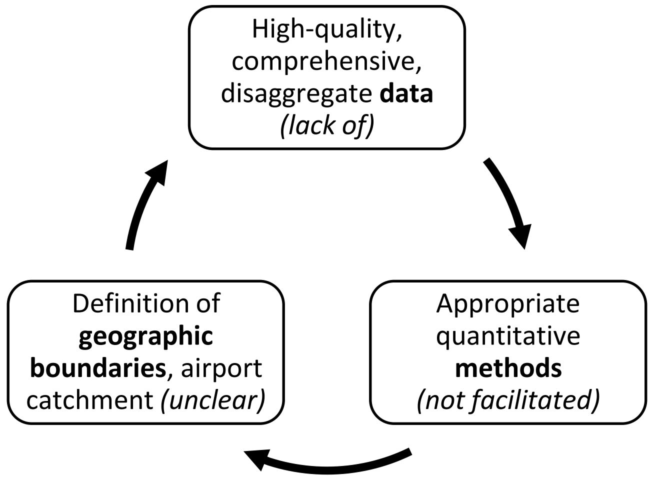

Figure 2 Vicious feedback loop in the study of airport market leakage.

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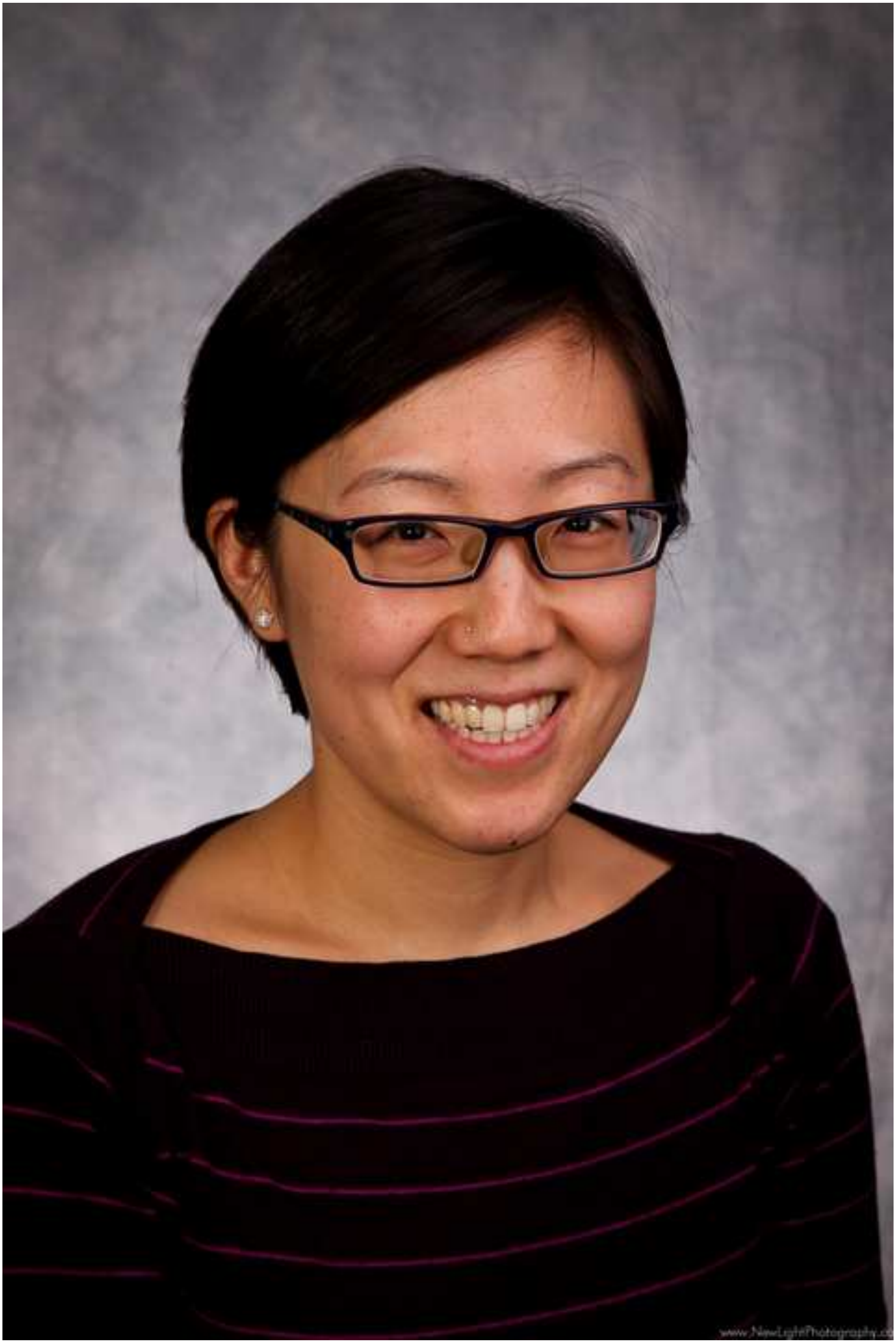

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