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AIRPORTS AS CONNECTED ACTIVITY CENTERS

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DISCLAIMER

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Technical Report Abstract

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16. Abstract (Limit: 200 words)

This research project determined how airports could function as connected activity centers. The current state of policy is to treat airports as secluded from the rest of the metropolitan area and only engage in reactive planning in response to specific threats or crises. To seek out other models of airport development, a combination of literature reviews and case studies was used to examine airports already functioning as connected activity centers. The literature reviews suggest that there has been substantial research covering on-airport development, while research on integration with surrounding land uses is focused on 'airport cities' and 'Aerotropolis' concepts. A literature review on airport economic development found a strong relationship between economic growth and air transport, but with uncertain causality, and secondly that most airport cities emerge as part of urban expansion, rather than due to independent effects. Six case studies provide detailed analysis of specific hub, commercial service, and general aviation airports. Scenarios based on the case studies include airports as freight hubs, airports as airport cities, and airports as airport resorts. The central finding is that creating airports as connected activity centers requires more coordination between airports, transportation, and airport-adjacent land-use planning.

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Executive Summary

Introduction

This report aims to examine how airports can function as connected activity centers. Airports have a considerable influence on urban form and economic development, but a lack of integration between aviation and regional planning means regions often fail to leverage the unique potential of airports as an economic development tool.

Literature Review – Airport Economic Development

Passenger activity is a powerful predictor of growth but (excepting high-income tourist destinations) there is little evidence to support a strong positive correlation between local air transportation and economic development. Airport development is negatively associated with ground transportation, implying it functions as a substitute for it. Contrary to most narratives, airport cities develop primarily as cities expand outward rather than as a direct consequence of air transportation.

Literature Review – Airport Development Trends

Airports everywhere have diversified their landside revenues with non-aviation commercial and industrial development to increase revenues and ensure stable revenue in the notoriously volatile aviation market. As intermodal hubs in a connected, globalized world, airports have evolved from transportation nodes into multi-faceted business enterprises. Airports and their environs are becoming new commercial anchors taking on many features of destination retail and of cities themselves. Because airport authorities themselves are no longer mere transport suppliers but full-fledged economic actors, the era in which airports merely provide infrastructure for airlines is over. When airports change from transport nodes into full-fledged hubs, they transform from infrastructure facilities to an economic system. A wide variety of sectors not traditionally considered aviation oriented are actually substantial consumers of aviation services. Developing an airport city requires balanced development of infrastructure and business parks and requires a public-private partnership for effective collaboration to manage infrastructure investment and development. The main emphasis of planning action is the effective management of airports and the mix of, and access to, services on surrounding land. However, high-quality surface transportation linkages enable airport-linked development to spread out further, making co-location and nearness less meaningful.

Case Study Selection

Six case studies were performed: Two General Aviation airports, two non-hub commercial service airports, and two hub airports. Van Nuys (VNY), Laughlin Bullhead (IFP), Jackson (JAC), Mesa-Phoenix Gateway (AZA), Charlotte-Douglas (CLT), and Atlanta (ATL) were analyzed. The Van Nuys Airport in Los Angeles, California is a business aviation mecca and Laughlin a remote desert location enabled by casino charter flights. The Jackson Hole Airport uses taxis to escape airport development constraints, and the Phoenix-Mesa Gateway airport has an educational cluster. The Charlotte-Douglas airport has created an intermodal (train/truck/rail) hub, and the Hartsfield-Jackson Atlanta Airport can claim to be an actual Aerotropolis.

Case Studies

Laughlin Bullhead: Initial status as a vacation-homes area leveraged into a hotel-and-casino resort cluster fueled by scheduled passenger jet service. Even after the cessation of scheduled passenger service, the cluster of amenities and activities proved sufficient to support sustained charter operations by integrating them with recreational activities, a pattern that Cedar City, Canyonlands, and Wendover airports might follow.

Van Nuys: The airport serves the general aviation market for the metro area, permitting LAX to focus on commercial service aviation. VNY does not own or control the land within the runway protection zones or the 65-DNL noise contour, and accordingly engages in active noise mitigation and compatible land-use efforts worthy of emulation. From an economic development perspective, VNY has grown an aircraft charter and leasing firm into a maintenance and manufacturing cluster. Based jet aircraft available for charter provide the capacity to ferry time-sensitive goods large distances very rapidly, making it a good location for 'just-in-time manufacturing' and specialty-parts depot functions.

Jackson Hole: Because of its location within a national park, the airport is effectively landlocked, with no capacity to expand in acreage. Despite this, the airport functions as a connected activity center by combining a luxuriant lobby with excellent taxi/shuttle service/remote parking to maintain connectivity to the broader region. The lobby serves as a gateway to the region. Despite locational limitations, the airport is sustained by the lack of a viable alternative; the combination of conservation land and steep slopes means viable competitors are over an hour away.

Phoenix-Mesa Gateway: A combination of infrastructure investments and developable land near the airport makes it an attractive place to grow and develop. The proximity of universities and community colleges has been leveraged through an array of aeronautically oriented facilities. There are no less than four education institutions within the bounds of the former United States Air Force base: ASU Polytechnic, Gilbert-Mesa Community College, Embry-Riddle Aeronautical University, and the East Valley Institute of Technology. Local FBO has been used as an economic development springboard for a maintenance and air freight cluster.

Charlotte Douglas: A large freight-oriented airport that has bought up a wide range of parcels near the airport but outside the airport boundary. While most of the parcels are used for parking, many nearby parcels host aviation-related businesses such as freight, logistics, and courier services. Many elements of the aerotropolis model are present in areas accessible to, but not near the airport. Co-located with a rail freight intermodal terminal. While not aviation related, rail freight shares a common need for truck access with air cargo. Tenant-rich fence line and ongoing economic development planning.

Hartsfield-Jackson Atlanta: Good example of an Aerotropolis—a metropolitan region oriented toward the airport. In 2016, the airport was the largest employer in the state of Georgia, directly employing 63,000 people. Relentless focus on freight fluidity to and from the airport. Mobility has been optimized through sustained investment in limited access highways—not just to one side of the airport, but to all sides, to the extent that the airport is effectively ringed by them and maintains access across that barrier through numerous overpasses and underpasses. Airport geographic bounds have repeatedly expanded—over freeways, around graveyards, across rivers through extensive excavation and fill.

Development Scenarios

Three scenarios are offered: Freight Hub, Airport City, and Airport Resort. Freight Hub is focused on maximizing the market area of the airport reachable by trucks using truck-only aero-lanes, improved limited-access highway connectivity, and capacity improvements. It also leverages truck connectivity through freight rail and inland port-like facilities near the airport as a form of cargo-oriented development, with development focused on specialized warehousing such as medical and perishables. Airport City suggests developing the airport as a CBD (Central Business District) analog by incorporating traditional CBD functions like conference centers, hotels, offices, and restaurants. The Airport Resort scenario suggests that while general aviation airports are not transportation hubs, they might become connected activity centers by functioning less strictly as transportation terminals, and more as 'gateway nodes' to the region while developing an associated amenity and recreation-rich district within proximity and coupling the two with shuttles and taxis.

Trends Shaping the Future of Aviation

Electric aviation has a real potential to revolutionize air transport. If electrification lowers the marginal cost of flying, it will increase the demand for flying. Long-haul jet flights are the most resistant to electrification; even short-haul jet flights remain some distance in the future. This may still revolutionize short-distance jet travel, by making short hops sufficiently economical to be common. In the short term, electrification seems most likely to revitalize the General Aviation market for fixed-wing aircraft, offering dramatically lower fuel costs but dramatically lower endurance. Electric aviation will change the nature of fixed-base operators at airports—battery charging remains slow, and the provision of large amounts of electricity requires a different infrastructure than providing fuel. Airport Rescue and Fire Fighting (ARFF) will need to develop the capacity to put out lithium fires.

Many of the proposed uses for eVTOL (electric vertical take-off or landing) are last-mile services from major airports, providing a costly but high-speed connection to and from the airport. Multiple rotor eVTOL has the potential to be revolutionary. Helicopters have existed for 75 years, and multi-rotor crafts have been viable for only about five years. For short intra-urban trips, the range limitations of even current batteries are immaterial. Lacking the need for an approach path, any location with sufficient clearance for VTOL could emerge as a node in the transportation network, including parking lots, parking decks, and the tops of buildings. The creation of a network of eVTOL nodes also makes air ambulances more feasible. However, rotorcrafts are noisy; even if eVTOL vehicles are quieter, expanded operations will represent the imposition of noise nuisance to a much wider variety of locations.

When (and if) aviation can be successfully automated, and that automation is demonstrated to be safe, and certified accordingly, it would represent a completely new mode of transportation. Urban air mobility would be free of the roadway capacity constraints that have proven a decisive limitation on unlimited automobility. Advanced Air Mobility will require the widespread provision of helipads or landing strips, where no such network currently exists. Accordingly, they will likely be (at least initially) integrated into or at the edge of existing airports.

1 Introduction

This research report examines how airports can function as connected activity centers. This research topic is important because airports have a considerable influence on urban form and economic development. Current planning practices do not typically address the influence of airports on urban form and economic development, and there is a lack of research to guide practice. Indeed, airports are the forgotten major land use, but their combination of size, noise/pollution impacts, and transportation access means they substantially affect the urban form around them. This lack of integration also often fails to leverage the unique potential of utilizing airports as a tool for economic development. This report is intended to explore how these limitations can be overcome.

Accordingly, the project objectives were to:

- Identify best practices for regional airport systems that treat airports as connected activity centers
- Analyze various development scenarios where airports serve as different types of activity centers
- Present the results to UDOT, MPOs (Metropolitan Planning Organizations), and local governments to aid and abet economic development efforts

By identifying best practices for regional airport systems, analyzing various development scenarios, and presenting the results to aid and abet economic development efforts, the findings of this report are expected to inform the strategic vision of the state system of airports, UDOT long-range transportation planning, MPO (Metropolitan Planning Organization) long-range planning efforts, local municipality efforts in community planning, and economic development planning efforts across the state.

What is an Activity Center?

Most broadly, an activity center represents a place identified as being prone to peak-period traffic congestion [1]. Accordingly, activity centers include regional shopping centers, university campuses, medical centers, airports, major recreation centers, and sports stadiums [2]; they may also be defined by a contiguous district of concentrated employment characterized by more jobs than housing, substantial amounts of development, and a mix of uses including entertainment, shopping, and jobs. In this report, the term ‘activity centers’ is used in urban planning to refer to (relatively) dense areas that attract people for shopping, work, school, recreation, and socializing. Activity centers are typically characterized by the presence of commercial uses amidst residential uses and represent examples of mixed-use development.

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1 Institute of Transportation Engineers. 1976. Transportation and Traffic Engineering Handbook.

J.E. Baerwald, ed. Englewood Cliffs, New Jersey: Prentice Hall.

2 Cervero, R. (1989). Americas Suburban Centers: A Study of the Land-Use Transportation Link. Washington, DC: US Department of Transportation.

In turn, 'connected' refers to access by multiple routes, modes, and directions. A characteristic of any activity center is its intermodal nature—where people and goods switch from one mode to another. Further, a 'connected' activity center is one with connections that are both numerous and direct, and it does not rely on access from a single direction, mode, or route. Hence, an airport as a connected activity center is where an airport and the area around it become dense, mixed use, intermodal, and highly connected. In contrast, most airports are poorly connected. For security and safety reasons, most airports are fenced, which limits connectivity with adjacent land uses.

Integrating Airports into the Region

Airports are often overlooked when discussing transportation infrastructure investments, and they are often planned to be segregated rather than integrated into the communities they serve. Strategic land use and transport access decisions that treat airports as connected activity centers can maximize the economic return on investment for both the airport and the community. Airports provide accessibility across the globe, but their access to the local area determines much of their utility; quality surface transportation access is critical for both passengers and freight.

Airports directly impact urban form through land purchase and regulation and indirectly through secondary economic effects. In the latter capacity, airports are also important economic development tools. Just as an interstate off-ramp connects a city or town with a national transportation network for trade and commerce, airports connect a region to the global transportation network for trade and commerce.

Airport planning focuses solely on meeting existing and projected aviation demand, which has meant that land-use planning near airports has focused foremost on safety and secondly on noise compliance. Efforts to manage conflicts between airports and the surrounding land uses have typically been accomplished by buffering airports from the surrounding community, either by outright land acquisition or by utilizing land-use restrictions to ensure compatibility. Too often, planning for airports focuses on mitigating detriments rather than proactive planning to maximize benefits. Further, planning in such a reactive way has resulted in airports with substantial land assets around the periphery of the airport. Further, efforts to mitigate congestion for airport-bound travelers mean that most major airports enjoy excellent freeway access. Hence, areas near airports have substantial development potential independent of airport proximity.

More active and integrated land-use planning could ensure that development near airports is not just airport compatible but airport oriented. The aerotropolis or airport city concept by John Kasarda has been widely discussed and applied around major airports across the globe, focusing on how aviation-related development has become a core economic driver for cities. This encourages co-locating activity centers not traditionally considered on or near airports that could still benefit from the airport.

Recognizing that the same development attracted to high-access land near an airport can result in congestion that reduces airport access, Kasarda's proposed aero-lanes and aerotrains, and airport-specific surface transportation access. As an example, development plans for the Northwest Quadrant of Salt Lake City suggest substantial additional development. The effects of this development will include increased travel demand on existing corridors, most notably I-80. This will affect the accessibility of Salt Lake City International Airport and its economic development potential for both freight and passenger traffic.

The Utah Division of Aeronautics aims to maximize the economic development potential of Utah's system of airports by supporting them with strategic investments. Investments, both on and off airport properties should complement each other to maximize the return on investment and benefit the community. This research helps airport sponsors become aware of the options that exist for airport development. This represents an opportunity to provide land-use planning near airports that does more than provide compatible uses (such as light industrial) but maximizes economic development potential, through such uses as high-tech business parks, aviation-related office space, and entertainment. Every airport serves a community or region that has specific market strengths and weaknesses. Land uses around the airport should support that vision, while simultaneously protecting the airport from incompatible uses.

2 Literature Review - Airport Economic Development

The following section documents the traditional methods for airport economic impact analysis, the limitations of airport economic impact studies, and a brief note on the relationship between airports and economic development. Additionally, examples of the different methods for conducting airport economics are provided alongside a list of additional resources that provide further insight into airports and economic development as well as further analysis of analyzing economic impacts.

Common Methods for Airport Economic Impact Analysis

The following review of the literature suggested that the three most common methods for analyzing the economic impact of airports include the input-output method, the collection of benefits method, and the catalytic method. Each of these is discussed below. The variables and indices utilized within each of these methods vary but frequently include employment, payroll, outputs, multiplier effect, quasi-economic, and qualitative factors.

Input-Output

The most common and most traditional method employed in analyzing the economic impact of airports is the input-output method which measures the sum of all direct, indirect, and induced impacts of an airport's activity on the economy. The most common models used in this method are RIMS II, IMPLAN, and REMI.

Collection of Benefits

The collection of benefits method analyzes beneficial economic activities that are associated with an airport or airport system. These include quantitative or qualitative measures, including community benefits, stimulation of business, tourism, as well as other recreation and commercial activities.

Catalytic Method

The catalytic method is not yet common in the United Stated. It measures the net economic effects (e.g., on employment, incomes, government finances, etc.) resulting from the contribution of air transport to tourism and trade (demand-side effects) and the long-run contribution to productivity and GDP (Gross Domestic Product) of growth in air transport usage (the supply-side performance of the economy). This method takes a broader but still quantifiable view of aviation's impact on the economy and analyzes the impact that growth in air transport has on the performance of other industries. It is important to note that this does not replace a traditional method, such as input-output, but is a tool that can be used to enhance the analysis.

Limitations of Airport Economic Impact Studies

Airports play a complex role in the economy, thus analyzing their impact is complicated, and there are several limitations. The cost associated with these studies can be prohibitive in addition to the lack of standardization concerning variables and how to apply multipliers. Additionally, a majority of economic impact studies neglect to assess offsetting impacts. It is important to consider these limitations and attempt to address them when conducting impact analyses. This can be done by clearly outlining which of the impacts are linked to airport operations, defining which impacts are additive, and centering the analysis on the incremental value of the airport by weighing the opportunity cost of using the property for aviation purposes.

Airports and Economic Development

Related to analyzing airport economic impact is the relationship between airports and regional economic development. The consensus in the literature is that aviation activity has a positive impact on regional development. However, it is a difficult econometric issue, as the direction of causation is not entirely clear despite the strong correlation between air traffic and economic growth. It is reasonable to suggest that airports lead to economic development, but it is equally reasonable that economic development leads to increased aviation activity.

Examples of Input-Output Method

***Analyzing the Economic Impact to the City of Fayetteville from Operations and Capital Improvements at Drake Field,* Center for Business and Economic Research, Sam M. Walton College of Business, University of Arkansas, Fayetteville, 2005.**

This study considered the change in total direct, indirect, and induced economic impact related to the loss of commercial air service at Drake Field in Fayetteville, Arkansas. The authors measured the quantitative economic value of the facility in terms of employment, economic output (purchases of goods and services in the region resulting from activity at the airport), and local taxes generated by the airport and associated businesses. They then used an IMPLAN input-output model to determine the three types of impacts (direct, indirect, and induced). Local tax impacts were calculated by generating the local tax burden per employee (total tax revenues/employment base). This estimate was then multiplied by the estimated number of jobs generated by the airport.

Beyers, B. and S. J. Hyde, *King County International Airport/Boeing Field; 2003 Economic Impact Study,* Airport Division, King County Department of Transportation, Seattle, 2003.

This analysis used traditional methods to estimate sales, employment, labor income, and regional purchases by tenants at the King County International Airport and was collected through tenant surveys. To calculate indirect and induced economic impacts, direct estimates of sales, employment, and labor income were utilized in the input-output model. One non-traditional method employed, estimated the amount of “new money” (non-local demand for airport goods or services that could not be satisfied if the airport were not there) activity generated by the facility. The estimated economic impact of “new money” was generated through data collected via tenant surveys.

Examples of Collection of Benefits Method

Airport Technology and Planning Group, Inc., *The Economic Impact of Aviation in Pennsylvania,* Bureau of Aviation, Pennsylvania Department of Transportation, Harrisburg, n.d.

This study measured the economic benefits of the state’s 150 airports within three airport segments: scheduled service airports, general aviation airports, and overall business dependence. Total economic benefits for the state’s scheduled service and general aviation airports were measured by total airport-related jobs and aviation-related output or spending (either capital improvements or spending by visitors arriving via the airport). To arrive at a total economic impact, these estimates were multiplied to account for successive waves of benefits. The authors also surveyed businesses to estimate the value-added benefits of the state’s airports based on the number of jobs that rely on the availability (or access) to an airport. Qualitative benefits (such as health, safety, and agriculture) were also provided.

HNTB, *The Economic Impact of Airports in Colorado,* Division of Aeronautics, Colorado Department of Transportation, Denver, 2003

This report quantified the economic impact of Colorado's public-use airports on the state economy. The methodology measured on-airport impacts, visitor spending, and spin-off impacts in terms of three indicators: total jobs, wages, and business sales. The study also suggests that Colorado airports provide qualitative benefits that add to the residents' quality of life in terms of public safety, air medical transport, and recreation to name a few.

Example of Catalytic Method

Cooper, A., and P. Smith. The Economic Catalytic Effects of Air Transport in Europe, Eurocontrol, 2002.

Although most airport economic impact studies concentrate on the direct, indirect, and induced contributions of airports, this study suggests that economic catalytic (or spillover) impacts have received relatively little attention and have not been adequately quantified. Catalytic effects are defined as the net economic effects (e.g., on employment, incomes, government, finances, etc.) resulting from the contribution of air transport to tourism and trade, and the long-run contribution to productivity and gross domestic product from growth in air transport usage. This study develops a methodology for quantifying the catalytic effects of Europe's airports in 2005 and projected catalytic effects to 2025. The authors further distinguish these effects into the demand side (through the transportation of tourists and goods) and supply-side (long-term contribution to productivity and GDP growth) catalytic effects from air transport.

Button, K., Doh, S., & Yuan, J. (2010). The Role of Small Airports in Economic Development. Journal of Airport Management, 4(2), 125-136.

This paper used a sample of 66 small airports in the state of Virginia to explore the functional relationship between local air transportation and regional economic development, noting that the direction of causation between air traffic and economic development is not entirely clear. It is also possible that generating traffic airports act as a catalyst for local investment, but the paper noted that "with the exception of some work on high-income tourist destinations, previous studies provide little clear evidence to support a strong positive correlation between local air transportation and economic development." The study concludes that the application of the multiplier method is likely to be faulty as it assumes there are no other limitations on economic growth than airport inputs, although it does suggest that additional air service does raise local incomes.

Additional Resources

Appold, S. J. (2015). The Impact of Airports on US Urban Employment Distribution. *Environment and Planning A: Economy and Space*, *47*(2), 412–429

The influence of airports on the distribution of employment within 51 large US metropolitan areas was measured in the context of three principal elements of urban spatial structure: centers, corridors, and clusters. Analysis of tract-level census data for 2000 using spatial regression models for each metropolitan area, revealed that central cities have a varying but strong effect on the distribution of metropolitan employment, as do highways and employment subcenters. Regressing metropolitan airport-anchored distance-decay parameters on a series of regional explanatory factors suggests that airport cities develop primarily as cities expand outward rather than as a direct consequence of air

transportation. These results inform plans relying upon airports to help shape and accelerate regional development.

Appold, S. J., & Kasarda, J. D. (2013). The Airport City Phenomenon: Evidence from Large US Airports. *Urban Studies* 50(6), 1239-1259.

As air transport for leisure trips, business travel, and goods shipment increased rapidly over the past several decades, the emergence of airport cities has been hypothesized. Busy commercial airports may be emerging as central transport nodes in large metropolitan areas, much as ports and rail terminals were in the past, anchoring employment, servicing passengers, facilitating frequent travelers, and providing a spatial focus for unrelated firms. An analysis of small-area employment data for the areas surrounding 25 major US airports and the related central cities reveals the concentration of employment within 2.5 miles of these airports to be substantial—half of that within 2.5 miles of the central point of the corresponding CBDs—and growing. The analysis refocuses a question about the nature of spatial differentiation within metropolitan regions supporting multiple employment nodes.

Bilotkach, V. (2015). Are Airports Engines of Economic Development? A Dynamic Panel Data Approach. *Urban Studies*, *52*(9), 1577–1593.

This paper applied the dynamic-panel-data generalized method-of-moments estimator to data on commercial passenger air traffic at all primary airports in the United States. The analysis evaluated the impact of traffic volumes and the number of non-stop destinations served with the key indicators of regional economic development. The study found the number of destinations served with non-stop flights has a much clearer and more robust impact on levels of employment, number of business establishments, and average wages. Passenger traffic volume affects employment and average wage, but not the number of business establishments. At the sample median, connecting a metropolitan statistical area with an additional non-stop destination, while keeping everything else constant, creates 98 new jobs and facilitates the opening of four new business establishments. The corresponding numbers for the sample mean are 223 jobs and 15 businesses. The impact of air travel on regional economic development is influenced by competition in the respective airline markets.

Green, R.K. (2007). Airports and Economic Development. *Real Estate Economics* V35, 91-112.

This article tests whether the activity at a metropolitan airport can be utilized to predict population and employment growth within the surrounding area. In regression equations explaining employment and population growth, the article uses various measures of airport activity, including boardings, originations, hub status, and cargo volume. Because airports may be a function of, as well as a cause of, growth, the article controls for this by using geographical and lagged variables. It finds that, under a variety of specifications, passenger activity is a powerful predictor of growth; cargo activity is not.

Weisbrod, G.E., Reed, J.S., & Neuwirth, R.M. (1993). Airport Area Economic Development Model. Paper presented at the PTRC International Transport Conference, Manchester, England.

This study provides a framework for understanding economic impacts and planning for development around new or expanded airports, based on studies by Cambridge Systematics of airports in Europe, Japan, and North America. The model constructed divided impacts in terms of airport facility employment, directly related business activity, businesses attracted to the surrounding area, and spin-off development. This paper describes the basic framework for identifying the nature of economic

activities occurring in each of these areas, the variable factors affecting their magnitude, and applications of the model system for airport-related planning. Commercial airports are emphasized here, but general aviation airports are also discussed.

Yao, S., & Yang, X. (2008). Airport Development and Regional Economic Growth in China. *Available at SSRN 1101574*.

This paper focused on the determinants of airport development in Chinese regions. “The empirical results based on an augmented production function indicate that airport development is positively related with economic growth, industrial structure, population density, and openness, but negatively related with ground transportation” and that “the growth of airport transportation in the eastern region is slower than in the inland areas, implying a more significant substitution effect of air transport on ground transport in the less densely populated areas, irrespective of economic activities.”

3 Literature Review - Airport Development Trends

The following section explores published literature on airport development trends, focusing on airport development planning that integrates with regional or metropolitan planning rather than simply on airport planning. However, relevant examples from the latter case have been included. This analysis focused on peer-reviewed/academic literature (as it represents better quality analysis) although high-quality trade publications have been referenced. Studies were found using a combination of snowball sampling and bibliographic snowballing. Almost all studies focused on hub airports.

Moulds & Lohman (2015) analyzed future trends in non-aeronautical revenue sources to identify both the opportunities available and threats to current revenue streams using Adelaide Airport operations as a case study. Their research investigates several factors potentially impacting non-aeronautical revenue [3].

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3 Moulds, J., & Lohmann, G. (2016). An analysis of future trends in non-aeronautical revenue: A case study from Adelaide Airport. *Journal of Airport Management*, *10*(4), 343-358

Kasarda and Appold (2014) discussed how the aerotropolis model provides a framework for understanding and addressing terminal and last-mile costs that otherwise place considerable friction on inter-regional trade in goods and services. The central tenets of the aerotropolis are outlined and the elements of the aerotropolis planning framework are given, using the Amsterdam Schiphol, Washington Dulles, and Zhengzhou airports as exemplars and case studies. The article concludes by noting that the

Fig. 3. The Golden Ring of Aerotropolis Planning.

spatial form of the aerotropolis represents the global-local interface of the airport, where "the combination of air connectivity and spatial propinquity yields advantages to businesses and regions," but that optimal outcomes are "contingent on bringing together and aligning multiple stakeholders" across private and public sector domains [4].

Freestone & Wiesel (2014) suggest that second-tier general aviation airports have received less policy and research attention. Yet these airports have also looked to non-aeronautical activities to complement their core aviation business. What has emerged is a new type of mixed land-use agglomeration conspicuously juxtaposing aviation and non-aeronautical uses. Smaller airports have all

4 Kasarda, J. D., & Appold, S. J. (2014). Planning a competitive aerotropolis. The economics of international airline transport, 4, 281-308

turned enthusiastically to property-based development models. As relatively low-cost structures on medium-term leases servicing wide catchment areas, direct factory outlets have become a staple of privatized airport development. At Essendon Airport, the real estate development following privatization included campus-style office development, retail outlets, and auto-strip development, and gradually developed into a large business hub. Following the privatization of the airport, what has emerged is a new type of mixed land-use agglomeration conspicuously juxtaposing aviation and non-aeronautical uses. Most of Essendon's non-aeronautical uses do not directly benefit from proximity to air services but do provide revenue and establish creditworthiness [5].

Freestone & Tice (2013) drew on census data for the period 1996-2011, working at three main spatial scales (airport, surrounding region, and global economic corridor). This paper explored employment trends in Sydney where the aerotropolis framework posits there would be evidence of significant airport-related development. The research provided insights into how the Sydney Airport itself acts as a growth node: how it has stimulated economic development within the contiguous area, its contribution to broader metropolitan development, and evidence for the aerotropolis model. The authors conclude that employment development in Sydney near the airport has lagged behind the rest of the region, a condition they attribute to constrained development opportunities on the airport, and the built-up characteristics of the nearby area such that "the airport city model said to be at the core of the aerotropolis concept has been impeded." The paper suggests that industrial development has escaped to off-airport locations and that business and knowledge industries have stayed put in historic locations, because "the relative high accessibility of the airport in metropolitan terms by motorway, conventional arterial roads and rail has enabled a spatial diffusion of airport-linked development." The implication is that having effective surface transportation to the airport makes co-location less meaningful [6].

Saldiraner (2013) discusses airport master planning in Turkey, concluding that the analysis of failed earlier master plans indicated that the coordination, planning, and implementation procedures were flawed and should be changed to clear the way for the development of airports, or else master plans would continue to not be brought into effect, continuing to hamper efforts to bring plans to fruition. Highlights from the article include: 1) master plans were not shared with other related authorities; 2) they were neither taken into proper consideration nor were they updated; 3) local or regional plans did not cover appropriate integration, and 4) major incompatibilities took place between the proposals and their realizations [7].

Burgouwt (2012) explored airline network development and development in the deregulated EU (European Union) air transport market, addressing three issues: post-deregulation route networks, their effects on the airport hierarchy, and the effects on the strategic planning of airport capacity. The research found that route network shapes bifurcated toward either hub and spoke or regional carriers to secondary cities, disrupting the existing hierarchy of airport hubs. The article provides a typology of hubs-to-base strategic planning of airport capacity on, viz: 1) global hubs all-around hubs; 2) specialized

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5 Freestone, R., & Wiesel, I. (2014). The Making of an Australian 'Airport City'. *Geographical Research*, *52*(3), 280-295.

6 Freestone, R., & Tice, A. (2013). Airports as Development Generators: A reconnaissance of employment trends in the Sydney airport region 1996-2011. In State of Australian Cities National Conference 2013: Refereed Proceedings. Sydney, (http://apo. org. au/node/59745).

7 Saldıraner, Y. (2013). Airport master planning in Turkey; planning and development problems and proposals. Journal of Air Transport Management, 32, 71-77.

hubs serving as links between national and international markets; 3) directional hubs serving long-haul traffic traveling through; and 4) regional hubs serving short-haul connections within the continent.

Baker et al. (2011) noted that "the airport city concept has been embraced by many airports of different scales and in varied ways around the world. Airports everywhere have diversified their landside revenues with non-aviation commercial and industrial development to increase revenues. As intermodal hubs in a connected, globalized world, airports have evolved from transportation nodes into multi-faceted business enterprises. They have assumed a critical role as 'transactional' spaces in the global economy" [8].

Wang et al. (2011) explored the development trend of airport cities in Hong Kong, South Korea, and Singapore as a basis for analysis of outcomes in Taiwan. Using grounded theory-based qualitative research the report concluded that the airport-city model is an effective framework for the long-term planning of airports. The article suggests that the main emphasis of planning action is in the mix of, and access to, services on land surrounding the airport [9].

Freestone and Baker (2011) found that "airports have been neglected in scholarly planning literature despite their historic role in shaping metropolitan form. Their transformation into major mixed-use urban nodes anchoring subregional realms of aviation-oriented development has underscored their significance as agents of and products of globalization." The article notes that, "The contestation of airport expansion that has made for epic political battles in diverse settings," with implications for models of airport-led urban development. The study concludes that "the notion of the sustainable airport region ultimately requires a rapprochement between airport master plans and broader urban planning strategies" [10].

Peneda et al. (2011) identified the underlying factors in the emergence of an airport city, listing four critical factors: 1) connectivity of the airport and its surroundings; 2) economic potential of the surrounding area, 3) a sustainable development context, and 4) the commercial attitude of an airport operator. The study notes that while "globalization and liberalization processes have led to a strong reliance of airport operators on non-aeronautical revenues" and that "real estate development centered on airports arises as a strategy to maximize nonaeronautical revenues and as a response to a need for revenue diversification," nonetheless, "evolution toward an airport city is difficult; several airports worldwide have failed in the attempt" [11].

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8 Baker, Douglas & Freestone, Robert (2011) The airport city: A new business model for airport development. In Macario, R & Van de Voorde, E (Eds.) Critical Issues in Air Transport Economics and Business. Routledge, United Kingdom, pp. 150-164.

9 Wang, K. J., Hong, W. C., Chen, S. H., & Jiang, J. T. (2011). Strategic development trend and key factors analysis of Airport City in Taiwan. Journal of Transport Geography, 19(4), 807-820.

10 Freestone, R., & Baker, D. (2011). Spatial planning models of airport-driven urban development. Journal of Planning Literature, 26(3), 263-279

11 Peneda, M. J. A., Reis, V. D., & Macario, M. D. R. M. (2011). Critical factors for development of airport cities. *Transportation research record*, *2214*(1), 1-9.

Wang & Honk (2011) suggest that “the focus of international airport development has shifted from a transportation hub towards a multi-functional aero metropolis…” and that “an airport city serves not only as an index of a country’s performance in development, but also plays the role as the impetus of national industries and a gateway to economic globalization” [12].

Cox (2010) examines “the history of Memphis as a center of distribution, the present economic impact of distribution, and the efforts underway to pave the community's path for the future.” The article notes that, “As the world's busiest cargo airport for the last 17 years, Memphis International Airport is ideally positioned to become North America's first true aerotropolis.” This research also details the concerted efforts by business leaders, elected officials, economic development agencies, and the Airport Authority to achieve the aerotropolis vision [13].

Kasarda (2010) is a book-length exploration and explication of the concept of the aerotropolis, its economic function, constituent parts, attempts to implement it both nationally and internationally, and analysis of the successes and flaws of those attempts. A guidebook on how to leverage land adjacent to airports to create ‘airport cities’ and then to leverage the capacity of the airport city as a regional economic development tool to create an aerotropolis [14].

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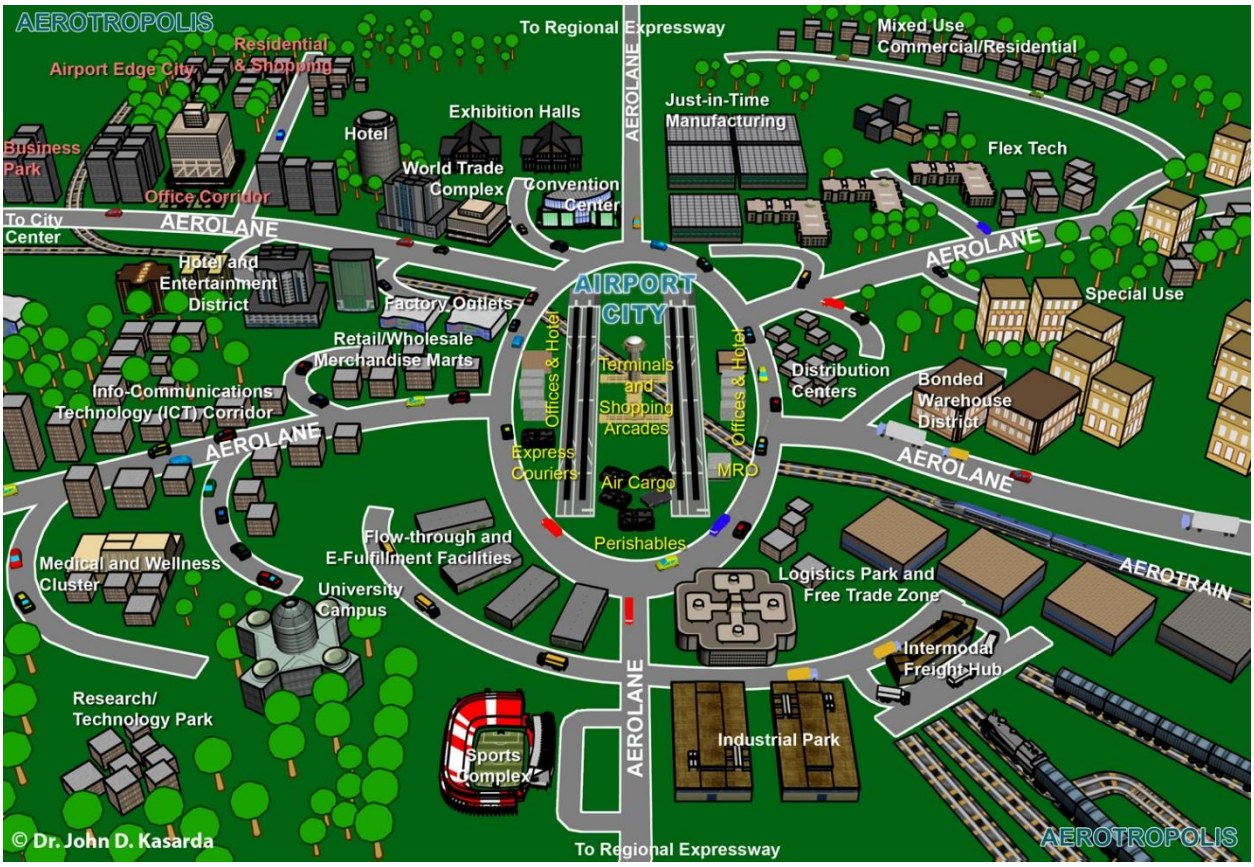
12 Wang, K. J., & Hong, W. C. (2011). Competitive advantage analysis and strategy formulation of airport city development—The case of Taiwan. *Transport Policy*, *18*(1), 276-288.

13 Cox, L. (2010). Evolving the Memphis aerotropolis. Journal of Airport Management, 4(2), 149-155.

14 Kasarda, J. D. (2010). Airport cities and the aerotropolis: The way forward. *Global airport cities, ed. J. Kasarda*, 1-31.



Stevens, Baker & Freestone (2010) discuss how, in Australia, airports have emerged as important sub-regional activity centers and now pose challenges for both airport operation and planning in the surrounding urban and regional environment. The article suggests that the interfaces of an 'airport metropolis' consist of four main domains: economic development, land use, infrastructure and governance, and then applied sustainability criteria (economic efficiency, environment, coordination, community) to highlight the interdependencies between airports and regions [15].

Freestone (2009) suggested that, "Airports are no longer places where planes just take off and land but have evolved into major business enterprises with spatial impacts and functional implications that extend deep into metropolitan areas." However, the article notes that airport-led urban development "notwithstanding its employment and income-generating capabilities and potentials" raises a host of planning issues, including the shift from NIMBY resistance to critiques based around issues such as climate change. The article concludes that this conflict can be mediated by linking airport planning to the broader planning of sustainable communities and regions [16].

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15 Stevens, N., Baker, D., & Freestone, R. (2010). Airports in their urban settings: towards a conceptual model of interfaces in the Australian context. *Journal of Transport Geography*, *18*(2), 276-284.

16 Freestone, R. (2009). Planning, sustainability and airport-led urban development. International planning studies, 14(2), 161-176.

McNeill (2009) suggests that airports have long shifted from being layover spaces to being central places, noting that integrated airport complexes will increasingly seek to marshal advantages to be gained from new economic centrality, and in turn, the airport hotel may come to reprise its historic role within downtown central business districts, acting as a meeting point, prioritizing the needs of time-poor but cash-rich travelers, operating as a fixed point for the traveler, and "both offering shelter and refreshment on their journey, but also allowing a reliable point of contact to business associates." The article does warn that such premium networked spaces are secessionary streetscapes that turn their back on the established urban form of the city rather than integrating with it [17].

Van Wijk (2008) notes that despite the global nature of aviation, "the institutional conditions for the actors involved remain rather local." The study illustrates how regional development agencies in the cases of Amsterdam (Schiphol Area Development Company) and Frankfurt (Rhein-Main Verkehrsverbund) impact planning, suggesting a need to "integrate infrastructure and land supply in planning… and find… a balance between exploiting and protecting the airport area." The article concludes that "an airport city, and even on a larger scale, the aerotropolis, requires balanced development of infrastructure and business parks." The article also suggests that such development requires a public-private partnership for effective collaboration to manage infrastructure investment and development [18].

Kasarda (2008) assesses the evolution of airport cities and the aerotropolis, pointing out the special opportunities and challenges that they offer to the retail, real estate, and retail industries. "Aerotropolis planning begins with the multi-modal core—the airport terminal—and moves outward sequentially to the airport city and the aerotropolis." The article notes that "airports and their environs are becoming new commercial anchors taking on many features of destination retail and of cities themselves--passenger terminals are morphing into shopping malls and leisure venues." The article further states that "strings and clusters of retail outlets, hotels, entertainment complexes, conference centers, and aviation-oriented businesses are locating outward along airport corridors forming a greater aerotropolis" [19].

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17 McNeill, D. (2009). The airport hotel as business space. Geografiska Annaler: Series B, Human Geography, 91(3), 219-228.

18 Van Wijk, Michel. "Development of airport regions: Varieties of institutions in Schiphol and Frankfurt." Aerlines, e-zine edition 40 (2008): 1-5.

19 Kasarda, J. D. (2008). Shopping in the airport city and aerotropolis. Research Review, 15(2), 50-56.

Prins (2008) suggested that the effects of market forces are more important than the actual economic or spatial planning policies. The article also noted a tendency to "address landside development through institutional channels of the aviation sector." The article also notes that (future) accommodation of civil aviation is strongly linked to the acceptability of the developments at regional and local levels, regarding noise, safety, and health, and warns about declining tolerance for health and environmental risks.

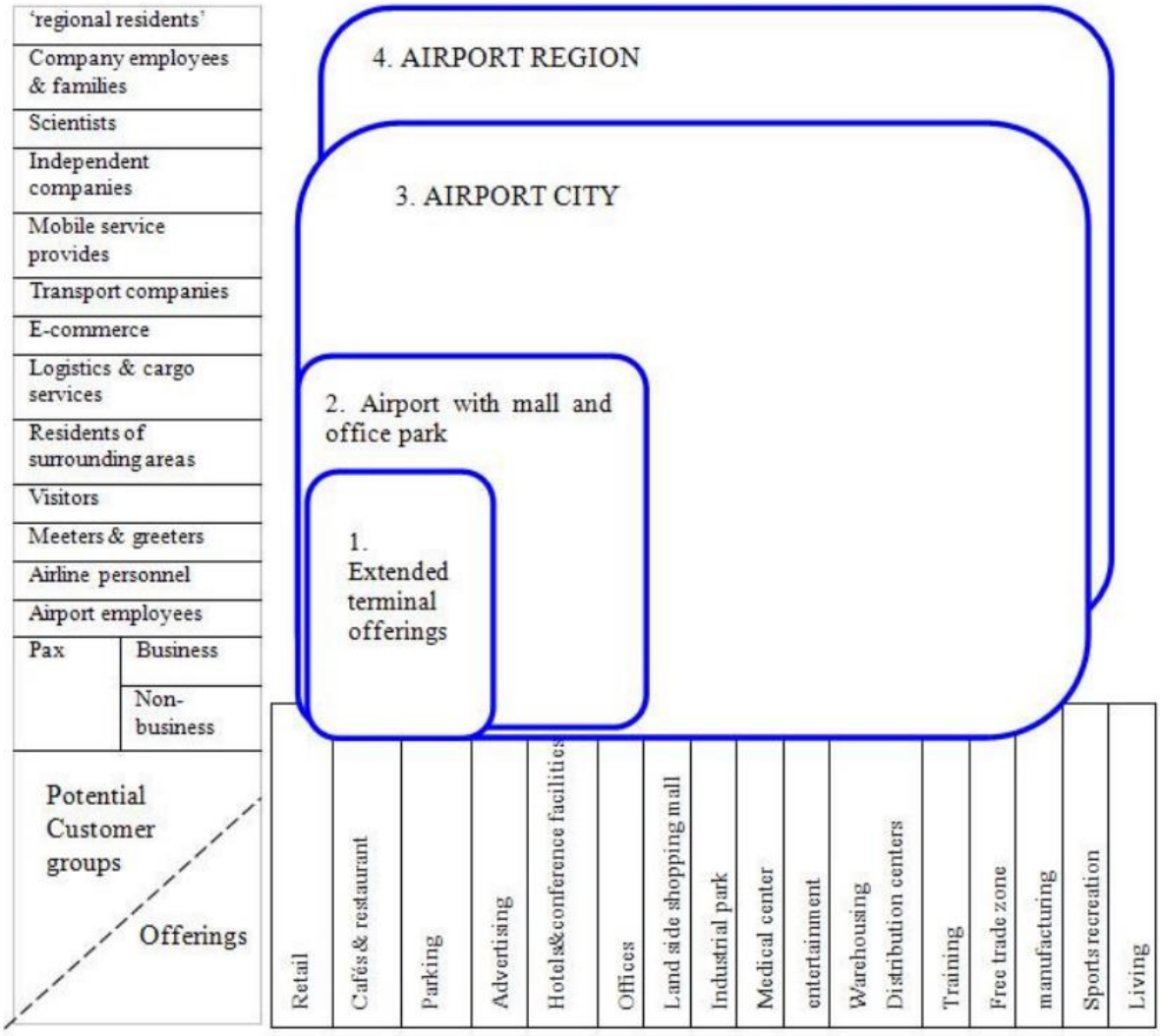

Figure 2. The importance of real estate to airport city development; the Fraport concept (Fraport,2007)

The feasibility of airport cities is assessed, noting that "recently airports re-develop into multiple function centers, destinations for mixed-use," suggesting that higher levels of non-aeronautical revenue can be provided by densification and diversification. This change is facilitated by increasing volumes of employees and passengers as airports become more like urban developments. The article provides an overview of how different groups and development types relate to airport development trends. Because "airport authorities themselves are no longer mere transport suppliers but full-fledged economic actors," such that the era of splendid isolation, in which airports merely provide infrastructure for airlines, is over, concluding that "the review of the features of and trends at airports reveals that when

airports change from transport node into a full-fledged hub, they seem to come at a turning point; they transform from an infrastructure facility to an economic system" [20].

According to **Stevens et al. (2007)**, "Modern airports are very different from traditional airports as they emerge as important sub-regional activity centers" and "as a result of these changes, airport impacts now pose considerable challenges for both airport operation and the surrounding urban and regional environment," noting that "the current issues surrounding airport development and expansion need to be defined by an understanding of the complex roles and spatial interactions now associated with airports" and that "the airport can no longer be managed in isolation from the metropolis that it serves." The study also "identifies and documents a range of issues and impacts to assist in understanding the changing role of airports in Australia, dimensions of which include land use, infrastructure, economics, and governance" [21].

Neo (2003) summarized common trends of new airports: 1) they are built much further away from cities, often on a manufactured island or reclaimed land; 2) a rail link has become an indispensable part of the airport transportation network, and 3) in a passenger terminal design, a commonly adopted hybrid is a central terminal building with connections to satellites or piers [22].

Kasarda (2000) explores the implication of explosive growth in business-to-business activity with just-in-time suppliers, sophisticated distributors, and logistics providers, as well as how it was transforming supply-chain transactions. The article also discusses the emergence and future importance of e-commerce. The article concludes that "to meet the imperative of speed in order fulfillment, e-commerce distribution centers are being built near airports that have extensive flight networks" as has already occurred with FedEx at Memphis International Airport and with UPS at Louisville International Airport where dozens of e-tailers have thus already located their fulfillment centers, allowing shippers to take orders for next-day delivery as late as midnight [23].

Caves and Gosling (1997) suggested that the progressive liberalization of air transport, together with trends in privatization and globalization caused the roles of airports to change, for airport planning to become increasingly decentralized, and for air traffic to become more volatile. The article further notes that airports are increasingly in competition for limited markets and traffic is more volatile, making it difficult to justify further investment, even as airport expansion is made difficult by environmental pressures that push towards sustainable transport [24].

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20 Prins, M. (2008). Landing an airport? Airport development and strategic land use planning in the EU. na.

21 Stevens, N., Baker, D., & Freestone, R. (2007). Understanding the Australian airport metropolis. In *Proceedings of the State of Australian Cities National Conference 2007:* (pp. 110-120). SOAC 2007.

22 Neo, T. C. (2003). *Airport development trends in Asia* (Doctoral dissertation).

23 Kasarda, J. D. (2000). Logistics & the rise of aerotropolis. *Real Estate Issues*, *25*(4), 43-43.

24 Caves, R. E., & Gosling, G. D. (1999). *Strategic airport planning*. Oxford: Pergamon.

4 Case Study Selection & Elements

Introduction

The case studies were intended to provide scenarios of alternate futures for different airports within the system. Accordingly, cases include general aviation airports, scheduled commercial service airports, and major hub airports. The initial scan of the literature suggested a larger number of potential airports. Following an extensive scan of available internet resources, a subset of this larger list was selected as targets for visits and more in-depth case studies. The following section provides the criteria used for selecting case studies of peer airports within the Utah Aviation System.

Case Selection

Hub Commercial Service

Utah has only one hub commercial service airport, Salt Lake City International Airport. Consequently, it seemed worthwhile to study airports like it, using similarly sized hub airports as peers. The Salt Lake City International airport is a large hub (defined as airports that account for at least one percent of total passenger enplanements [25]). This generated a list of 30 candidates. Airports with similar or greater capacity were given preference in identifying peers and exemplars.

Over the past century, as aircraft range has increased, the need for airplanes to make stopovers has declined, aviation has become increasingly concentrated in a smaller number of airports, and status as a hub has become increasingly critical. However, airlines go bankrupt or merge with some regularity, typically resulting in a reduction in the number of hubs. While there are a large number of airlines in America, there are only four major airlines that account for a majority of all passenger enplanements: United Airlines, American Airlines, Delta Airlines, and Southwest Airlines. (Jet Blue and Alaska Airlines are the next most dominant). Despite this, each major airline tends to retain about one major hub per time zone – a pacific hub, a mountain-west hub, a central hub, and an eastern hub. While nearby mountain airports (Denver, Phoenix, Albuquerque) are the nearest competitors, they were also assumed to be already the most familiar to Utahns, and cases from further abroad were identified.

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25 https://en.wikipedia.org/wiki/List_of_the_busiest_airports_in_the_United_States

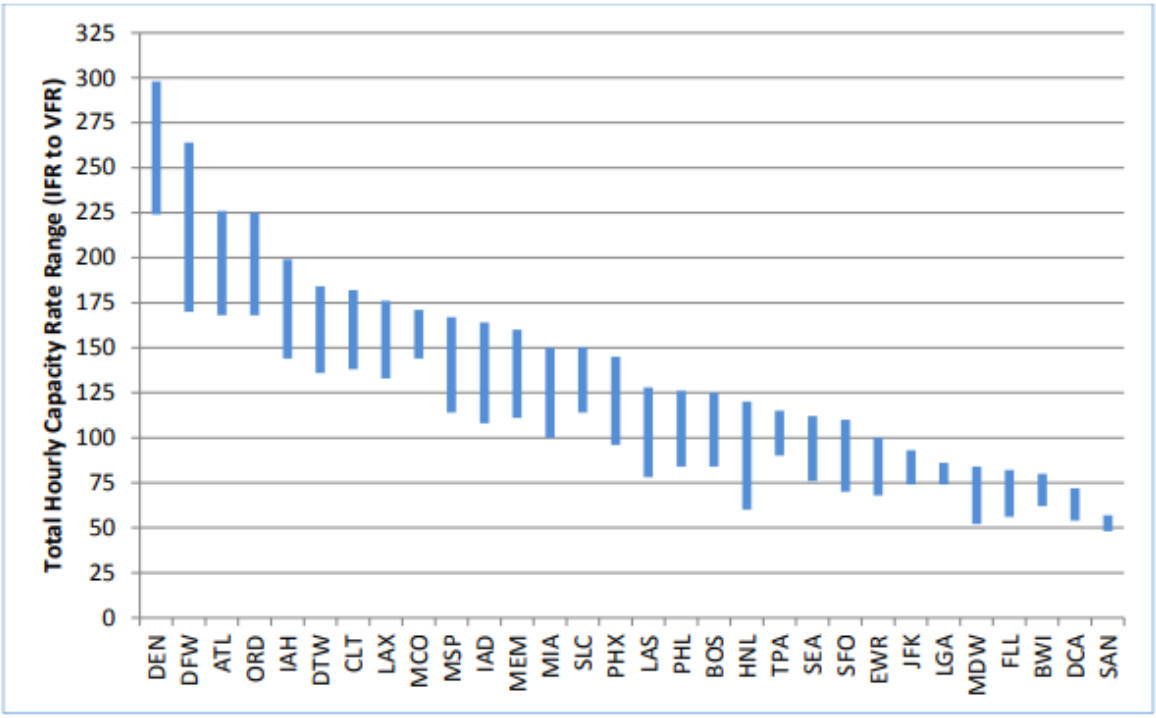

Figure 2. Range of Capacity Rates for Current Operations at the Core Airports

The hub networks of the major airlines tend to have about one hub per time zone: one hub on each coast, two mid-American hubs, and (potentially) a gulf-coast hub. Such an arrangement 'tessellates' airport coverage in America so that no airport is more than a few hundred miles from a hub. While an airline bankruptcy might deprive an airport of its hub status, the same characteristics that made an airport an attractive hub for one airline often make it an attractive hub for another airline. A limited number of airports have managed to become hubs for multiple airlines, a list which includes JFK, LaGuardia, LAX, O'Hare, Atlanta, Phoenix Sky Harbor, and Denver International. Given Salt Lake City's proximity to both Phoenix and Denver, it seems unlikely Salt Lake City International will be able to do so.

A review of other hub airports reveals that there are two main paths: continued expansion at the current location, or the establishment of a new airport at a remote location peripheral to the metropolitan area. The return of military airbases to civilian use was the genesis for many current hub airports, but more recent examples of greenfield airports include Dulles, Denver International, Dallas/Fort Worth, and George Bush Intercontinental. After some consideration, the greenfield airports were considered poor peers for Salt Lake City International: They are distant from the CBD, and Salt Lake City International Airport is unlikely to relocate. Salt Lake City International Airport already has a larger acreage [26] than most airports in America and could (potentially) displace general aviation operations or relocate its Utah Air National Guard unit if additional space is required. Taken altogether, these

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26 https://panethos.wordpress.com/2013/01/15/americas-largest-commercial-airports-by-acreage/

criteria suggested case studies on Charlotte-Douglas International Airport (NC) and Hartsfield-Jackson Atlanta International Airport (ATL).

Commercial Service

Reference to the National Plan of Integrated Airport Systems (NPIAS) 2018-2023 [27] classified non-hub commercial service airports by enplanements. At the time of case-study site selection, the Provo and Saint George airports each had about 78,000 enplanements, Wendover about 47,000, Ogden-Hinkley and Cedar City about 15,000, and Vernal Regional about 4,000 enplanements. In addition, the Cedar City, Moab Canyonlands, and Vernal airports enjoy scheduled commercial service thanks to the federally supported *Essential Air Service (EAS)* program.

To choose comparable commercial service airports, proximity to a major international airport was also considered. The Ogden and Provo airports are both within the air service catchment area of Salt Lake City International, and Saint George is within the catchment area of Las Vegas. By this criteria, Bellingham International Airport (BLI) (in the shadow of SeaTac), Eugene (in the shadow of Portland), Tucson (in the shadow of Phoenix), and cities with similar population sizes were considered more likely to be good peer airports. Likewise, cities with substantial student populations were considered to help make airports peer.

To choose comparable commercial service airports, service by a regional non-hub airline like Allegiant Air, which serves Ogden and Provo. Consulting the Allegiant Air route map [28] suggested a half dozen airports, including those in Austin, TX, and Orange County, CA.

Further, Utah has a large number of conservation lands, including national parks, forests, and recreation areas, where airports provide access to second homes by charter flights and private aviation. Consequently, an exemplar of how an airport could grow from general aviation to scheduled commercial service was desirable. After consideration, Phoenix-Mesa Gateway (AZA) and Jackson Hole Airport (JAC) were chosen as case study sites.

General Aviation

Utah has a wide variety of general aviation airports, in a variety of contexts, serving a variety of purposes: business, medical, tourism, recreation, etc. However, general aviation airports are not transportation hubs, forcing a reconsideration of how such airports could act as connected activity centers. Thus, it is suggested that general aviation airports might function less as strictly transportation terminals, and more as ‘gateway nodes’ to the region. Many general aviation airports already function as gas stations. Fixed Based Operators (FBOs) sell fuel and may compete with other FBOs based on services and amenities available. Most FBOs provide bathrooms, and the presence of a loaner car for pilots to use is common. Given that most general aviation airports are remote, this suggests general aviation airports might fulfill a role as connected activity centers by leveraging existing facilities to serve/support non-aviation populations. Minimally, this might include aviation-related businesses, but might also include heavy users of aviation services such as medical and tourism. Consequently, the

27 https://www.faa.gov/airports/planning_capacity/npias/current/historical/

28 https://www.allegiantair.com/interactive-routemap

general aviation airports selected for further study were those where existing infrastructure was leveraged to go beyond the 'FBO (Fixed Based Operators) as gas station' model. Van Nuys (VNY) and Laughlin-Bullhead (IFP) were chosen as case study sites.

Case Study Elements

Each case study is organized into the following major sections: Takeaways, Context (Surface Transportation), Airport-Specific Elements, Aerotropolis/Airport City, and UDOT Goals.

Takeaways provide a summary of key understandings from the case study. Context provides airport site and situation information, including details on surface transportation access. The Airport-Specific section contains subsections unique to each airport. The Aerotropolis/Airport City uses the Aerotropolis model as an analytical framework for development on and near the airport. Finally, UDOT goals evaluate how knowledge gained from the case study might better help UDOT meet its goals.

Preserve Infrastructure

Airports are a major infrastructure asset. However, unlike highways, their primary endangerment is from functional obsolescence. An airport may be encroached upon by urban development such that it can no longer be expanded. In combination with the nuisance effects of noise and pollution, this has in many cases required the complete relocation and duplication of the physical infrastructure to a new, inferior location. Airports are much larger than roadways and adding a major increment of capacity (another runway) requires enormous amounts of land. To avoid this, several case studies address ways in which airports have avoided encroachment or resolved encroachment issues after they occurred.

Optimize Mobility

Air travel is much faster than the alternatives, but speed comes at a cost. Correspondingly, travel time linked to air travel (journey to and from the airport, time within the airport) has a very high value. Likewise, travelers tend to be disproportionately well paid and well off, suggesting a very high value of time. Considering the journey to the airport as part of a single aviation trip suggests an extremely high premium on travel time to and from airports. Ongoing investments in costly but quick surface-transportation access facilities (such as limited-access highways and heavy rail) support this idea. Consequently, each case study includes a review of how each airport has invested in providing mobility.

There are many ways to reduce travel time. Travel time is a function of accessibility, which includes both the mobility provided by the transportation network and the distribution of activities along with the network. It is well recognized that on the network, increasing vehicle-miles traveled (VMT) without increasing capacity inevitably leads to substantial delay. It is less well recognized that efforts to increase capacity to match increases in VMT have been a failing strategy. It is impossible to "build your way out of congestion." Congestion-induced delay, and thus travel time (vehicles hours traveled), has grown explosively even in the most proactive metropolitan areas.

Consequently, the importance of the distribution of activities along the transport network has been recognized as increasingly important. Concentrating new development as infill and redevelopment reduces average trip distances. Concentrating development in an existing center, already well served by transportation infrastructure, also makes it feasible to transfer trip modes away from automobiles and toward active transportation modes. Clustering trip-ends in centers also makes fixed-guideway transit service feasible. But doing so generates somewhat of a chicken-and-egg problem: such a modal shift is

not feasible without a shift in urban form, while the shift in urban form cannot occur without the presence of alternative modes. Hence, reducing travel time requires integrated land use/transportation planning.

In the context of airports, mobility can be optimized by integrated land use/transportation planning to enable aviation-related and aviation-dependent activities to cluster in closer proximity to airports. As exposited by Dr. John Kasarda in his book, Aerotropolis, a wide variety of economic activities not traditionally considered aviation related are actually substantial consumers of aviation services. Consequently, one area of focus in the case studies is to investigate ways in which peer airports have engaged in integrated planning as a method to cluster trip ends and concentrate new development in existing centers in a way that enhances the effectiveness of the airport as a transportation terminal, and thus the metropolitan area as a place to do business.

Economic Development

Economic development is defined as activities that develop the capabilities of economic actors (individuals, firms, or industries) through asset accumulation, greater resource productivity, and a wider range of economic opportunities.

When discussing economic development, there is a tendency to overfocus on roadways; airports are also significant transportation infrastructure investments that can benefit economic development. Just as an interstate off-ramp connects a city or town with a national transportation network for trade and commerce, airports connect the region to the global transportation network for trade and commerce.

Airports are often overlooked when discussing transportation infrastructure investments and are often planned to be segregated from the community they serve, rather than to be integrated into it. Strategic land use and accessibility decisions that treat airports as connected activity centers can maximize the economic return on investment for both the airport and the community. Airports provide accessibility across the globe, but their access to the local area determines much of their utility; quality surface transportation access is critical, both for passengers and freight.

5 Case Study – Laughlin/Bullhead International

Takeaways

Laughlin/Bullhead International Airport (IFP) was investigated because of its unique attributes due to being a border airport and servicing two nearby cities. Gaming, recreation, lodging, and other amenities are located close to the airport and provide a steady stream of economic activity to the region. In and around IFP airport, are functions of economic activity such as charter flights, its proximity to recreational sites such as Lake Mohave, Havasu National Wildlife Refuge, Lake Havasu City, Lake Havasu State Park, Lake Mead National Recreation Area, Las Vegas, and Hoover Dam. Although near to these recreational areas, this airport is a good example of implementing economic toolkits to bolster how airports can function as connected activity centers. With the airport situated between the California, Arizona, and Nevada borders, cross-state transit could benefit from a proposal utilizing the geographic advantages that IFP possesses. At Laughlin/Bullhead International Airport, there is a large emphasis on charter flights from surrounding areas to facilitate travel to Laughlin's gaming amenities and infrastructure. IFP also leases land and warehouses for businesses that may partake in domestic and international shipping and logistics. Storage, parking, shipping, and supply chain management can be handled through IFP. The airport is situated in Bullhead City, Arizona, however, the city of Laughlin resides across the Colorado River in Nevada. Economic activities between the two cities can be facilitated through the arrival of travelers at IFP.

IFP is where an airport functions as a portal to the multitude of recreational facilities that reside in this region of the United States. Laughlin/Bullhead International airport can operate as a connected activity center due to its unique geographical setting, proximity to natural landmarks such as the Colorado River, and its associated recreational areas located within Bullhead City and Laughlin. Consequently, it offers

lessons for airports such as Wendover, Canyonlands, and Cedar City on how to use a combination of recreational amenities to leverage additional air traffic.

Canyonlands Field Airport can apply similar economic strategies by promoting charter flight businesses due to its proximity to a multitude of amenities in the region. The airport is situated on UT-191 and is a 20-minute drive to the city of Moab. Moab is immensely popular during peak touring seasons as Moab is the urban gateway to Arches National Park and Canyonlands National Park. While Moab may not boast casinos or gaming recreation, there are many lodging amenities within the small city. Wendover Airport (ENV) shares many similarities with IFP. ENV airport sits on the Utah side of the border with Nevada. On the Nevada side of the border are numerous gaming recreational facilities, resorts, a golf course, and restaurants. Cedar City Airport (CDC) is in Cedar City, Utah. Near Cedar City are Southern Utah University, numerous recreational trail systems, ski resorts, camping sites, and parks. By utilizing charter flights in and out of CDC, transportation for customers who wish to utilize these facilities will have an easier time getting to these locations.

Context

The Laughlin/Bullhead International Airport (IFP) is a primary commercial service airport that has had intermittent scheduled commercial service since the 1990s. It is located one mile north of Bullhead City, on the Arizona-Nevada border, approximately 80 nautical miles from Las Vegas. The airfield itself is in Arizona but primarily serves visitors of the casinos on the Nevada side of the river.

The airport was selected as a case study because it offered a series of lessons: that of a primary commercial service airport on the cusp of scheduled commercial service; with substantial charter enplanements; on the edge of the catchment area of a major airport (McCarran International in Las Vegas). The airport is located at the foot of the Davis Dam, which transforms the Colorado River into Lake Mohave (part of the larger Lake Mead Recreation area). Despite not having scheduled commercial service, it manages over 120 thousand enplanements a year through charter flights [29]. Consequently, it offers lessons for airports such as Wendover, Canyonlands, and Cedar City on how to use a combination of recreational amenities to leverage additional air traffic.

The airport was constructed in 1943 on Bureau of Land Management (BLM) land in association with the construction of the Davis Dam. George Petterson leased a parcel from the BLM and built the airport that would become Laughlin/Bullhead International Airport, before selling it to Don Laughlin 13 years later [30]. Laughlin was the developer and promoter of Riverside resort, a motel and casino tourism operation leveraging proximity to Katherine Landing on Lake Mohave [31]. In 1986, Laughlin funded the construction of the Laughlin bridge over the Colorado River, replacing/supplementing the shuttle boats

29 https://en.wikipedia.org/wiki/Laughlin/Bullhead_International_Airport

30 https://mohavedailynews.com/news/42964/sharing-history-airports-founder-provides-photos-from-its-early-days/

31 https://en.wikipedia.org/wiki/Laughlin,_Nevada

previously used to transfer passengers across the Colorado River [32,33] from the airport to the resorts and casinos on the Nevada side of the river. Laughlin donated the airport to the Mohave County Airport Authority in 1990 [34], which included a flood control and flood planning arrangement as part of the deal. The airport lost scheduled commercial service following the September 11th terrorist attacks but maintains daily charter flights by 162-seat Boeing 737s by Sun Country Airlines and 80-seat CRJ-700s by Elite Airways; both are casino charters [35]. Charter air service began in the 1990s; many flights were offered in conjunction with hotel packages [36].

Surface Transportation Access

Laughlin/Bullhead International Airport connects travelers to numerous major roads in the surrounding region. Bullhead Parkway, Mohave Valley Highway, and Laughlin Highway are the primary roads in the area. Laughlin is 40 miles west and 20 miles north of I-40. Public transportation between urban centers and IFP is available. The Red- and Green-line buses from Bullhead City center take approximately 30 minutes to reach the airport from the central transit hub. Shuttle services are offered to the airport from surrounding cities (Las Vegas, Kingman), as well [37].

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32 https://en.wikipedia.org/wiki/Laughlin,_Nevada

33 http://www.riversideresort.com/don-laughlin-history-founder-riverside-resort-casino/

34 https://mohavedailynews.com/news/32793/petterson-laughlin-share-history-of-local-airport/

35 https://www.bullheadcity.com/community/bullhead-area-transit-system/other-transportation/laughlin-bullhead-international-airport

36 https://en.wikipedia.org/wiki/Laughlin/Bullhead_International_Airport

37 https://flyifp.com/ground-transportation

Airport-Specific Elements

Recreational Amenities

North of the airport, in Bullhead City, is Katherine Landing Marina, which hosts dozens of recreational boats for activities along the Colorado River. Also at this marina are picnic areas, a restaurant, a hotel, and other resort amenities. Recreational boats can travel quite a ways north up the Colorado River into Lake Mohave in which there are many coves to explore. Lake Mohave offers jet-ski rides. The USS Riverside offers tours on the Colorado River. Other famous recreational sites are located near IFP; these include Lake Mohave, Havasu National Wildlife Refuge, Lake Havasu City, Lake Havasu State Park, Lake Mead National Recreation Area, Las Vegas, and Hoover Dam. ATV/UTV recreations are popular in the area, as there are swaths of open desert in the area. El Rio Golf Course, Riverview Resort Golf Course, and Laughlin Ranch Golf Club are located close to the airport [38].

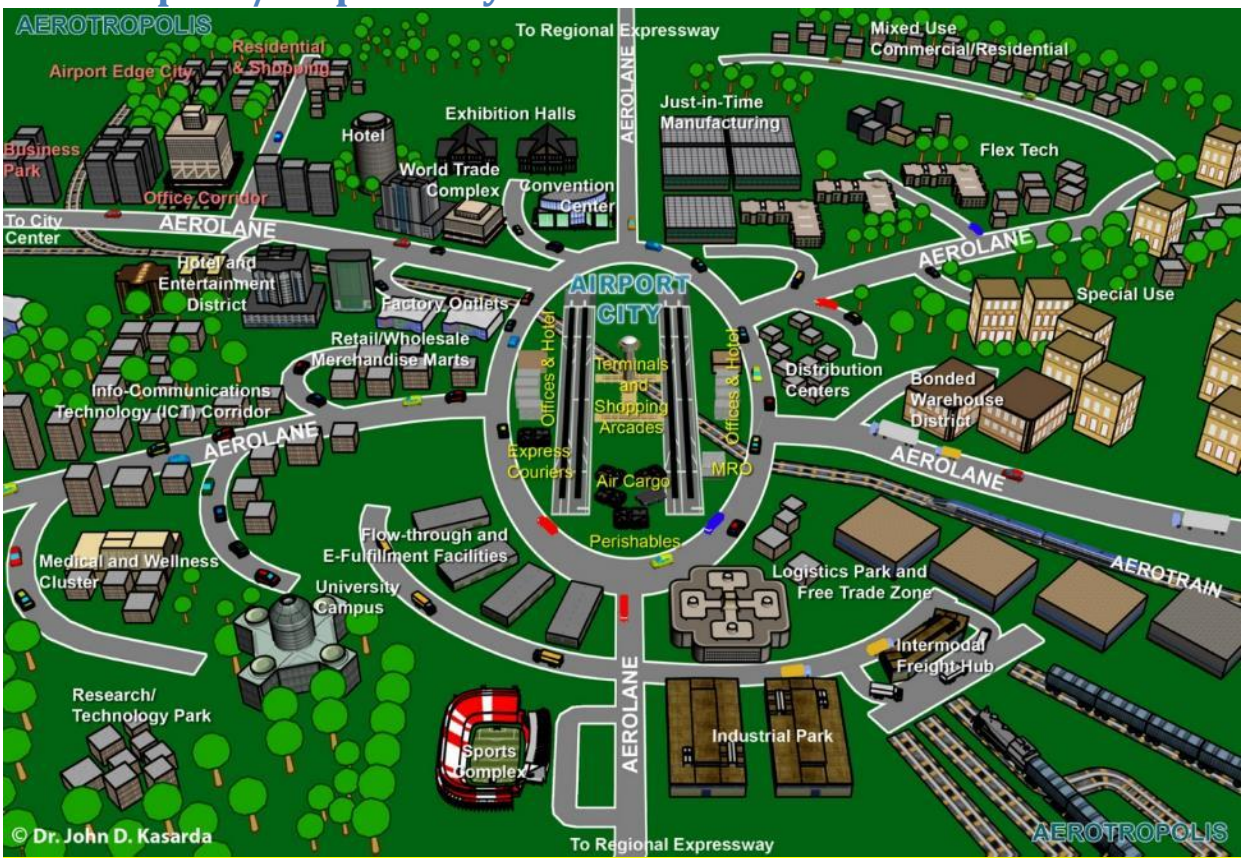
Casino Amenities

In Laughlin, numerous casinos and resorts dot the riverfront. Don Laughlin's Riverside Resort Hotel and Casino, Aquarius Casino Resort, Edgewater Casino Resort, Colorado Belle Casino Resort, Tropicana Laughlin, Golden Nugget Laughlin Hotel and Casino, and Harrah's Laughlin are the most notable lodging facilities close to Laughlin/Bullhead International Airport. These resorts and casinos offer a multitude of recreational activities for customers and travelers to take part in. Slot machines, live shows, spas, nightlife, and gambling are common in all the casinos. Edgewater Casino Resort has a jet-ski rental facility located within the building and has a dock right outside of the resort. Located in Don Laughlin's Riverside Resort Hotel and Casino is a bowling area, cinema, and classic car museum [39].

38 https://www.visitlaughlin.com/things-to-do/

39 http://www.riversideresort.com/entertainment-dons-celebrity-theatre/

Aerotropolis/Airport City



Kasarda's Aerotropolis proves unexpectedly applicable at Laughlin/Bullhead International Airport. The casino's dependence on the airport means much of the associated development matches the airport city concept. Aspects of airport city include the **hotel and entertainment district** of the casinos, an **outlet mall** (Laughlin Outlet Center), and a **distribution center** (DOT Foods).

UDOT Goals:

Regarding the UDOT goals of preserving infrastructure, optimizing mobility, and spurring economic development, the Laughlin Bullhead Airport offers several lessons.

Preserving Infrastructure

Laughlin/Bullhead International Airport is located alongside the low-lying areas next to the Colorado River with poorly draining soils and associated flood risks. To effectively preserve the infrastructure in the area required the establishment of flood control facilities. IFP is novel in the creation of a detention basin running parallel to the runway between the taxiway and the terminal [40].

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40 https://apps.azdot.gov/files/Airports/MP_PDF/Laughlin_Bullhead/IFP_Ch1_Inventory.pdf

Optimizing Mobility

Laughlin/Bullhead International Airport serves as the gateway to an otherwise remote area. The nearest large city (Las Vegas) is almost 75 miles away. The Highway 163 bridge over the Colorado River was constructed to improve connectivity between the airport on the Arizona side and the casinos on the Nevada side. Originally developed along Arizona Highway 95 to the west, the airport made it feasible to develop Bullhead Parkway to the east, aligning with the orientation of the airport, and providing a bypass to the increasingly urbanized and congested Arizona Highway 95. Normally, the long rectangular block of an airport is problematic because it blocks traverse access, but this airport sits parallel and proximate to the Colorado River, mitigating the issue.

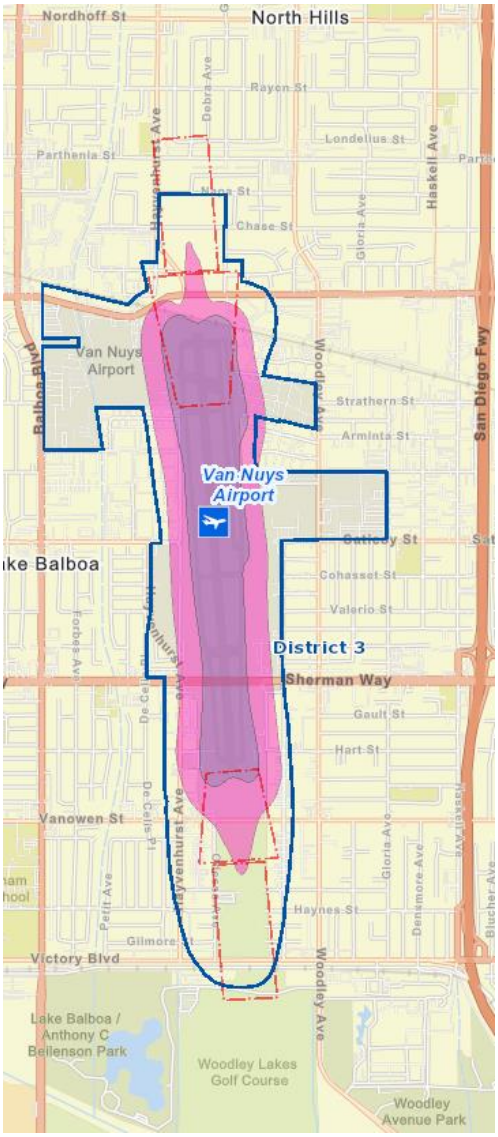
Economic Development

The development of both Laughlin, Nevada and Bullhead City, Arizona are both largely predicated on the existence of casinos, whose function is in turn contingent on access by passenger jets. The presence of the Colorado River and associated Katherine Landing Marina bolster the area's attractiveness for recreation tourism, and thereby for hotels, vacation rentals, and real estate development. The casinos develop amenities for tourists, and casino employees provide a population base sufficient for the provision of basic retail and services. The combination of urban services, gambling, and recreation make the location feasible for vacation homes, driving the flywheel of the urban growth cycle. The cluster of uses has proven resilient—even after losing scheduled passenger service, it has been able to sustain itself through rotating charter pairs to selected airports.

6 Case Studies – Van Nuys

Takeaways

The Van Nuys Airport (VNY) was investigated because it is one of the busiest general aviation airports in America, and because it represents a potential future for the South Valley Regional Airport and Heber City, both of which might benefit from similar land-use policies. The Van Nuys Airport has an 8000-foot runway, a feat made possible by the 1957 project converting Sherman Way into an underpass [41] so that the airport fits within the half-mile arterial network of the San Fernando Valley. This would be analogous to converting 7000 South into an underpass for South Valley Regional.



Van Nuys Airport itself is tightly constrained by surrounding development. The airport does not own the land in its runway protection zones and does not own or control all the land within the 65 DNL noise contour [42]).

Due to early permits by the local zoning board, the Van Nuys Airport is tightly bound on all sides by single-family detached residential homes. However, rather than the 'condemn and demolish' approach common to larger airports, VNY has utilized a mix of compatible land-use planning and a noise-insulation program.

The compatible land uses along the east and west edges of the airport can be classed as airport-oriented development: businesses making use of, but not dependent upon, aviation services. In the case of Van Nuys airport, based jet aircraft available for charter provide the capacity to ferry time-sensitive goods large distances very rapidly, making it a suitable location for just-in-time manufacturing and specialty parts depot functions.

The airport also serves an important surface transportation function, by hosting the FlyAway bus that uses the airport as a remote parking depot for a bus-based shuttle to LAX, thereby reducing emissions and traffic congestion for travelers en route to LAX and reducing the need for parking at LAX. South Valley Regional Airport could likewise be used as a parking depot to replicate the FlyAway bus system for SLC (Salt Lake City).

41 https://www.discoverlosangeles.com/things-to-do/van-nuys-airport-the-story-of-an-la-icon

42 https://lacounty.maps.arcgis.com/apps/webappviewer/index.html?id=acf2e87194a54af9b266bf07547f240a

Context

The Van Nuys Airport (VNY) is a single runway general aviation airport located in the San Fernando Valley, 18 miles northwest of downtown Los Angeles and 7.5 miles west of Hollywood-Burbank Airport (the nearest commercial service airport). It is surrounded by suburban residential housing in all directions, although its immediate environs are buffered by a well-developed industrial district. The airport owns an industrial district west of the north end of the runway and an outcropping on the eastern side where the FlyAway bus service and associated parking are located. The total airport area is only about 1.29 square miles.

Surface Transportation Access

The interstate 405 route runs north/south to the east of Van Nuys Airport. Interchanges connect to Sherman Way and Roscoe Boulevard, the major roads connecting drivers to the airport. Travelers who arrive or depart from the airport have an efficient pathway to the freeway. Moreover, airport access to this section of interstate 405 is close to interchanges with highway 101 and highway 118. Bus infrastructure includes the LAX FlyAway bus that uses the airport as a remote parking depot.

Airport-Specific Elements

Airport Development History

The airport owes present prosperity to military investment. The airport is a former WWII airbase, and it was home to the California Air National Guard (146th Airlift Wing), which flew C-130s. The operating requirements for the C-130s supplied the demand which supplied the basis for the 8000-foot runway, making the airport jet-capable at the start of the jet age. In 1964, Van Nuys was the destination of a demonstration cross-country flight from New York to Los Angeles by Clay Lacey, which established the feasibility of cross-country private jet travel. In combination with proximity to Hollywood, this made Van Nuys an excellent location to base the first charter jet service on the West Coast, Clay Lacey Aviation. The availability of charter aircraft correspondingly has made the airport an attractive location for specialized manufacturing.

Van Nuys
Los Angeles World Airports

Generalized Land Use Categories in the Airport Environs

Figure: 2

- Airport Boundary
- Runways / Taxiways
- Residential (Non-Compatible)
- Residential (Compatible)
- Public Use
- Recreational / Open Space
- Commercial Use
- Manufacturing and Production
- Airport Property
- Vacant, Utility, Transportation
- Water
- River / Streams
- Roads
- Railroad

Basemap: Los Angeles World Airports (LAWA), Southern California Association of Governments (SCAG), Environmental Systems Research Institute (ESRI), United States Geological Survey (USGS)

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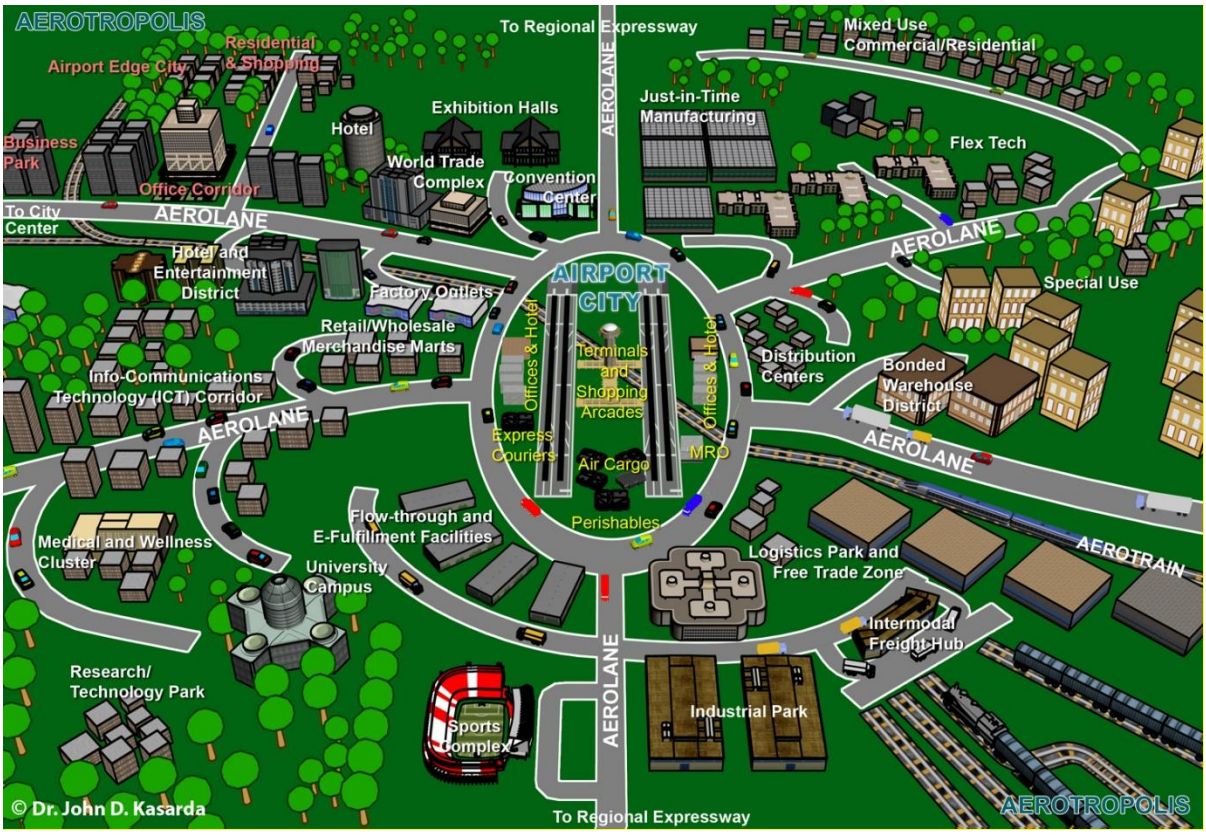
HARRIS MILLER MILLER & HANSON INC.

Aerotropolis/Airport City

The aerotropolis and airport city concepts articulated by John Kasarda [43] suggest a variety of airport-oriented development not only compatible with airports but that also benefit from co-location.



For commercial service airports, capturing part of the value of a supply chain relies on capturing intermodal freight flows between airplanes and truck freight and dray. In contrast, just as general aviation focuses on non-standard passengers, general aviation airports focus on non-standard freight, acting as a centralized depot and distribution center. The industrial district along the airport edge includes distribution centers, e-fulfillment centers, wholesale merchandise marts, and factory outlets, in addition to just-in-time manufacturing, logistics, and medical analysis (including cryopreservation). The airport also offers on-site customs clearance [44]. Uniquely, the airport has added solar panels to most of its buildings, supporting local solar suppliers/maintenance. The airport land-use map on the following page shows the extent of the industrial districts near the airport [45].

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43 Kasarda JD and Lindsay G. (2011) 'Aerotropolis: the way we'll live next'. Macmillan.

44 https://www.aeroplex.net/aeroplexaerolease-group-successfully-manages-launch-new-u-s-customs-facility-van-nuys-airport-2/

45 https://www.lawa.org/-/media/lawa-web/environment/files/chapter_1_introduction.ashx

The Van Nuys Airport (VNY) has managed to build an economic cluster around aviation services. Because the California Air National Guard was based at Van Nuys Airport until 1990, the airport had a longer-than-usual runway. As the private jet market came into existence with the first Learjet and Gulfstreams in the 1960s [46], Clay Lacey Aviation selected it as the location for charter jet services. This in turn led to a high number of based jet aircraft. Consequently, the considerable number of based Gulfstream jets (130) made it an attractive place to have a parts depot for Gulfstream [47]. Later, the presence of this depot made it possible for Gulfstream to relocate its maintenance, repair, and overhaul facility from Long Beach to Van Nuys [48,49,50]. Today, there are over 200 businesses and 5,300 on-airport jobs [51] on 1.29 square miles of airport property.

Clay Lacey Aviation continues to grow and expand the competitive cluster of services. The carbon-intensive nature of air transportation is increasingly well known, and the carve-outs and exceptions once granted are beginning to be withdrawn [52]. Accordingly, developing a greener fuel source for long-distance flights is becoming increasingly economically important. In partnership with World Fuels, [53] Clay Lacy was able to leverage Sustainable Aviation Fuel (SAF) produced by the local Paramount Jet-Fuel Refinery [54], and Van Nuys Airport was one of the first airports in the world to offer SAF, including demonstration flights [55]. While touted as a drop-in fuel, SAF is still novel and has uncertain associated maintenance needs, which makes demonstrated expertise important.

UDOT Goals:

Regarding the UDOT goals of preserving infrastructure, optimizing mobility, and spurring economic development, the Van Nuys Airport (VNY) does well on all accounts.

Preserving Infrastructure

The Van Nuys Airport (VNY) represents decades of cumulative investment in infrastructure. As with all airports, residential encroachment and noise complaints represent a danger to continued operations. While north of the runway end shows signs of a buyout of blocks of homes, compatible land-use

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46 https://en.wikipedia.org/wiki/Business_jet

47https://www.gulfstreamnews.com/en/news/?utm_source=facebook&utm_medium=social&utm_campaign=van-nuys-sc-opening&id=c79a3243-c45f-44ca-894d-2371d7311b36

48 https://www.asdnews.com/news/aerospace/2019/12/11/gulfstream-opens-service-center-at-business-aviation-hub-van-nuys-airport

49https://www.gulfstreamnews.com/en/news/?utm_source=facebook&utm_medium=social&utm_campaign=van-nuys-sc-opening&id=c79a3243-c45f-44ca-894d-2371d7311b36

50 https://labusinessjournal.com/news/2020/oct/29/gulfstream-relocate-employees-van-nuys-airport/

51 https://nbaa.org/aircraft-operations/airports/vny/

52 https://www.ft.com/content/5df5fb54-274b-4078-ba8e-1904d045edb5

53 https://www.globenewswire.com/en/news-release/2021/03/23/2197863/0/en/Clay-Lacy-Teams-with-World-Fuel-Services-and-World-Energy-to-Offer-Sustainable-Aviation-Fuel-SAF-at-Van-Nuys-and-Orange-County-FBOs-Transitions-Ground-Support-Vehicles-to-Renewable.html

54 https://labusinessjournal.com/news/2020/jan/22/world-energy-gets-11-million-state-tax-credit/

55 https://www.lawa.org/news-releases/2021/news-release-013

planning helps mitigate negative effects. This includes the golf course at the south end of the runway and industrial development adjacent to the airport.

Optimizing Mobility

Van Nuys is novel in optimizing surface transportation mobility through the FlyAway bus service which offers direct connections to LAX from a variety of locations while offering long-term parking for five dollars a day. The FlyAway bus from Van Nuys operates 24 hours a day, providing 55 daily departures to LAX [56]. FlyAway provides a direct connection from one airport to another, without the multiple transfers that a comparable journey by transit would otherwise require. (LAX still lacks a rapid transit connection).

Economic Development

Van Nuys Airport promotes economic development in the region in two ways: First by growing the aviation industry within the region, and second, by improving access to business aviation. Van Nuys represents an industrial cluster formed around the seed of a charter aircraft company. The considerable number of based aircraft attracted maintenance firms, and the combination of demand for parts and aircraft attracted manufacturers.

Within general aviation, the term business aviation is often used in preference to the perhaps more accurate corporate aviation—air travel associated with the management of companies. Aviation makes it feasible to disaggregate companies to discrete geographic regions and relocate production and administrative functions to appropriate wage-point locations while maintaining administration and management from a central location. In much the same way that air travel represents a higher tier of costs and speed than travel by automobile, travel by private jet represents a higher tier of travel than by commercial jets. Charter aircraft make the benefits of private jet ownership incrementally available. As an analogy, sending packages by express mail is prohibitively expensive for general application, but may be situationally useful. Charter jet rental extends the productivity-enhancing capacity to more economic actors and results in greater resource productivity for travelers. The availability of charter jet aviation to extend commercial aviation makes locating management capacity within the Los Angeles region more attractive.

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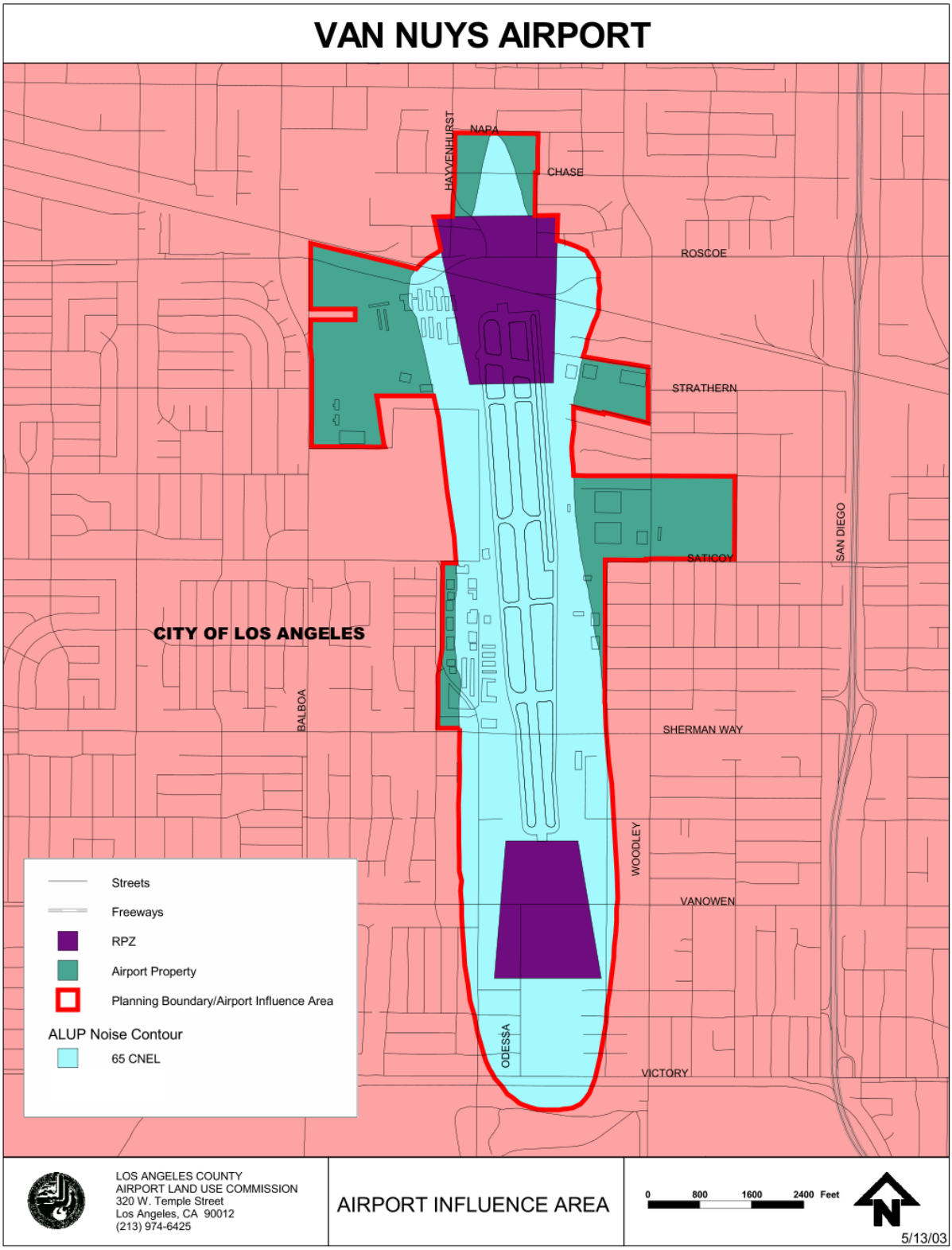
56 https://www.flylax.com/-/media/flylax/pdfs/flyaway/flyaway-brochure.ashx


VAN NUYS AIRPORT
HAYVENHURST
NAPA
CHASE
ROSCOE
STRATHERN
SATICOY
SAN DIEGO
CITY OF LOS ANGELES
BALBOA
SHERMAN WAY
WOODLEY
VANOWEN
ODESSA
VICTORY
Streets
Freeways
RPZ
Airport Property
Planning Boundary/Airport Influence Area
ALUP Noise Contour
65 CNEL
LOS ANGELES COUNTY
AIRPORT LAND USE COMMISSION
320 W. Temple Street
Los Angeles, CA 90012
(213) 974-6425
AIRPORT INFLUENCE AREA
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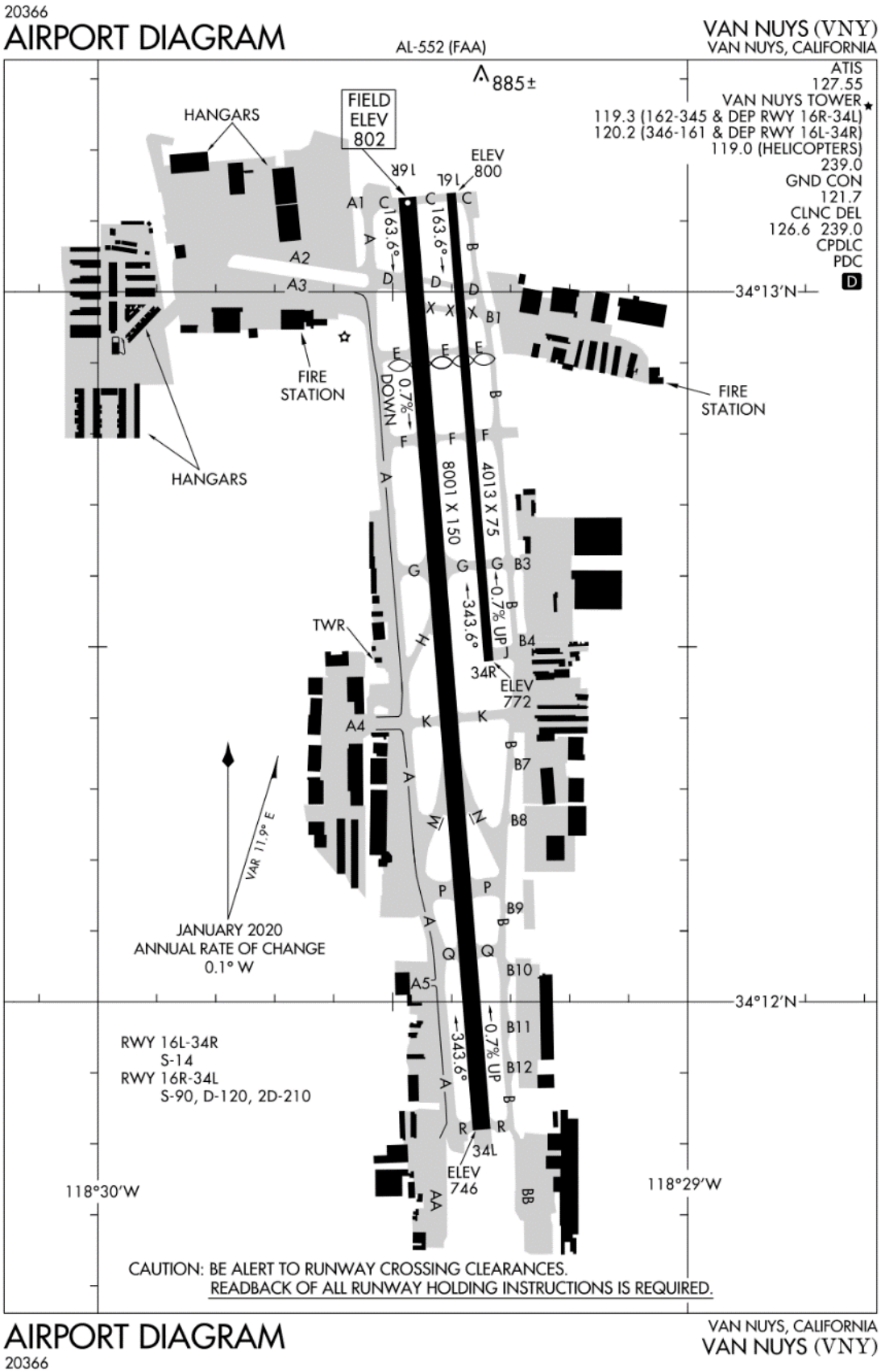
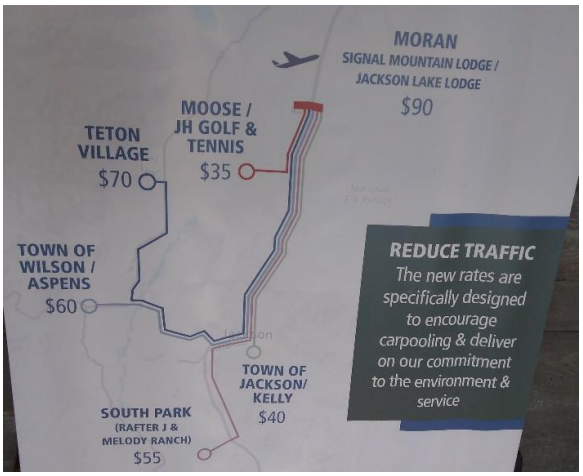

20366
AIRPORT DIAGRAM
AL-552 (FAA)
VAN NUYS (VNY)
VAN NUYS, CALIFORNIA
885±
ATIS
127.55
VAN NUYS TOWER
119.3 (162-345 & DEP RWY 16R-34L)
120.2 (346-161 & DEP RWY 16L-34R)
119.0 (HELICOPTERS)
239.0
GND CON
121.7
CLNC DEL
126.6 239.0
CPDLC
PDC
D
HANGARS
FIELD ELEV 802
16R
16L
ELEV 800
A1
A2
A3
163.6°
34°13′N
FIRE STATION
0.7% DOWN
8001 X 150
4013 X 75
FIRE STATION
HANGARS
TWR
343.6°
0.7% UP
34R
ELEV 772
A4
A5
B1
B3
B4
B7
B8
B9
B10
B11
B12
VAR 11.9° E
JANUARY 2020
ANNUAL RATE OF CHANGE
0.1° W
34°12′N
RWY 16L-34R
S-14
RWY 16R-34L
S-90, D-120, 2D-210
34L
ELEV 746
118°30′W
118°29′W
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.
SW-3, 17 JUN 2021 to 15 JUL 2021
AIRPORT DIAGRAM
20366
VAN NUYS, CALIFORNIA
VAN NUYS (VNY)

7 Case Study – Jackson Hole Airport

Takeaways

The Jackson Hole Airport (JAC) has a unique combination of development restrictions and a resort community environment have led to novel solutions whereby the airport relies on shuttles and taxis to provide surface transportation access rather than on-site parking, and JAC facilitates the additional time requirements associated with transfers by making it more pleasant to wait, so that wait times seem shorter. The airport also leverages that time by using the lobby to 'brand' Jackson in a way that helps generate an identity or brand for the region, unifying the experience of the place. The airport functions as a connected activity center (despite on-site development limitations) by combining a luxuriant lobby/waiting area with excellent taxi/shuttle service.



While only Bullfrog Basin and Hite airports are similarly so constrained to development, the use of the airport as a regional gateway suggests applying the same principles to other Utah airports near recreational areas, such as the Bryce Canyon and St. George Regional airports.

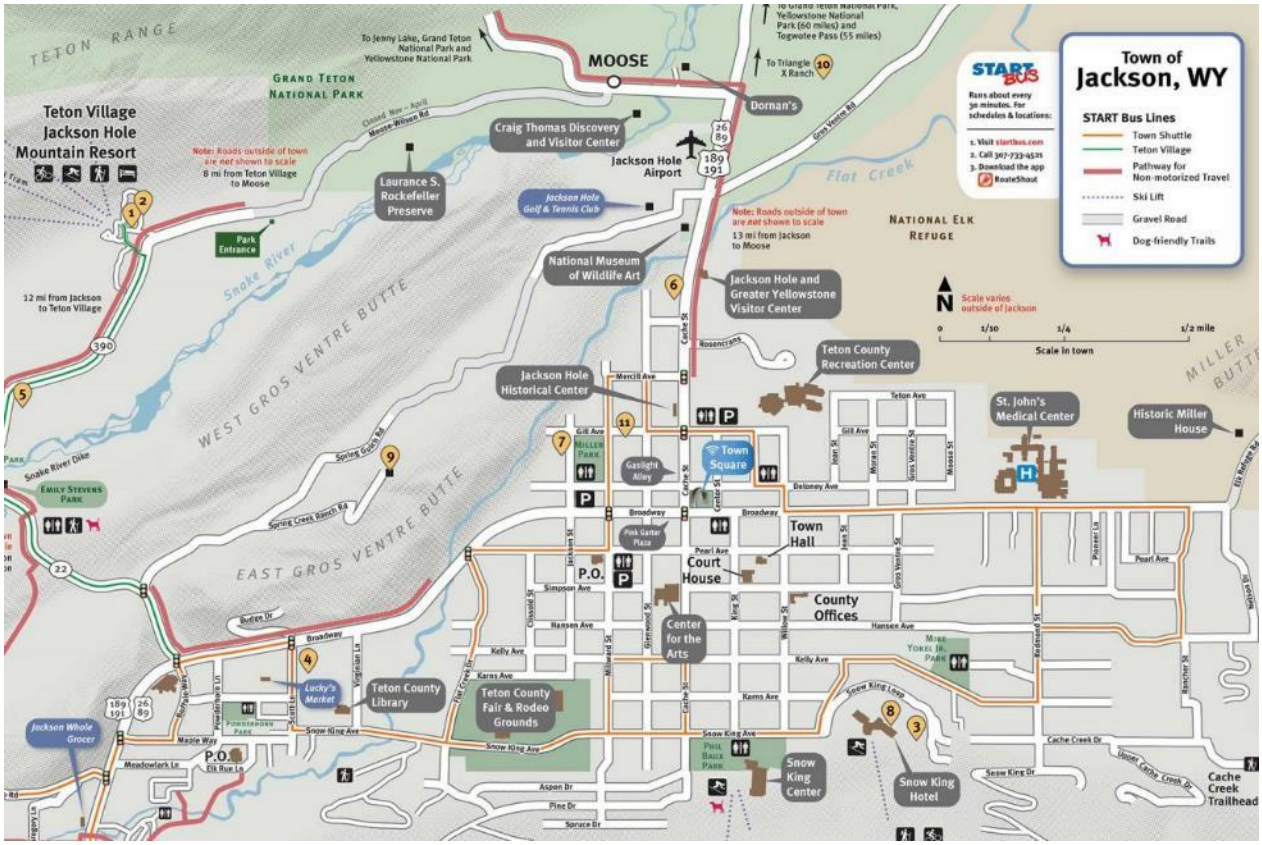
Context

JAC is a commercial service airport located near Jackson, Wyoming, about seven miles north of the center of town. The airport is located south of both Grand Teton National Park and Yellowstone National Park, a short drive to the Jackson Hole Mountain Resort, and a skiing/snowboarding destination. This makes it a reasonable analog for Heber Valley Airport (HCR). Because of its location within a national park, the airport is effectively landlocked, with no capacity to expand its boundaries. Core to the success of the airport is the lack of competition. The airport was originally sited at the best location in the region, and the combination of conservation land and steep slopes rules out a comparably proximate location to the Jackson Hole Mountain Resort. At the same time, the location within a national park limits

development capacity. When the new terminal was constructed, the Park Service limited it to no more than 16 feet in height [57].

Surface Transportation Access

JAC represents a case where the airport functions less as a transportation terminal and more as a gateway node to the region. The airport is neither central within the region nor the area's transportation network. It is located about seven miles north of the center of town, the city of Jackson, along a busy two-lane highway. The airport can act as a connected activity center due to a variety of scheduled and charter transportation services. In addition to rental car services, a variety of charter transportation services operate. Before Uber and other transportation network companies, over 30 registered taxi companies were serving the airport. It seems reasonable to assume that people who arrive by charter aircraft or private jet are not distressed by $70 taxi rides. As a resort town, the area consists of several widely separated areas (Teton Mountain Village,



57 https://en.wikipedia.org/wiki/Jackson_Hole_Airport

downtown Jackson, etc.). With limited space for roadway and parking, the town of Jackson operates shuttles between Teton Village and downtown Jackson, and a town shuttle within Jackson [58]. Hotels also operate shuttles. The airport offers designated waiting places for ride-sharing vehicles.

The effort to reduce the friction of transportation extends to the security cordon. Rather than by TSA (Transportation Security Administration), screening is provided by contract employees under the TSA's Screening Partnership Program (SPP) [59]. While not universal, at Jackson Hole Airport, this resulted in an attitude that was manifestly more customer focused.

Airport-Specific Elements

Both Node and Place

The second element that acts to help make JAC a connected activity center is the nature of the structure itself. While all terminals are liminal spaces, Jackson Hole Airport is an excellent place to wait. Despite its small size, it contains restaurants, a gift shop, and several food carts. Further, it is beautiful. Despite strenuous design limitations (16' height limit), the interior space is an architecturally award-winning design, as well as having LEED-certified status [60]. The airport is wood-paneled and warm-toned [61], containing both décor and artwork that references regional motifs.

The airport serves a role as the community's gateway for high-spending visitors. Accordingly, the airport operates as the lobby for visitors entering and exiting the region. The lobby between the curb and the security cordon is beautiful and inviting, like that of a first-class hotel. Because the airport is entirely a destination airport, rather than a hub airport focused on transfers, there is minimal need for passengers to linger inside the security cordon. Accordingly, the airport has been free to lavish funding on the areas outside the cordon. In recognition that taxi and shuttle-dependent passengers may spend a larger-than-average time waiting outside of the security cordon, the lobby has been enriched by design and amenities to

58 http://www.jacksonholetraveler.com/article/jackson-hole-map/

59 https://www.aviationpros.com/home/news/10402682/tsa-awards-jackson-hole-airport-board-private-screening-contract

60 https://clbarchitects.com/projects/jackson-hole-airport-expansion/

61 https://clbarchitects.com/wp-content/uploads/2015/06/02-CLB_Arch-JacksonHoleAirport-0154-1680x1194.jpg

ensure it remains a pleasant and comfortable environment. Partially, this enrichment is possible because the Jackson Hole Airport enjoys a unique and higher-income clientele.

Parking

The Jackson Hole Airport has a limited and non-expandable footprint. The 2015 conceptual development plan calls for increased development of hangars, suggesting that less on-airport parking will be available in the future [62]. The US Forest Service-mandated height limit means that the airport mainstay of developing an above-ground parking garage is impossible. A sub-surface garage would require costly drainage and humidity control, with an estimated cost of $40,000 per stall [63], and a combination of an on-site transit center and remote parking as an alternative.

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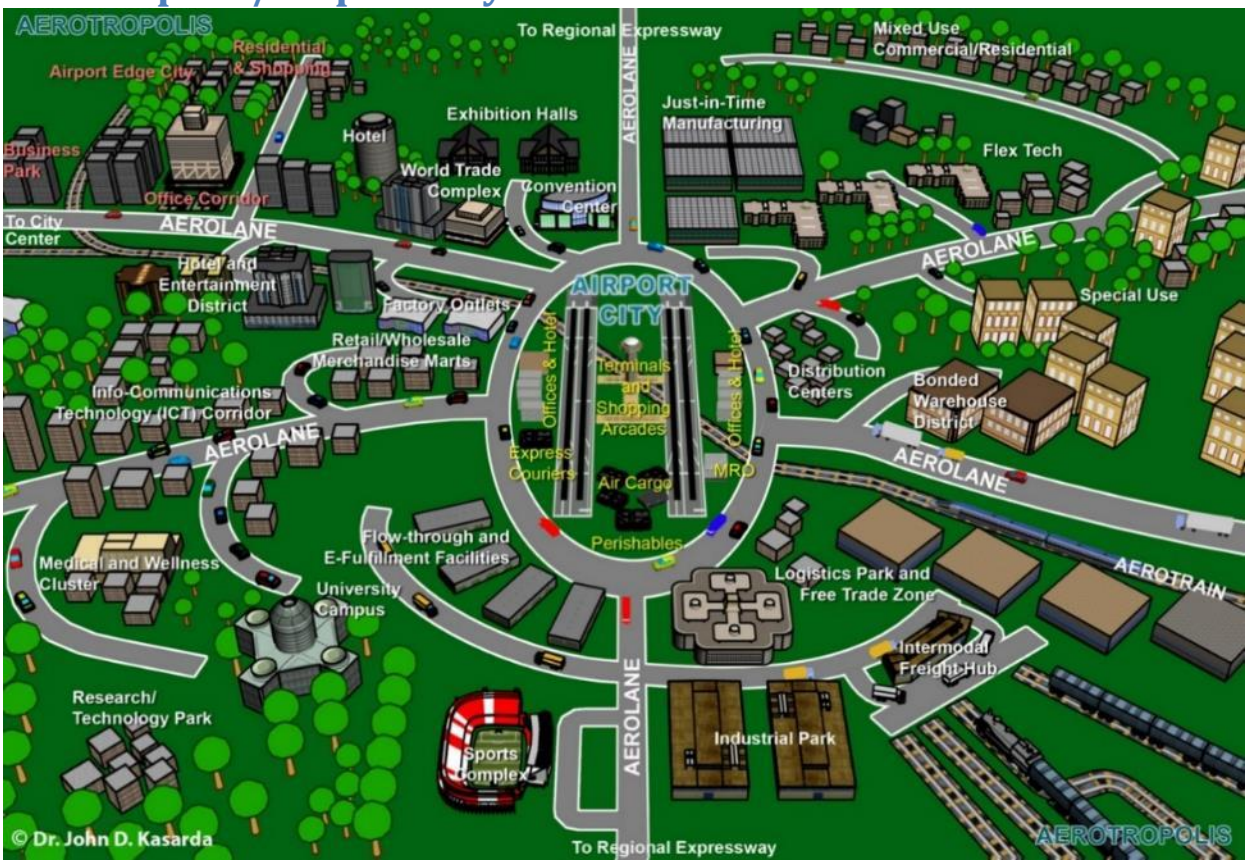
62 https://www.jacksonholeairport.com/wp-content/uploads/2019/03/JAC-Conceptual-Area-Dev-Plan-2015.pdf

63 https://www.jacksonholeairport.com/wp-content/uploads/2019/03/JAC-Conceptual-Area-Dev-Plan-2015.pdf

Aerotropolis/Airport City



Jackson Hole Airport is a small airport, so the connection to Kasarda's Aerotropolis model was limited. The only associated development types are hotels, residential and shopping, and mixed-use commercial/residential.

UDOT Goals:

Preserving Infrastructure

As Jackson Hole Airport provides a gateway to the region's beautiful natural landscapes and sights, preserving the pristine infrastructure around the airport is key. As the airport is located away from the city center of Jackson, residential encroachment does not seem to be an issue. Additionally, with strict development procedures, preserving the infrastructure around Jackson Hole Airport is done through means of efficient surface transportation.

Optimizing Mobility

As JAC airport is more of a gateway node to the region, surface transportation access is unique. A rental car facility is located at the airport and provides easy car access for travelers. Ridesharing has also become a popular means of getting travelers to and from the JAC airport. Hotel shuttle services are also available to and from the airport.

Economic Development

Economic development around the airport is facilitated through the tourism sector in the region. Numerous outdoor activity sites such as snowboarding/skiing facilities, hiking trails, resorts, and national parks help bring business and economic activity to the area. The airport facilitates access to those amenities, which encourages second-home buying.

8 Case Studies – Phoenix-Mesa Gateway Airport

Takeaways

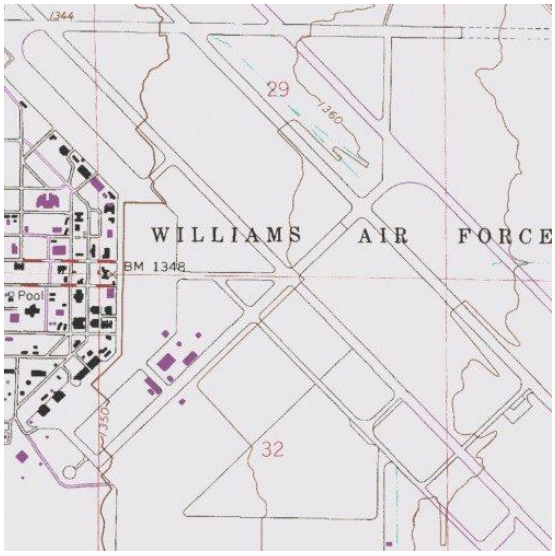
The Phoenix-Mesa Gateway Airport is effectively leveraging its initial endowment of a surplus military airbase to create an economic cluster combining aviation-related employment and industries. It is overcoming the regulatory limitations that otherwise hamper the creation of tightly integrated US/Mexican/Latin American manufacturing supply chains able to depend on reliable air transportation. A combination of infrastructure investments and developable land near the airport makes it an attractive place to grow and develop. Problematically, the airport is failing to consider the long-term impacts of residential development and envelopment on landside transportation access and airport development potential.

The airport was selected as a case study as a proxy for an integrated airport/aviation cluster including both aviation-related businesses and aviation-dependent businesses. The airport functions as a connected activity center by directly integrating institutional development into buildings literally across the street from the airport. Reference airports in Utah include the Ogden and Provo airports. All are non-hub commercial service airports sited in the 'passenger catchment area' of a large hub airport, with similar population sizes, passenger enplanements, and a substantial student population nearby. Provo Airport might apply a similar strategy to inducing a community college or university to co-locate a special technical college focused on aviation next to the airport in coordination with a fixed-base operator.

Context

Phoenix-Mesa Gateway Airport (AZA) is a commercial service airport located in the city of Mesa, about 30 miles southeast of Phoenix and 20 miles east of Sky Harbor International Airport.

The airport was developed as an activity center to counter the closure of Williams Air Force base, which preceded it at the same location. When Williams Air Force Base opened in 1941, the airfield was a remote facility far to the east of the Phoenix-Mesa urbanized area. Consequently, it was built to contain base housing for officers and enlisted soldiers. After being closed through the Base Re-Alignment and Closure (BRAC) process, efforts were made to hand off the airbase facilities to responsible local institutions. The airfield itself became an airport, and the airbase facilities were transferred to Chandler-Gilbert Community College and Arizona State University. A former history as an airbase means that aviation-oriented businesses located at the airport enjoy substantial federal tax advantages, further bolstered by Arizona's Private Activity Bond program [64].



64 https://www.selectmesa.com/business-districts/mesa-gateway-area

Surface Transportation Access

Freeway access is provided by the 202 Freeway and the Power Road interchange northwest of the airport. There is no fixed guideway transit, and a single bus route (184 Power Road) accesses the airport. Despite the presence of a new interchange (Highway 24) to the northeast of the airport, the airport has no connectivity on three sides: the only access is from the west. Historically, the main access was along Williams Field Road, an arterial/highway running ten miles from Chandler, Arizona. The access loop function, a characteristic of larger airports, is provided by Sossaman Road. The road follows the hangars and airfield structures and is shaped as three sides of an octagon, wrapping the former base facilities to the west. Roadway connections originally present as part of the street grid of the base, have been severed to aid this function. Closing those streets has also reduced traffic passing through the Arizona State University (ASU) Polytechnic campus. The historic base access, via Williams Field Road, terminates at the western edge of the ASU campus, becoming part of an internal loop road named Innovation Avenue. Many of the former base roads have been closed to automobile traffic and are used as pedestrian malls, creating a human-scaled campus within walking distance of the airport. Kent Street forms the de facto boundary between the University campus and airport-oriented facilities such as rental car lots and Embry-Riddle Aeronautical University. The area north of Innovation Avenue is largely allocated to Chandler-Gilbert Community College.

Airport-Specific Elements

Integration with Educational Institutions

The proximity of the universities and community colleges has been leveraged through an array of aeronautically oriented facilities. There are no less than four education institutions within the bounds of the former airbase: ASU Polytechnic, Gilbert-Mesa Community College, Embry-Riddle Aeronautical University, and the East Valley Institute of Technology. All provide some form of aviation-related education. The Polytechnic offers an array of four-year and post-graduate degrees [65]. Gilbert-Mesa Community College offers two two-year degrees and several certificates in aviation maintenance and technology [66]. Embry-Riddle offers a variety of aviation-related degrees at the associate, bachelor, master, and Ph.D. levels [67]. The ASU campus includes the Simulator Building, which hosts the Haas

65 https://poly.engineering.asu.edu/aviation/

66 https://www.cgc.edu/Academics/aviation/Pages/Aviation-Program.aspx

67 https://worldwide.erau.edu/locations/phoenix-mesa

Technical Center. The campus also includes the Ira A. Fulton School of Engineering, which engages in a variety of projects as well as applied research. The residential portion of the college also hosts a community focused on aviation. Many colleges offer degrees or certifications related to Unmanned Aerial Vehicles (UAVs), in terms of operation, maintenance, or design.

As a residential college, the ASU Polytechnic is also a consumer of air services. There is currently a residential capacity of 10,000 students with a planned increase to 20,000 students. Allegiant Airlines provides low-cost no-frill service and is located across the parking lot from the campus, making it an attractive alternative to Sky Harbor for out-of-state students.

On-Airport Employment

Reciprocal to the numerous training programs and degrees being offered near the airport are potential proximate employers. This includes Textron Aviation (an aviation manufacturer) [68], Embraer Executive Jets [69] (jet rental and leasing), Gateway Aviation (FBO) [70], and Able Aerospace Services (repair and refit) [71], as well as Aerocircular and Constant Aviation [72]. The city of Mesa has been proactive in funding the construction of additional facilities at the airport, including both hangars and offices. This proved a key element in supporting the expansion of Able Aerospace Services, which has added over 200 employees in the past five years [73]. Hot, dry air makes many Arizona airports attractive places to store aircraft. Consequently, this has made Arizona an attractive location to repair, restore, and retrofit aircraft.

Research and Development

The airbase was the home of the Air Force Research Laboratory; the city leased the property in 2011, assumed ownership in 2014, and then leased it to Danan Technologies [74]. Currently, it provides DoD-(Department of Defense) oriented facilities (offices, labs, vaults) for experiments and prototype evaluation in a secured environment [75]. It is located between Sossaman Road and Innovation Way, directly adjacent to the airport. The City of Mesa has several regional economic development initiatives attempting to leverage proximity to the airport including high-quality fiber connections and low-cost water, resulting in the development of nearby data centers.

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68 https://txtav.com/

69 https://www.ainonline.com/aviation-news/business-aviation/2015-11-13/embraer-executive-jets-celebrates-10-years

70 https://www.gatewayfbo.com/

71 http://www.ableengineering.com

72 https://www.selectmesa.com/business-districts/mesa-gateway-area

73 https://azbigmedia.com/business/economic-development/skybridge-development-launches-phx-east-valley-into-the-stratosphere/ac

74 https://www.selectmesa.com/business-districts/mesa-gateway-area/azlabs

75 https://danantechnologies.com/azlabs-%2F-city-of-mesa

Sky Bridge Arizona

Phoenix-Mesa Gateway Airport (AZA) is home to a free trade zone, similar to an inland port, with duties deferred on imports and exempted on exports [76]. The zone is being leveraged to create an international air cargo hub, intending to facilitate shipments between the US and Mexico. Known as the Unified Cargo Processing Program, Mexican customs officials will be on site, allowing shipments to pre-clear customs upon leaving the airport and making it possible to avoid a stopover in Mexico City [77]. Ryan Smith, communications director for the airport, suggested that it can sometimes take several weeks for shipments to clear customs without the Unified Cargo Processing Program. Reliable transportation access between the two countries will likely have significant impacts on cargo volumes. The plan is to leverage these new functions and facilities to develop a large new business park (350 acres) along the southern quadrant of the airport [78]. The business park will include warehouse space, office space, light industrial, retail and restaurants, and it is expected to significantly increase cargo flights in and out of the airport [79]. Substantial investments were made to local infrastructure a decade ago, and substantial investments in airfield facilities have been made more recently [80].

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76 https://www.selectmesa.com/business-environment/incentives-programs/mesa-foreign-trade-zone

77 https://azgovernor.gov/governor/news/2018/01/skybridge-arizona-marks-new-era-cross-border-commerce

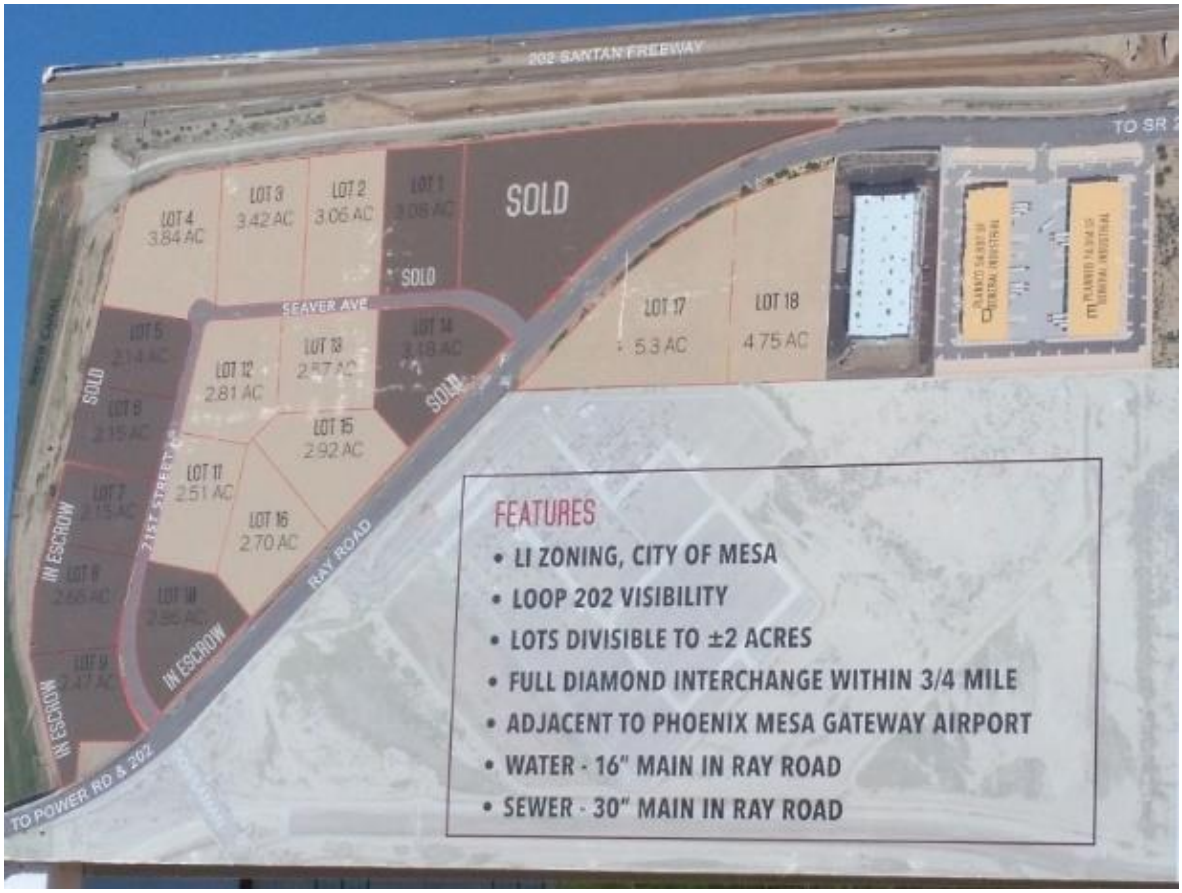
78 https://www.choosegatewayairport.com/sitecontent/skybridgearizona.pdf

79 https://azbigmedia.com/business/economic-development/skybridge-development-launches-phx-east-valley-into-the-stratosphere/

80 https://azbigmedia.com/business/economic-development/skybridge-development-launches-phx-east-valley-into-the-stratosphere/ac

Collaborative Planning

While the initial planning of the airport was collaborative, such is no longer the case. While planners are active and engaged in planning on-airport development, engagement with the rest of the metropolitan area is lacking beyond attempts to ensure non-conflicting uses. The metropolitan area has been expanding toward the airport for decades but has reached the point where it has begun to envelop the airport [81]. Obvious signs of new residential subdivisions can be found east of Ellsworth Road, the airport's eastern border. Potential homeowners have been warned of airport proximity through an attachment to deeds, but the interface has not otherwise been considered. Thanks to the proximity to the 202 freeway, north of the airport the land is being developed as light industrial and warehousing. While proximity to the airport is advertised, the synergy between the airport and future warehouses is doubtful. The last master plan for the airport was completed in 2009 with a new plan currently under



development [82].

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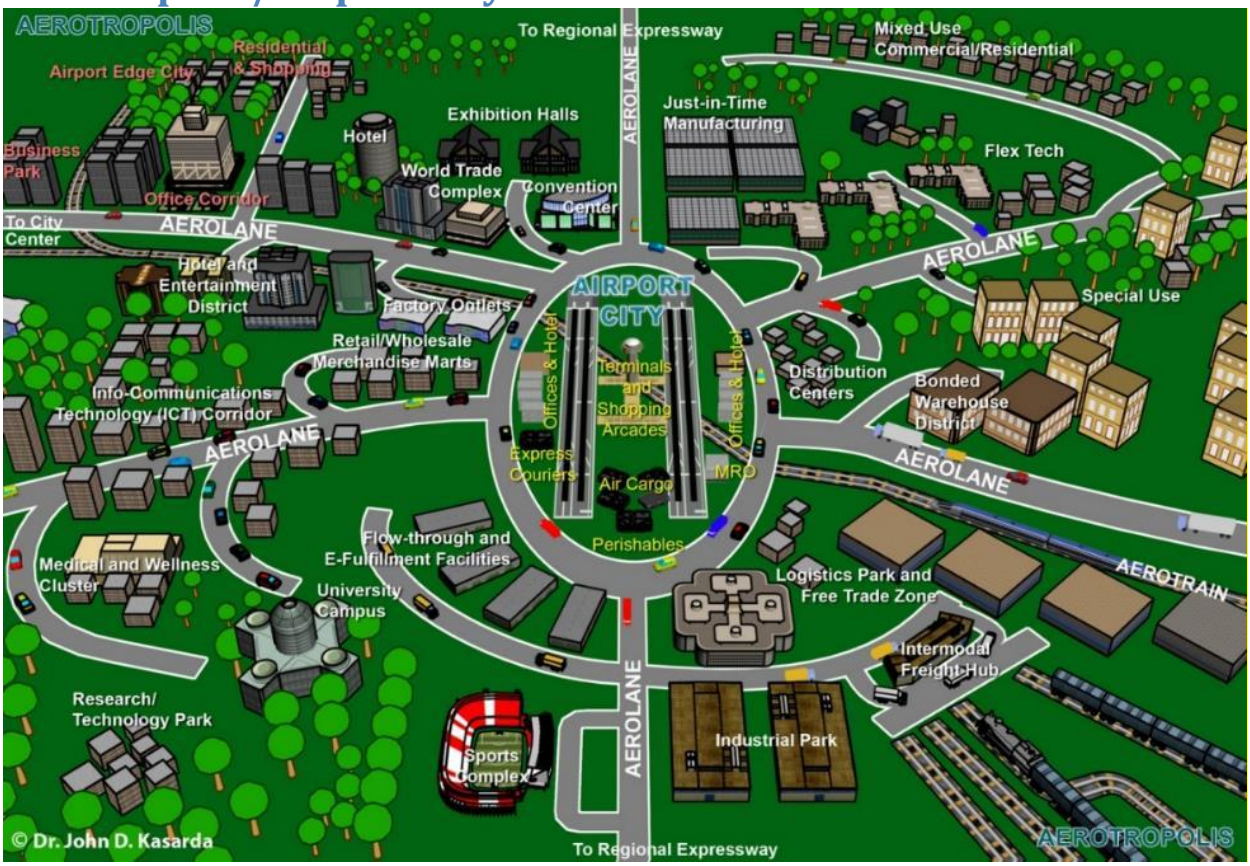
82 https://pmgaamasterplan.com/

Aerotropolis/Airport City



Looking at Kasarda's Aerotropolis model highlights many aspects of the Phoenix-Mesa Gateway Airport that share similarities. Aspects of the aerotropolis model seen at this airport include; **distribution centers** (directly north of the airport), **retail/wholesale merchandise markets** (northwest of the airport there are large stores such as Target and Walmart), a **medical and wellness cluster** (below the large retail markets are a large hospital, surgical clinic, dentist, and health center), a **university campus** (Arizona State University Polytechnic campus is located right beside the airport to the left), as well as a **logistics park and free trade zone** (directly north of the airport).

UDOT Goals:

Preserving Infrastructure

The Phoenix-Mesa Gateway Airport represents decades of cumulative investment in airport infrastructure. Ensuring the long-term viability of the airport in the face of resident opposition requires present planning for both the protection of runway-end safety areas and compatible land-use planning. In the northwest, the airport has shifted the road network to accommodate the safety area. The airport and its sponsor have been proactive in designated areas for logistics/distribution centers near the airport, creating a buffer around the airport.

Optimizing Mobility

Airports are best understood as access nodes for the air transportation network. As a commercial service airport, Phoenix-Mesa Gateway Airport provides an additional node for passengers. Rather than

forcing all travelers to pass through a single central point (Sky Harbor), it offers a closer, more convenient access point for the southeastern portion of the metropolitan area.

While the runway protection zones to the northwest and southeast force diversions of the surface streets to the north of the airport (Ray Road) and the south (Pecos Road), street grid connectivity has been maintained, easing travel along and past the airport. Surface street access to the north of the airport has been maintained by preparing for an underpass (Hawes Road) through the new Gateway Freeway interchange, thus maintaining access to the northeast side of the airport despite the barrier posed by the San-Tan and Gateway freeways.

In addition to the regular grid of surface streets, Sossaman Road threads between the terminal facilities and the old Air Force Base, providing direct access that connects to the street network at both ends, rather than terminating at the airport.

Economic Development

The Phoenix-Mesa Gateway offers two things that Sky Harbor does not: 1) developable land near a passenger airport with good freeway access, and 2) higher educational institutions within walking distance of the airport. Accordingly, it is attracting merchandise marts and research/technology firms to the area near the airport. It is also well positioned for employers (such as Able Aerospace) wishing to co-locate with skilled trades labor emerging from the community college and Arizona State University Polytechnic.

9 Case Study – Charlotte Douglas

Takeaways

Charlotte Douglas International airport (CLT) was investigated because of the presence of the Norfolk-Southern Intermodal Terminal on airport property as a comparable to the Utah Inland Port near Salt Lake City International Airport. On-site interviews suggested the actual rationale was less for freight integration and more a matter of convenient co-location made possible by an excess of airport property [83] and an attractive location for truck access. Salt Lake City International might benefit from trucking facilities near the inland port for the same reason.

83 https://www.airportprojects.net/clt-capacity-ea/

However, the site visit revealed the extensive development along the eastern fenceline of the airport. In addition to typical general aviation uses and air-cargo development, there was a substantial corporate aviation presence (Duke Energy) as well as a military presence, with both Air National Guard and National Guard tenants at the airport edge. An interview with the National Guard suggested that the location was chosen because the airport fenceline location was valuable by helping provide a secured perimeter. In the future, airports such as St. George regional might recruit security-conscious tenants such as the Utah National Guard Armory.

The airport shows signs of spatial disaggregation, having bought up a wide range of parcels near the airport but outside the airport boundary. Most of the parcels are used for parking, but aviation-related businesses (freight, logistics, and courier services) are also located on these parcels.

Context

Charlotte Douglas International airport (CLT) is located about five miles west of downtown Charlotte, near the intersection of I-85 and the I-485 beltway. Near the eastern edge of the airport is another limited-access highway, the Billy Graham Parkway (functionally an inner beltway [84]) which connects to I-77. On the north edge of the airport is a rail line. The airport has three parallel runways (with a fourth in planning), and one crosswind runway planned for eventual elimination. It is a hub for American Airlines, and the location of the American Airlines Flight Training Center and Maintenance Training Facility.

While the City of Charlotte has a light rail system, the airport lacks a rapid transit connection, although the West Corridor/Lynx Silver line is in planning [85]. Recent changes to the FAA (Federal Aviation Administration) Passenger Facility Charge Program may help advance this planning [86,87]. The airport is one of the top-ten busiest airports in the United States, primarily as a transfer airport, with 70% of enplanements not leaving the airport [88]. Parking, especially long-term parking, supplies a substantial amount of airport revenue, which enables the airport to reduce landing and gate fees, which has likely aided the growth in aviation activity.

Surface Transportation Access

Charlotte Douglas International Airport has immediate access to numerous freeway systems near the airport. These freeways include interstate route 485, and interstate route 85. These freeways connect to other road networks in the region. Josh Birmingham Parkway connects travelers to the multiple long-term parking options that CLT airport offers. Josh Birmingham Parkway also connects inbound and outbound travelers to the arrivals area and departure gates located at the terminal. Numerous rental

84 https://en.wikipedia.org/wiki/Charlotte_Route_4

85 https://en.wikipedia.org/wiki/Lynx_Silver_Line

86 https://www.faa.gov/airports/pfc/pfc_updates/media/pfc_75_21_rail_access_policy.pdf

87 https://www.faa.gov/airports/pfc/pfc_updates/media/pfc_75_21_rail_access_policy.pdf

88 https://www.youtube.com/watch?v=oJa4yZLU1t4&t=428s

car companies such as Budget, Hertz, Avis, Enterprise, etc., are located at CLT airport and provide transportation for travelers. Multiple shuttle services are provided at CLT airport. The Charlotte Area Transit System's (CATS) Sprinter bus provides frequent and efficient transportation to Charlotte Douglas International Airport and center-city Charlotte.

Airport-Specific Elements

Intermodal Terminal

Fifteen years after it was first envisioned, Norfolk Southern broke ground on a new 200-acre intermodal terminal on airport grounds to replace a previous space-constrained 40-acre terminal located in downtown Charlotte [89]. The new terminal has space for 1,300 trucks and has an anticipated capacity of 200,000 cargo containers per year [90]. The development was part of the broader Norfolk Southern 'Crescent Corridor' initiative [91] "aimed at providing truck-like intermodal service to shippers looking to reduce transportation costs and carbon emissions" [92] in response to a "faster network for domestic intermodal traffic to move between the Northeast and the Southeast" for truck shipments of over 550 miles [93]. The strategy was based on an analysis of truck origin-destination pairs and focused on the most lucrative flows. While not aviation-oriented, pairing the intermodal center with the construction of a new runway helped defray the cost of both [94]. Plans include leveraging the presence of three modes of transportation (truck, rail, and air) to attract distributors and specialized supply chain companies [95]. A strategic development plan has the goal to "position Charlotte as the fourth major logistics hub on the East Coast of North America by consolidating all major logistics functions at the airport to increase efficiency and reduce urban truck transfer traffic" [96].

Fenceline Development

Charlotte Douglas International Airport has a much longer fenceline than the perimeter of the airport suggests, thanks to the extensive development between runway 18/36C and 18/36L (south of the terminal). The area is associated with status as an American Airlines hub and flight training for maintenance, but there is also substantial air cargo: USPS, Delta Cargo, a USPS ship center, and Amazon Prime Air. Uses along Airport Drive, along the eastern fenceline include Wilson Aviation (a major FBO), Duke Energy, the Air National Guard, and substantial amounts of corporate aviation, such as Bank of America. Along the southeast corner of the airport lies the North Carolina National Guard. Just across West Boulevard along Horseshoe Lane is a pod of warehouses and distributors. Similar clusters of expediters, couriers, specialized manufacturing, freight forwarders, logistics, and wholesale warehouses exist along Yorkmont Road beyond the airport's southern boundary. The Norfolk Southern rail line provides a barrier along the northern edge of the airport, eliminating the potential for fenceline

89 http://www.nscorp.com/content/nscorp/en/news/norfolk-southernsnewcharlotteregionalintermodalfacilitywillsuppo.html

90 https://www.wbtv.com/story/24406309/norfolk-southern-shows-charlotte-airport-yard/

91 https://coe-sufs.org/wordpress/ncfrp44/44-freight-mode-shifts-case-studies/44-selected-case-studies/44-the-crescent-corridor/

92 https://www.joc.com/rail-intermodal/class-i-railroads/norfolk-southern-railway/ns-enhances-intermodal-service-new-charlotte-terminal_20131211.html

93 https://www.joc.com/rail-intermodal/class-i-railroads/norfolk-southern-railway/ns-enhances-intermodal-service-new-charlotte-terminal_20131211.html

94 https://www.aviationpros.com/airports/airports-municipalities/article/10370969/charlottes-intermodal-hub

95 https://downloads.ctfassets.net/jaw4bomip9l3/7uXSM106WtPJ97O4b41D4Z/d9213e2d85d9959c3087e88b66487834/CLT_ACDS_-_FINAL_Website_Size.pdf

96 https://www.aviationpros.com/airports/airports-municipalities/article/10370969/charlottes-intermodal-hub

development, but the area between the rail line and I-85 is developed in a mix of parking, freight/and warehousing, and business hotels. The airport fence line is leveraged to provide a secure perimeter to a variety of security-conscious clients (National Guard, corporate aviation, etc.). The airport manages to develop not just along the fenceline, but also on roads connecting to airport peripheral roadways, thus substantially increasing the area available for development.

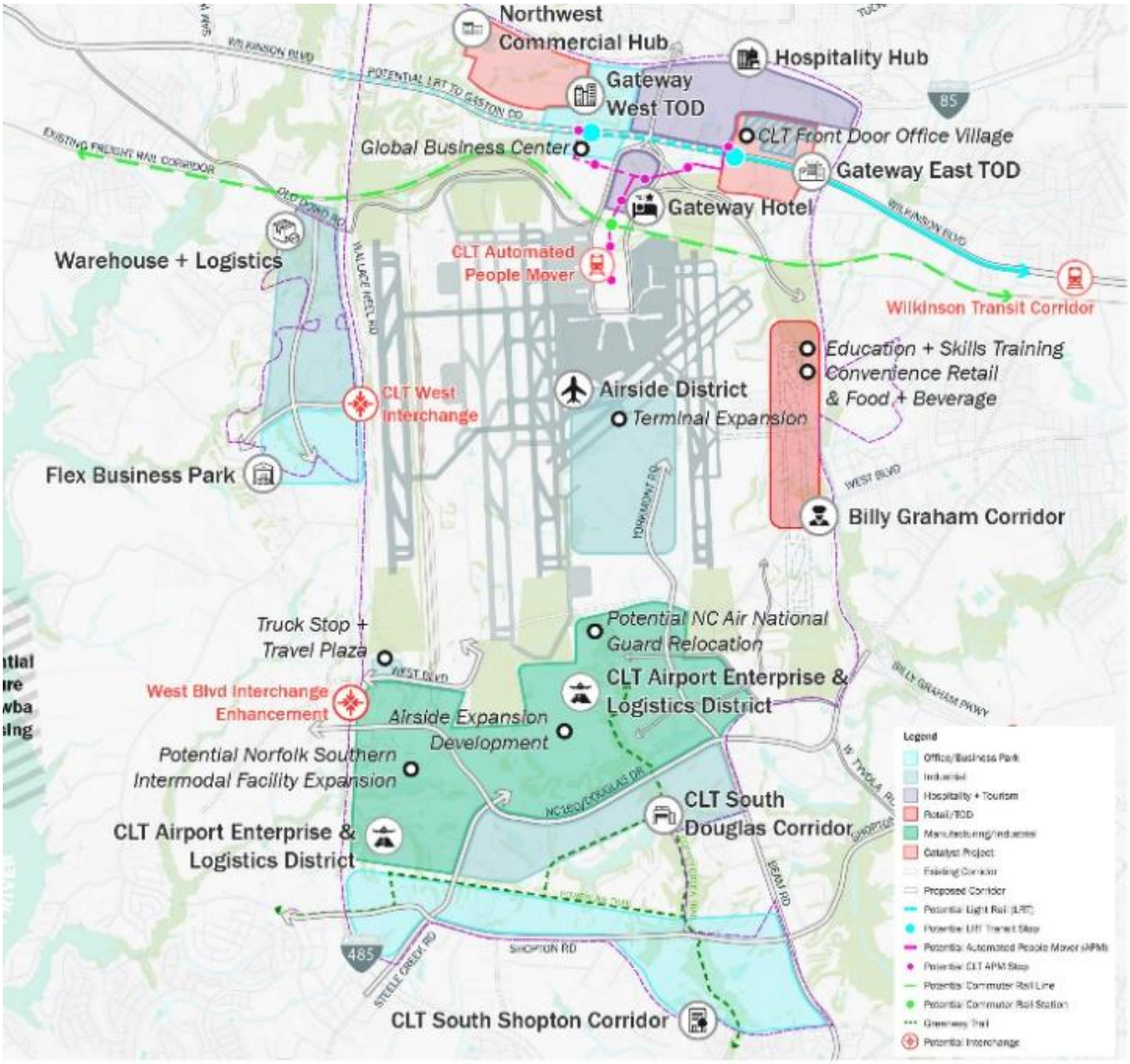
Airport Land-Use Planning

Charlotte Douglas International (CLT) has an Airport Area Strategic Development Plan intended to generate revenue, put underutilized airport property to use, and ensure land-use compatibility around the airport. One of the focuses of the airport master plan is to "attract businesses such as manufacturing, warehousing, transportation, trucking, distribution, R&D, and data to the available 6,000 acres of land that surrounds the Airport" [97]. The associated Charlotte Douglas Airport Commercial Development Strategy maps what land uses were planned to be attracted to which districts and details the infrastructure improvement necessary and appropriate to facilitate private-sector development of airport properties [98]. The report provides a comparison of other airport-connected development at other major airports, time-distances appropriate for different land use, and catalytic surface

DEVELOPMENT DISTRICT METRICS	TOTAL ACRES
Total acres identified	4,914 AC
Acres after screen	3,654 AC
Acres owned by CLT	1,695 AC
Vacant acres owned by CLT	**894 AC**
Acres considered for ownership by CLT	721 AC
Vacant acres considered for ownership	**342 AC**
Acres not owned by CLT	1,238 AC
Vacant acres not owned by CLT	124 AC

97 https://www.cltairport.com/community/commercial-development/strategic-plan/

98https://downloads.ctfassets.net/jaw4bomip9l3/7uXSM106WtPJ97O4b41D4Z/d9213e2d85d9959c3087e88b66487834/CLT_ACDS_-_FINAL_Website_Size.pdf



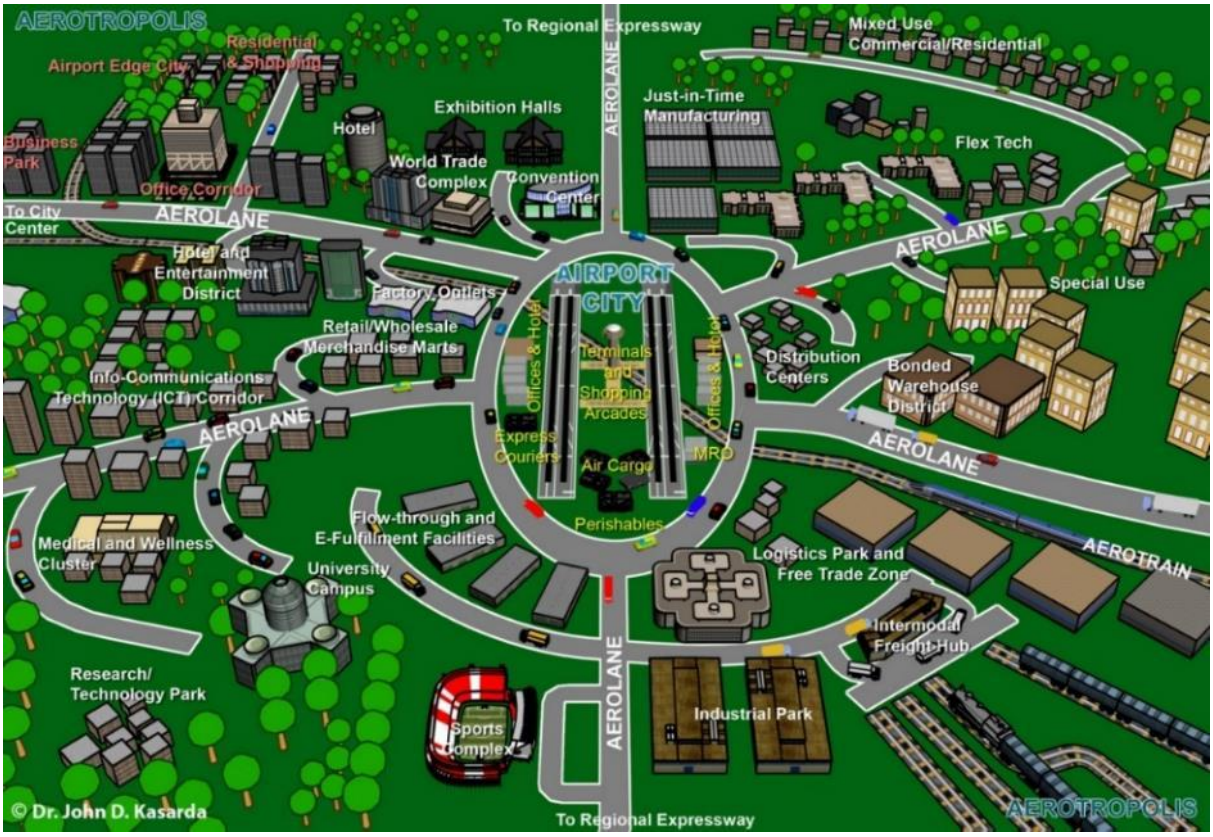
transportation investments necessary for the development of each district. Implementation requires the relocation of some on-airport tenants and re-orienting of the 'gateway' area north of the airport as an activity center intended to hold airport administration and conference facilities and connected to the terminal by a people mover. The south district (where the Norfolk Southern intermodal terminal) is planned to attract manufacturers, distributors, and specialized supply chain companies in the aviation, automotive, and retail fulfillment sectors, and it is intended to leverage the airport's foreign trade zone status as part of a broader enterprise and logistics district. Planned renovations require removing West Boulevard, a circumferential airport highway, and replacing it with a new corridor one mile further south to provide room for a temperature-controlled logistics facility [99]. Such long-term planning is possible

99 https://downloads.ctfassets.net/jaw4bomip9l3/7uXSM106WtPJ97O4b41D4Z/d9213e2d85d9959c3087e88b 66487834/CLT_ACDS_-_FINAL_Website_Size.pdf

because the airport owns considerable land outside the airport boundary and is considering purchasing much of the remaining undeveloped land.

Aerotropolis/Airport City

When it comes to airport development, the aerotropolis model is inescapable, and Charlotte-Douglas International Airport is no exception [100]. The aerotropolis and airport city concepts [101] suggest a few land uses that should be developed in proximity to the airport.



100 https://www.linkedin.com/pulse/clt-airport-burgeoning-aerotropolis-charlotte-region-galles/

101 Kasarda JD and Lindsay G. (2011) 'Aerotropolis: the way we'll live next'. Macmillan.

An analysis of the development near Charlotte Douglas International Airport shows that many are present, suggesting that the airport is developing as a connected activity center in the airport city model. Land uses suggested but omitted include refrigerated perishables, just-in-time manufacturing, a hotel/convention center, exhibition halls, an information technology center, and flexible tech spaces. The absence of the convention center, entertainment district, sports stadiums, and exhibition halls can be explained by the airport's proximity to the central business district only six miles away. Just-in-time manufacturing is incorporated within other activities (such as logistics and warehousing) but is scattered across the metropolitan area and is not strongly associated with the airport. The regional research park is located near UNC Charlotte, northwest of the Charlotte CBD. Altogether, this suggests that airport development as a connected activity center is in tension with an existing activity center. While the airport is capable of attracting depot functions (warehouses, distribution centers, e-commerce, merchandise marts, etc.), competition means it has not been able to attract core central place functions associated with the concentration of people rather than goods. The airport has not been able to develop as an 'edge city' with an endowment of commercial office and residential, likely due to the lack of nearby executive housing. The Eagle Lake business district (a mile from the airport) has a substantial amount of office development, but not the full degree.

Elements	Status
Aerolanes	NA
Aerotrains	(Planned)
Offices/Hotel	1 mile away
Express Couriers	On Airport
Airport MRO	On Airport
Air Cargo (Perishables)	NA
Convention Center	NA
Just-in-Time Manufacturing	NA
Distribution Centers	3 miles way
Logistics park & Free Trade Zone	On-Airport
Flow-through & E-Fullfillment Services	2 miles away
Retail/Wholesale Merchandise Marts	3 miles away
Factory Outlets	4 miles away
World Trade Complex	On AIrport
Convention Center	NA
University Campus	1 mile away
Hotel & Entertainment District	NA
Exhibition Halls	NA
Research/Technology Park	NA
Information Technology Ccluster	NA
Flex Tech	NA
Bonded Warehouse District	2 miles away
Sports Complexes	Downtown
Intermodal Freight Hub	On Airport
Industrial Park	2 miles away
Mixes use Commercial/Residential	NA
Airport Edge Cities	NA
Business Park	1 mile away
Hotel & Entertainment District	Downtown
Medical/Wellness Cluster	NA

While there is a Foreign Trade Zone at the airport [102], the Charlotte Inland Port (with a direct rail connection to the Port of Wilmington) is associated with the CSX double-stack line and intermodal terminal [103] rather than the Norfolk Southern intermodal terminal south of the airport.

UDOT Goals:

Preserving Infrastructure

The Charlotte Douglas International Airport (CLT) represents decades of cumulative investment in infrastructure. As with all airports, residential encroachment and noise complaints represent a danger to

102 https://charlotteregion.com/public-policy/foreign-trade-zone-57/

103 https://ncports.com/port-capabilities/rail-connectivity/

continued operations, something the airport sponsor has managed to mitigate through the strategic purchase of relevant parcels.

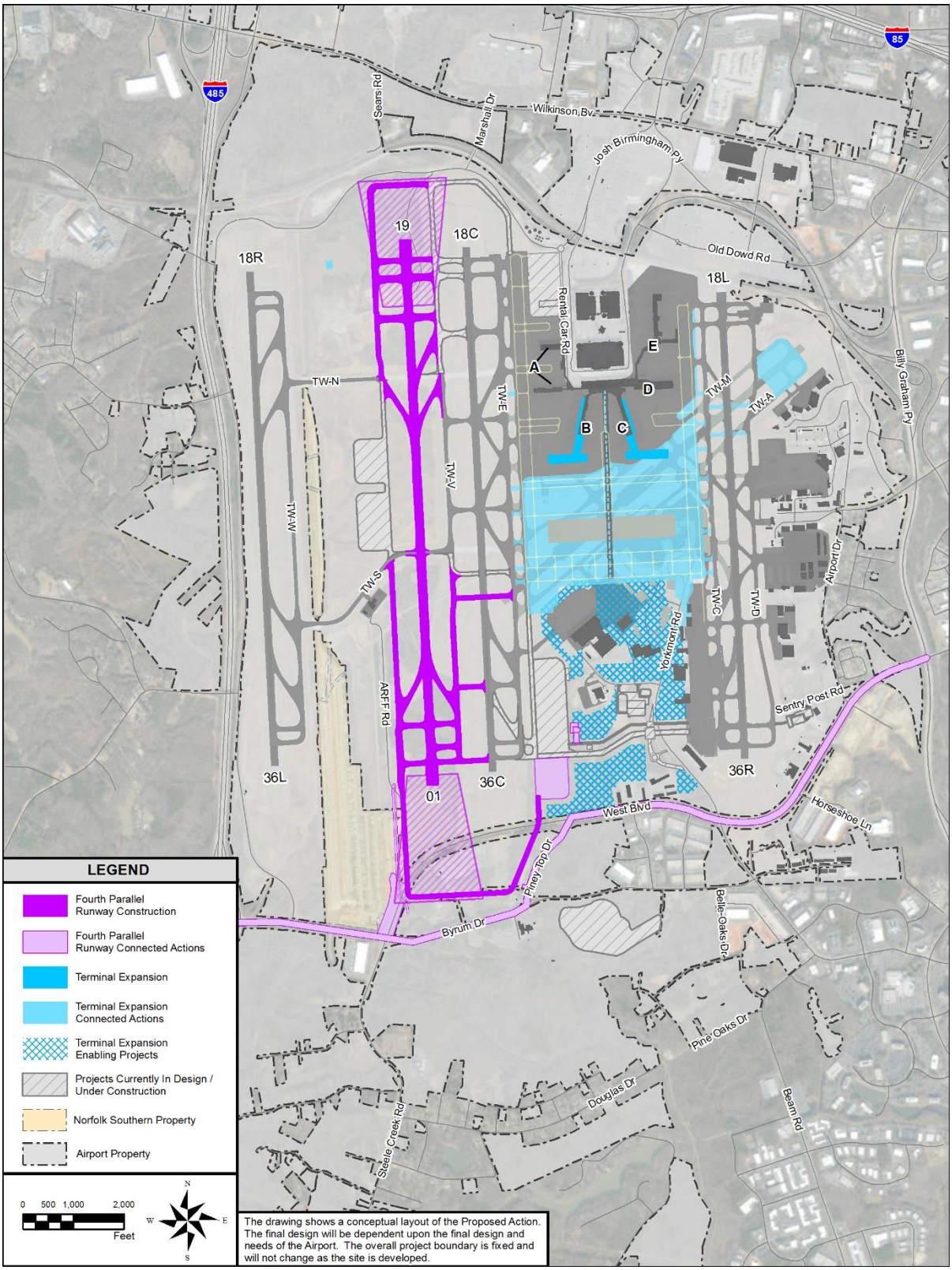
Optimizing Mobility

The airport currently enjoys quality surface transportation mobility thanks to a location next to an interstate/beltway interchange, as well as an associated limited-access highway (Billy Graham Parkway). Optimizing mobility requires managing roadway capacity, such as through congestion pricing. For the airport, airport-specific toll lanes ('Aerolanes') would be ideal. While no designated 'Aerolanes' exist, there are already toll lanes along a connecting freeway (I-77) with toll lanes planned for the I-485 freeway, although not currently for the airport adjacent segment [104]. While rich in limited-access highways, the airport lacks an associated arterial network, relying instead on airport loop roads and airport access roads, which seems likely to become a long-term problem. Lacking rapid transit access, the airport is currently reliant on optimizing mobility to reduce travel times. A rapid transit corridor is planned but to the north of the airport, rather than on airport property. Connecting to the airport will require a transfer to a shuttle mode for the connection. Long term, a people mover may prove necessary. Short term, the need will likely be met by parking access shuttles.

Economic Development

The Charlotte Douglas Airport facilitates economic development in the region by improving regional accessibility. Proof of the value of this accessibility can be found in the prevalence of distribution centers, offices, hotels, retail/wholesale markets, factory outlets, and business parks near the airport. While Kasarda's Aerotropolis predicts their appearance, Charlotte Douglas Airport demonstrates they do not need to be directly adjacent to the airport if surface transportation is sufficient. Special limited-access highways acting as aerolanes mean the associated 'airport city' can stretch for several miles around the airport.

104https://www.ncdot.gov/projects/i-485-express-lanes/Pages/default.aspx


485
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Sears Rd
Marshall Dr
Wilkinson Bv
Josh Birmingham Py
19
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Old Dowd Rd
Rental Car Rd
A
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Billy Graham Py
TW-V
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TW-S
TW-C
TW-D
Airport Dr
Yorkmont Rd
ARFF Rd
Sentry Post Rd
36L
01
36C
36R
West Blvd
Horseshoe Ln
Piney Top Dr
Byrum Dr
Belle Oaks Dr
Pine Oaks Dr
Douglas Dr
Steele Creek Rd
Beam Rd
LEGEND
Fourth Parallel Runway Construction
Fourth Parallel Runway Connected Actions
Terminal Expansion
Terminal Expansion Connected Actions
Terminal Expansion Enabling Projects
Projects Currently In Design / Under Construction
Norfolk Southern Property
Airport Property
0 500 1,000 2,000
Feet
N
W
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S
The drawing shows a conceptual layout of the Proposed Action. The final design will be dependent upon the final design and needs of the Airport. The overall project boundary is fixed and will not change as the site is developed.

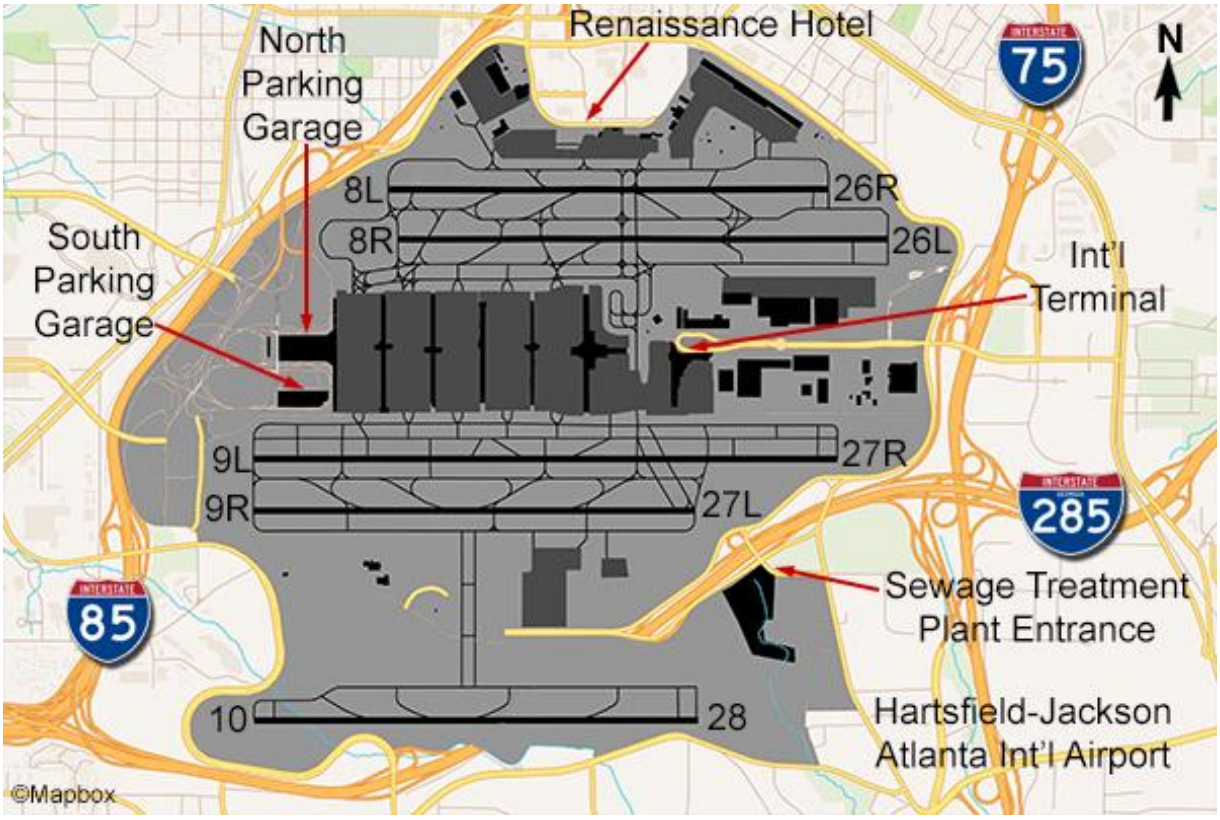
10 Case Study – Hartsfield-Jackson Atlanta Airport

Takeaways

It is always possible to expand an airport. Residential neighborhoods, cemeteries, rivers, and interstate highways can all be incorporated while maintaining spatial continuity. For Salt Lake City International Airport, neither the Jordan River nor I-80 should be considered an insurmountable barrier.

Like many primary commercial service airports, Hartsfield-Jackson Atlanta International Airport (ATL) belongs to a class of airports that are simply too big to move, due to decades of infrastructure investment. Where incompatible uses threatened airport operations, the incompatible uses were removed. From the dawn of the railroad age, Atlanta was aggressive in its efforts to develop as a freight center, a tradition continued today by the singularity of purpose displayed in efforts to ensure that ATL can continue to grow and develop.

Becoming an activity center requires extending uses beyond those associated with or dependent on airports. Happily, ATL demonstrates that the variety of uses with on-airport locations and airport proximate locations is surprisingly large. As it has expanded, ATL has managed to tolerate a surprising number of legacy non-aviation uses on airport property. This implies if Salt Lake City International Airport were to construct an additional runway to the west, it could incorporate parts of what is currently the International Center.



ATL shows that an effective surface transportation system is key to maintaining the vehicular mobility for an airport to be a connected activity center. Freight is a focus in Atlanta, and substantial effort is made to ensure freight fluidity by reducing delays to truck traffic through both infrastructural and

information technology improvements. Mobility has been optimized through sustained investment in limited-access highways—not just to one side of the airport, but on all sides to the extent that the airport is effectively ringed by highways, with access maintained through numerous overpasses and underpasses.

Context

The Atlanta Hartsfield-Jackson Airport (ATL) is located south of downtown Atlanta, just inside the I-285 beltway. Three interstates (I-85, I-75, & I-285) enwrap the airport. Like the (new) Salt Lake City International Airport, Atlanta moved from pier concourses to the present midfield terminal plan, and a terminal fixed-guideway rail station is located on airport property. The airport is a non-coastal Delta hub, and the Atlanta region has a strong historic focus on freight: Atlanta was founded as a rail freight hub and developed into a trucking hub. Atlanta's pre-eminence as a trucking hub in turn made it an excellent location for an air-freight hub.

While primarily in Clayton County, parts of the airport are also in Fulton County, the city of Atlanta, College Park, and Hapeville [105]. Part of the reason that the ATL airport has been able to continue to develop as a commercial air service airport is the diversion of most general aviation operations to the nearby Peachtree DeKalb Airport.

Surface Transportation Access

Interstate routes 85, 285, and 75 create numerous pathways for civilian and commercial vehicles in and around the airport. Central Avenue runs diagonally above ATL airport and provides a major arterial road for the airport. ATL is a terminus of the MARTA (Metropolitan Atlanta Rapid Transit Authority) rapid transit line.

Girded by the extensive infrastructure of Atlanta's freeway system, ATL has access to airport terminals from both the east and west sides. The western edge of the airport is characterized by numerous grade-separated transportation facilities: on-ramps, elevated roadways, a MARTA heavy rail line, a people mover, and other elevated roadways connecting the airport to areas beyond the barrier of limited-access highways. While many airports have runways passing over roads, ATL is unique in being the sole airport with an active runway built across an Interstate Highway.

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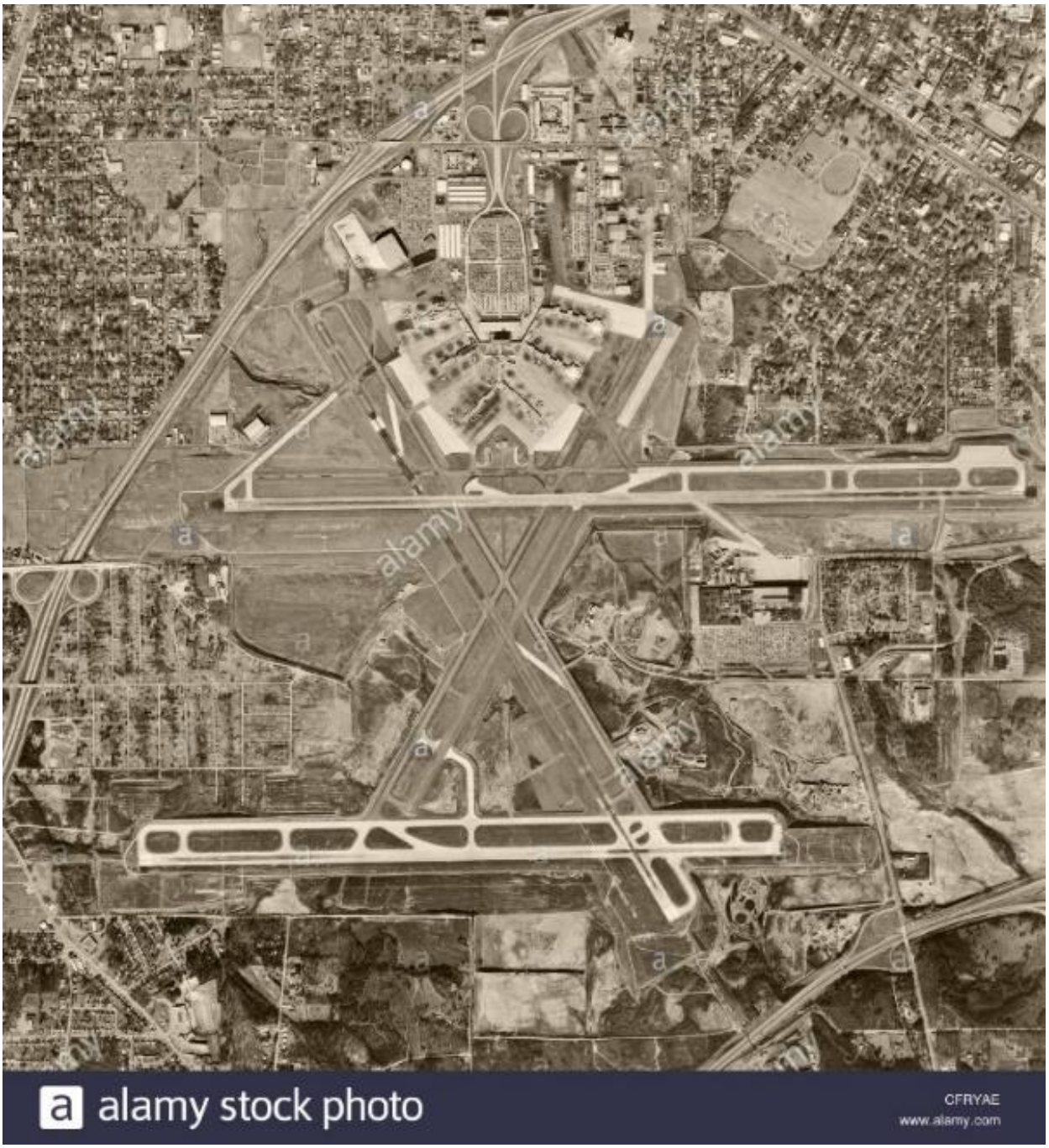
105 https://en.wikipedia.org/wiki/Hartsfield%E2%80%93Jackson_Atlanta_International_Airport

Airport-Specific Elements

Ever-Expanding Airport

Atlanta demonstrates that it is feasible for an airport to continue to expand despite existing



development, geographical barriers, or freeways. The airport has grown from the original 287 acres

[106] as a racetrack to its present size of over 4,700 acres. The airport has expanded substantially [107] as increasing operations and noise impacts from jet aircraft lead the airport to incrementally buy out entire neighborhoods.

In addition to incorporating residential neighborhoods, there are several still-extant cemeteries on airport property [108] and the Flint River passes under the airport [109]. The airport has extended an active runway (Runway 10/28) over Interstate I-285 and filled hollows to a depth of 35 feet.

The airport has demonstrated the potential to revise not only the surrounding built environment but the airport itself. Despite the construction of a massive new terminal in 1961 with six pier concourses radiating out, in 1977 the airport was re-oriented and redeveloped with the present mid-field terminal plan.

The airport is an active developer and redeveloper of on-airport property, with a regularly expanding footprint. This can conflict with efforts to develop alongside the airport. In 2008, Jacoby Development purchased a defunct Ford Plant, intended to develop it as a mixed-use (office, warehouse & entertainment) district [110]. While part of the site was developed as the Porsche North American Headquarters (with associated test track and hotel) [111,112] a substantial portion was purchased by the airport [113] for an approach light system. The airport still seeks to provide an on-airport convention hotel through a ground lease, with efforts ongoing [114].

An Integrated Airport

It is often difficult to tell where the Atlanta airport begins and ends, without recourse to specialized mapping [115]. The airport owns substantial property outside of the airport boundary.

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106 https://www.sunshineskies.com/atlanta-speedway.html

107 https://www.alamy.com/stock-photo-historical-aerial-photograph-atlanta-municipal-airport-atl-1968-44166934.html

108 https://www.thegenxjourney.com/atlanta-airport-cemetery/

109 https://www.businessinsider.com/atlanta-airport-facts-busiest-in-world-2019-5#there-is-a-5k-race-held-every-year-on-one-of-the-runways-4

110 https://www.bizjournals.com/atlanta/stories/2008/06/09/daily75.html

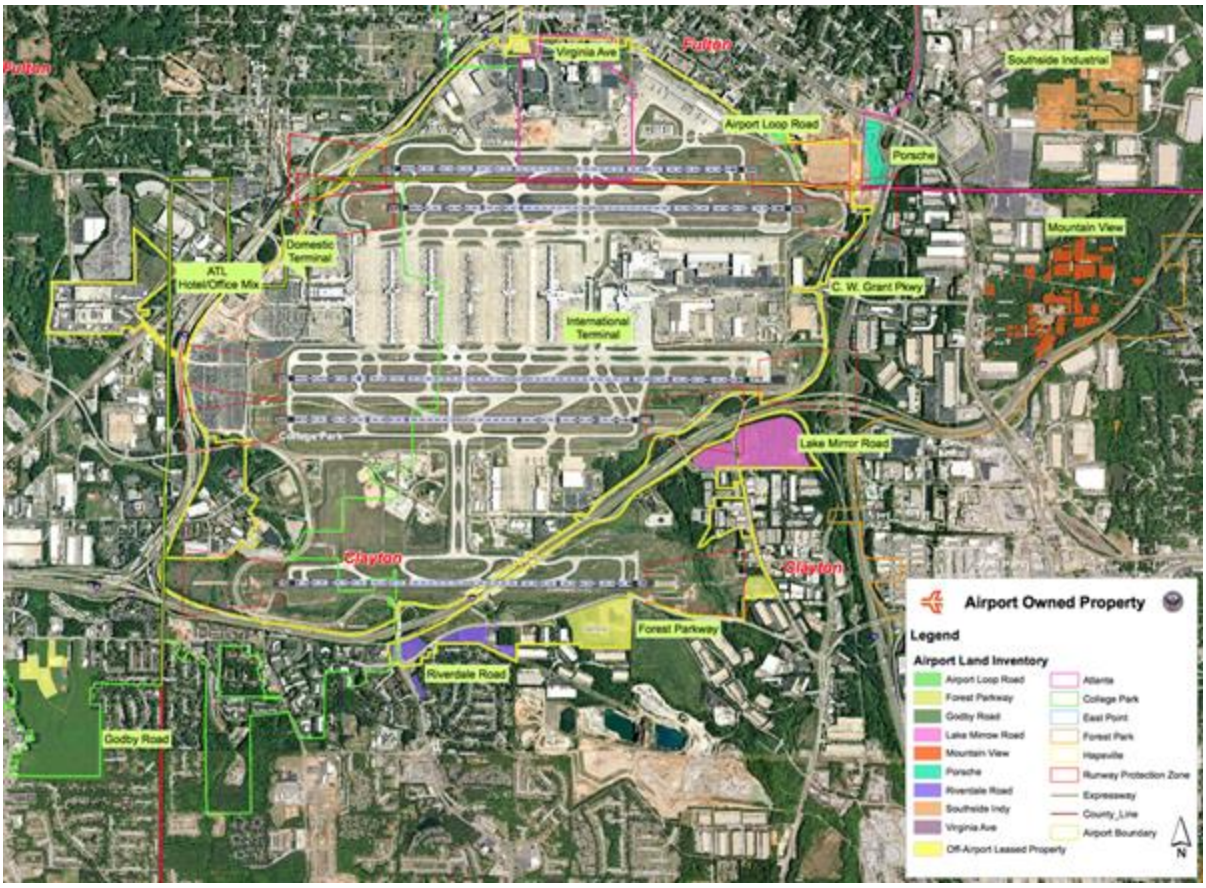
111 https://en.wikipedia.org/wiki/Aerotropolis_Atlanta

112 https://jacobydevelopment.com/porsche.html

113 https://www.agg.com/news-insights/client-successes/jacoby-development-porsche-selects-aerotropolis-site-for-new-hq/

114 https://atlanta.curbed.com/2020/1/6/21051752/hartsfield-jackson-atlanta-airport-aerotropolis-development-rfp

115 https://valdostatoday.com/wp-content/uploads/2015/07/atlanta-airport-owned-property.png

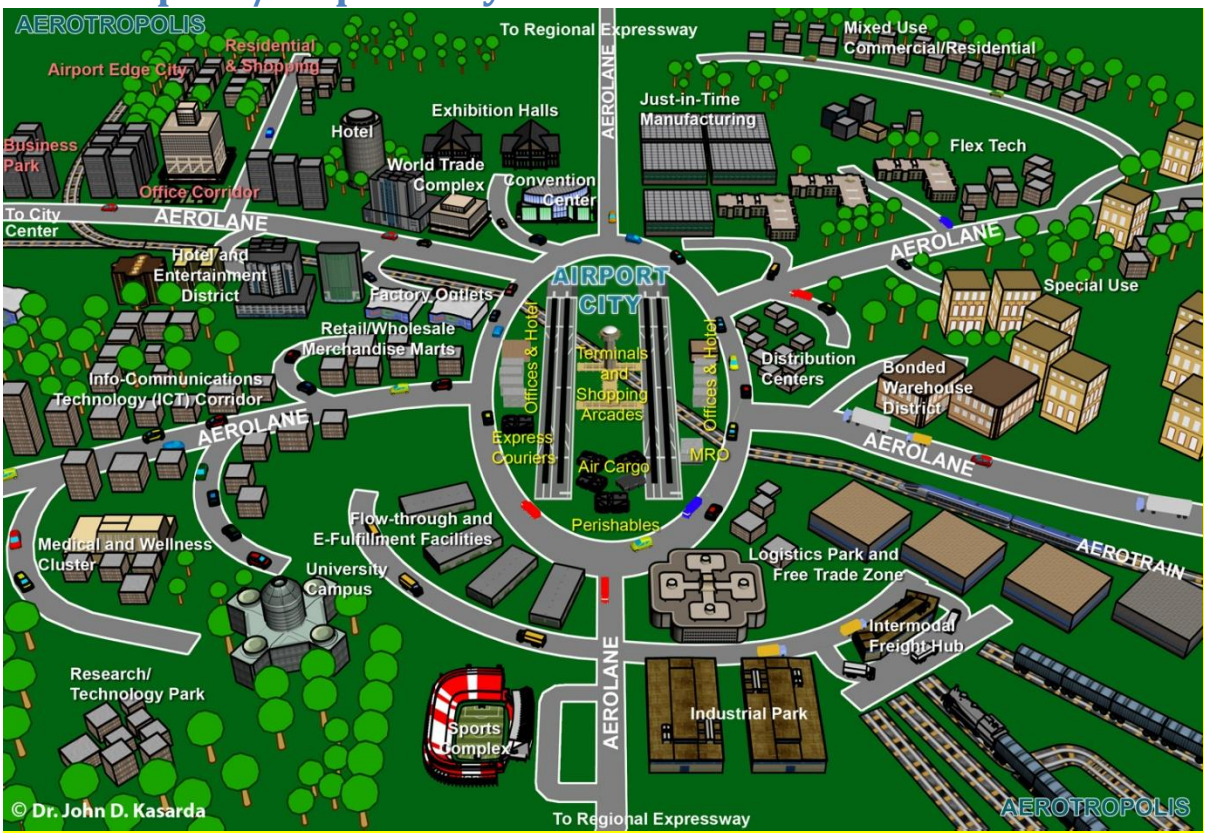


The airport crosses the I-285 freeway and the I-85 freeway to the west. The edges of the airport are made permeable by grade separation. The western edge of the airport is characterized by numerous grade-separated transportation facilities: on-ramps, elevated roadways, a MARTA heavy rail line, a people mover, and other elevated roadways, connecting the airport to areas beyond the barrier of limited-access highways. In a sense, these connections make it possible to disaggregate the airport: remote parking no longer needs to be next to the terminal because it is connected by the SkyTrain, a people mover, which also connects to off-airport hotels and an airport-oriented convention center.

The variety of aviation-dependent businesses near the airport strongly suggests that there is no need for airport-associated activities to be contiguous with the airport, so long as they are nearby. There is a substantial cluster of airport-associated development located to the east of the international terminal, which includes U.S. Customs, freight expediters, FedEx, pilot services, and refrigerated warehousing.

Development around the airport is facilitated by the fact that the Atlanta airport is not the terminus of the limited-access highway network but rather, is central to it. In turn, this centrality makes it attractive to non-aeronautically oriented development. The area near Atlanta Hartsfield-Jackson airport offers excellent freight access, excellent automobile access, and a connection with the regional rapid transit system. The area near the airport is a good place for an edge city, regardless of proximity to the airport, even without proximity to the airport.

Aerotropolis/Airport City



The claim that the airport represents a good example of a functional aerotropolis—a metropolitan region oriented toward the airport—has merit. In 2016, the airport was the largest employer in the state of Georgia, directly employing 63,000 people. It supports half a million jobs in the region and accounts for $383 thousand in direct expenditures and $52.5 billion in economic impact for the metro Atlanta region [116].

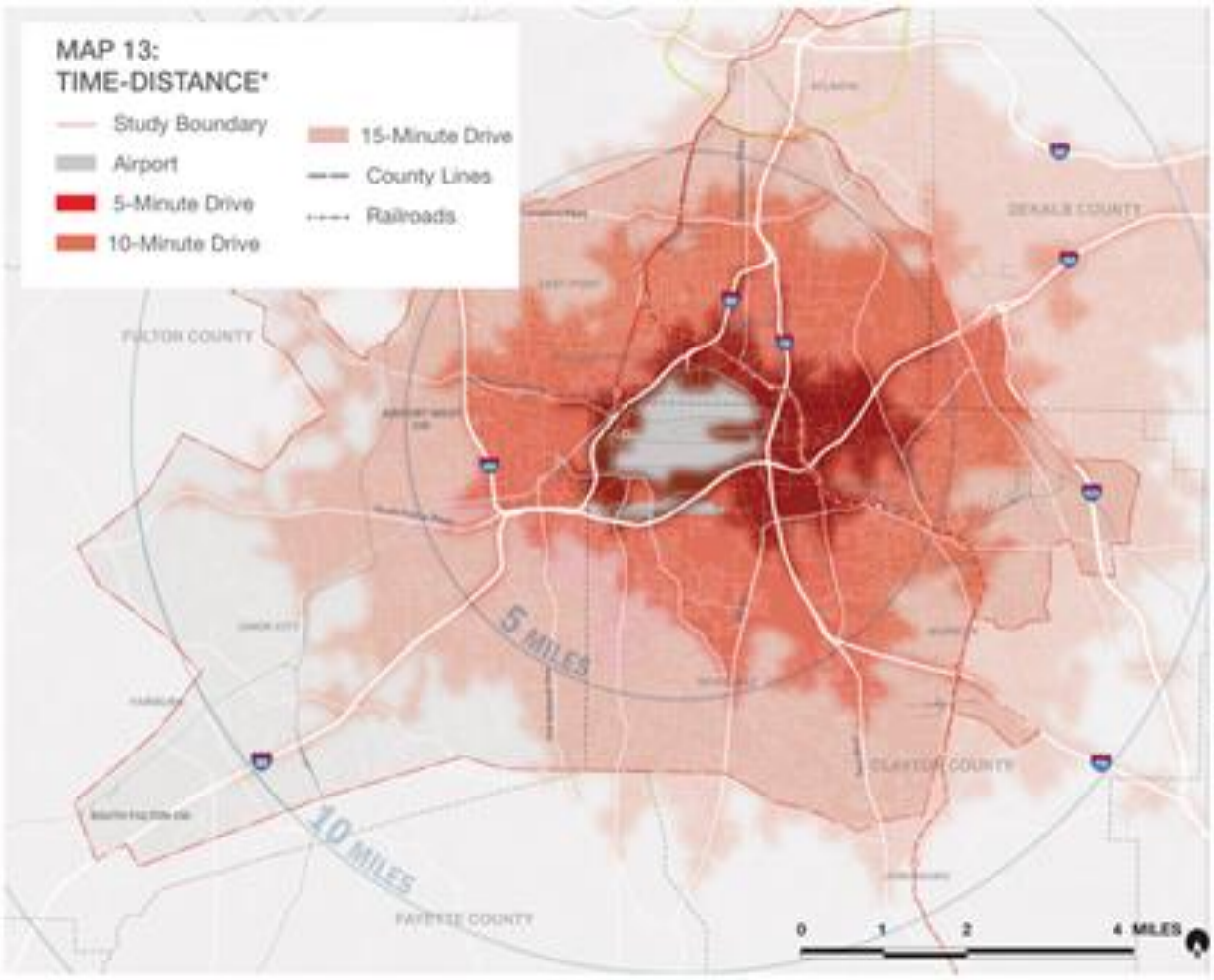
A public-private partnership called the Aerotropolis Atlanta Alliance works on planning and implementing. In concert with the distinct interests of its local government partners the alliance helps coordinate meaningful economic development that fully integrates into the functions and impacts of the airport, aiming to create an “ecosystem of unique places people want to live, work, play, and stay” [117].

The Aerotropolis Atlanta Blueprint provides the framework for developing the south side of the airport. The Blueprint was funded by a $200,000 grant from the regional MPO, the Atlanta Regional Commission (ARC) [118]. The Blueprint itself provides a vision and strategy and is similar in scale and scope to the

116 https://www.aviationpros.com/airports/airport-revenue/press-release/21124847/hartsfieldjackson-atlanta-international-airport-atl-hartsfieldjackson-serves-as-economic-engine-for-entire-southeast

117 https://aeroatl.org/about/

118 https://aeroatl.org/blueprint/



comprehensive plan of a major metropolitan city. The plan's scope includes land-use and transportation facilities extending miles from the airport, and it includes both existing conditions, long-term vision, implementation strategy, and a phased action plan [119]. The blueprint identifies potential uses by integration with the airport and plots time-distances access contours to assess land-use suitability.

The Atlanta Aerotropolis Alliance, recently renamed AeroATL, continues to be active in planning development near the airport, recently espousing a plan for a 320-acre development within the City of College Park [120,121].

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119 https://aeroatl.org/wp-content/uploads/2017/06/aerotropolis-atlanta-blueprint-final.pdf

120 https://atlanta.curbed.com/2019/2/12/18221670/college-park-airport-city-aeroatl-aerotropolis-hartsfield-jackson

121 https://atlanta.curbed.com/2019/8/7/20758875/college-park-atl-airport-city-plans-project-atlanta

Evidence from Atlanta strongly suggests it is possible to spatially disaggregate an airport while integrating an airport with the surrounding urban area. This can be done by moving some traditionally on-airport functions to off-airport locations while allowing non-aeronautical uses on airport property. Disaggregating the airport requires maintaining excellent surface transportation access between elements of the airport. Integrating non-aviation uses on airport property requires open-mindedness regarding the compatibility of uses. There is a new mid-rise apartment building less than half a mile from the end of a runway, made feasible by improved noise insulation [122].

Air Cargo and Truck Freight

ATL has two cargo ramps, one to the north of the airport and one to the north of Runway 10/28, with the first serving Southwest Airlines and American Airlines Cargo, and the second serving Delta, Lufthansa, Alaska Airlines, and other cargo-only airlines, and a major cargo facility south of Maynard H. Jackson Boulevard, near the international terminal. In addition, ATL's status as a major passenger airport benefits its air cargo operations--most air cargo travels in the belly of passenger aircraft. The ability to transfer cargo between dedicated cargo aircraft and passenger aircraft is another source of synergy for ATL. The substantial on-airport cargo facilities also enable rapid intermodal transfer between aircraft and trucks. The airport facilitates rapid distribution by maintaining connectivity with surface streets and reducing the need to detour around runways. Unlike most airport loop roads, those for Atlanta have overpasses crossing a major Interstate (I-285) and direct on-ramps to and from that Interstate. Within the airport, Sullivan Road also passes under an active taxiway to provide access to the south cargo ramp from the west.

Airport Terminal as a Connected Activity Center

Atlanta Hartsfield-Jackson is the busiest passenger airport in the United States, due in part to the airport's centrality--80% of the US population is less than two hours away by air [123]. With the highest passenger volumes, the airport has the largest internal 'population' of any airport, and hence is the best able, of any airport, to act as an independent activity center. The airport handled 110 million passengers

122 https://www.atlantamagazine.com/news-culture-articles/5-things-know-pad-harvard-college-parks-first-new-mid-rise-40-years/

123 https://en.wikipedia.org/wiki/Hartsfield%E2%80%93Jackson_Atlanta_International_Airport

in 2019. The airport has six passenger concourses and two terminals, all with shopping, dining, and entertainment options; the domestic terminal has a large central atrium [124] and offers executive office space and an interfaith chapel [125]. Atlanta is perhaps unique in offering a hotel inside the secure cordon [126].

The 'Airport City' [127] concept strongly suggested that airports can become the center of a wide variety of central place functions, including destination retail, conferences, museums, and restaurants. While many major airports can and do support many of these functions, the necessity for a secure cordon creates a barrier to travel such that establishments inside the cordon cannot be drawn on as part of the 'population' of visitors on the other side of the cordon to meet threshold populations necessary for certain economic activities. Hence, the airport city inside the terminal can never be more than that of a small town (albeit one with a major mall proximate).

UDOT Goals:

Preserving Infrastructure

Hartsfield-Jackson Atlanta International Airport represents decades of cumulative investment in infrastructure. The airport's economic importance to the state is well recognized. Situated in a largely built-out context, residential encroachment is no longer an issue and ATL has already shown the capability to overcome the barrier of the limited-access roads that gird the airport using a variety of grade-separated overpasses and underpasses. Rather, for ATL, the issue is future expandability. Long term, the ad hoc and incremental addition of links will prove problematic and ATL will need to rationalize surface transportation access. The lack of current planning to do so represents a danger to the long-term utility of expensive capital investments. The mid-field terminal plan provided decades of expandable capacity, a feat difficult to repeat.

Optimizing Mobility

Mobility around the airport is excellent as there are many different modes of transport readily available for people wishing to arrive or depart ATL airport. Shuttles, limousines, taxis, ride-sharing companies, hotel shuttles, off-site parking, rental cars, as well as public transportation options such as MARTA trains, MARTA buses, and even Amtrak are available. Moreover, the ATL SkyTrain helps to facilitate travel between the airport, convention center, hotels, and the car rental center.

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124 https://ellisdownhome.com/have-fun-in-the-atlanta-airport/

125 https://www.atl.com/maps/

126 https://www.sleepinginairports.net/hotel/minute-suites-atlanta-airport.htm

127 Appold, S. J., & Kasarda, J. D. (2013). The airport city phenomenon: Evidence from large US airports. Urban Studies, 50(6), 1239-1259.

Economic Development

While not the largest metropolitan area in the United States, Atlanta may well be one of the most accessible, due to its centrality in the air transportation network. Atlanta has leveraged this centrality by maximizing transportation infrastructure to ensure its status as a hub location. Accordingly, there are large volumes of both passengers and freight flowing in and out of Atlanta, ensuring that there are plentiful flights and trucks available. Accordingly, this has made Atlanta an attractive location for 'central place' functions. Easy and rapid air travel has made Atlanta an attractive location for the headquarters of companies, while excellent surface freight networks make it an attractive depot location, where goods can be rapidly distributed throughout the region as needed. Indeed, most of the U.S. population is within a few hours of air travel from Atlanta, making it possible to make single-day roundtrips to most of the United States, facilitating business management. Further, most of the southern US can be accessed in a single day's truck journey from Atlanta. Anything made near Atlanta can be trucked to ATL and then air-freighted to anywhere in the world.

11 Development Scenarios Based on Best Practices

This section contains a discussion of different development scenarios evidenced by airports in both the case studies and John Kasarda's book *Aerotropolis*, and it presents best practices associated with different development scenarios. The purpose of these scenarios is not to predict a distinct outcome, but to explore potential development trajectories for Utah airports based on development patterns at other airports. They are not intended to represent a planned outcome, but to explore the limits of what might be possible under policy and investment choices without regard to limitations.

This section presents three aviation development scenarios based on best practices. While containing elements relevant to all airports, the *Freight Hub* and *Airport City* scenarios are most relevant to commercial aviation hubs while the *Airport Resort* is most relevant to general aviation airports. All focus on creating airports as connected activity centers: the first does so by maximizing mobility, the second by maximizing development in proximity, and the third by reducing the psychological friction of travel.

Background

Before exploring future development trends, it is first useful to present some background on airport development history to explore how airport development dynamics have generated the status quo.

Most airports have their history in private, municipal, or military airfields and were designed for use by propeller aircraft, most of which are characterized by crosswind runways. Military runways tend to have both more runways (to enable all-weather operation) and longer runways (to tolerate higher speeds). They tend to be located on the periphery of an urban area. Over time, as the urban area expanded, aviation activity increased. Heavier aircraft required longer runways but were better able to tolerate crosswinds, so most airports focused on having a single primary runway. Busy airports added additional runways. Commercial air travel was highly regulated.

The first major change was the introduction of passenger jets. The advent of passenger jet aircraft changed airports; jet aircraft were faster and noisier, with greater impacts on the surrounding area. Compounding this, over time, urban development simultaneously increased until it was proximate to airports. In addition to causing conflicts over noise, this also limited airport expansion. Three alternatives were pursued: the creation of new airports, expansion through eminent domain, and multiple airports. Chicago O'Hare (ORD) might be said to exemplify the first alternative, Los Angeles (LAX) the second, and New York's trifecta of JFK, LaGuardia, and Newark International the third.

The second major change affecting airport development was airline deregulation, which induced major airports to move to a 'hub and spoke' transfer network that relied on aggregating passengers in a few hub networks and using large jets to fly between hubs. While this reduced the total number of aircraft operations, it centralized airline operations at a few hub airports. This, in turn, induced cities to compete to serve as hub locations for different airlines, using airport capacity (infrastructure, funding) for competitive advantage. Status as a hub airport ensured not only FAA funding, but also non-stop connections to many destinations, making the hub city an attractive location for conferences, corporate headquarters, government administration, sales, and other centralized activities. Before the telecommunications revolution, personal transportation was even more critical to communication than today. The same network centrality that made hub airports attractive for personal transportation also made them attractive for freight transportation, attracting warehouses and distribution centers to hub airports.

The combination of revenue from fuel sales and the Passenger Facility Charge program has meant that most hub airports have a reliable source of income to support a steady program of on-airport improvements. Recognizing the economic importance of aviation, host regions that implement a holistic planning approach have been supportive through both direct funding and airport servicing transportation improvements, such as limited-access highways and rail linkages.

Deregulation also upset the previous system of airports. The winner-takes-all nature of hubs reduced traffic to many airports and airlines ceased to provide scheduled commercial service to some. A limited number of these airports have been designated as reliever airports, with the capacity to handle passenger jets in the event of disruption of a nearby major airport. Accordingly, these airports often campaign to establish scheduled passenger service and have done so during periods when low fuel costs made smaller jets feasible to operate. Airports sufficiently distant from larger airports or with larger population/employment bases have been especially successful in doing so.

Non-commercial service airports continue to serve private aircraft; larger general aviation airports can serve light jets and business jets while smaller general aviation airports are mostly limited to propeller craft. In cases where capacity is a limitation at nearby major airports, landing fees have been used to direct smaller general aviation aircraft away from hub airports and some commercial service airports.

In most regions, this functional division has been formalized through explicit system planning. System planning exists to avoid duplication of infrastructure. Rather than funding a series of competing airports with similar facilities, airports are assigned roles and infrastructure investments appropriate to those roles assigned. Competing airport sponsors/owners can and do still generate competition between airports for different roles.

Scenarios

The following section presents three scenarios under which airports might be developed as connected activity centers: 1) as a freight hub; 2) as an airport city; or 3) as an airport resort. The first focuses on ensuring freight connectivity to and from an airport; the second on integrating central city and business district uses near to and within the airport as well as leveraging that density to create an ‘airport city,’ and the third focuses on how smaller and rural airports might leverage connectivity to support the region.

Freight Hub

In this scenario, Salt Lake City International Airport (SLC) development focuses on freight. Relevant exemplars include Memphis, Louisville, and Chicago. Because air cargo often travels in the belly of passenger jets, passenger service and freight capacity are often intertwined. Salt Lake becomes a super-hub or sorting point for one or more major parcel companies (DHL, UPS (United Parcel Services), FedEx, or Amazon) while expanding sorting facilities for other services. (Amazon and UPS have committed to expanding their existing operations in Salt Lake City.) General aviation would be relocated to another airport.

Surface transportation investments would be targeted to maximize the market area of the airport, maximizing the share of population and employment reachable by delivery trucks from the airport. This would include the use of both truck-only aerolanes and improved limited-access highway connections, including a beltway around all sides of the airport, permitting direct truck connections on a limited-

access highway from the north/west of the airport to I-80 and I-215, like what is seen in Atlanta today. Bangerter Highway through Glendale becomes a limited-access highway and Mountainview Corridor is connected to I-80, which would be upgraded to handle the increase in truck traffic. Truck-only highways north of I-80 (through the wetlands) and west of I-215 (through Farmington Bay) would be built to avoid congestion along the interstates. A railroad freight spur (running parallel to the runways) would be built (potentially on-airport) to facilitate stocking the warehouses and distribution centers of the cargo-oriented development. Substantial semi-truck parking would be needed both on and off the airport; off-airport parking would be centered around a 'truckers oasis' supplying fuel, dining, showers, and other amenities. Ensuring low-income worker access for on-airport and off-airport businesses would require the development of a robust bus/shuttle network using the airport TRAX station as a transfer point.

Land-use regulation and development would be oriented toward distribution centers and warehouses, with a focus on cargo requiring special storage conditions, such as medical or perishable foodstuffs. Due to the combination of noise and pollution (from aviation, truck, and manufacturing sources), new residential development would be excluded from the area around the airport, and existing residential development eliminated over time.

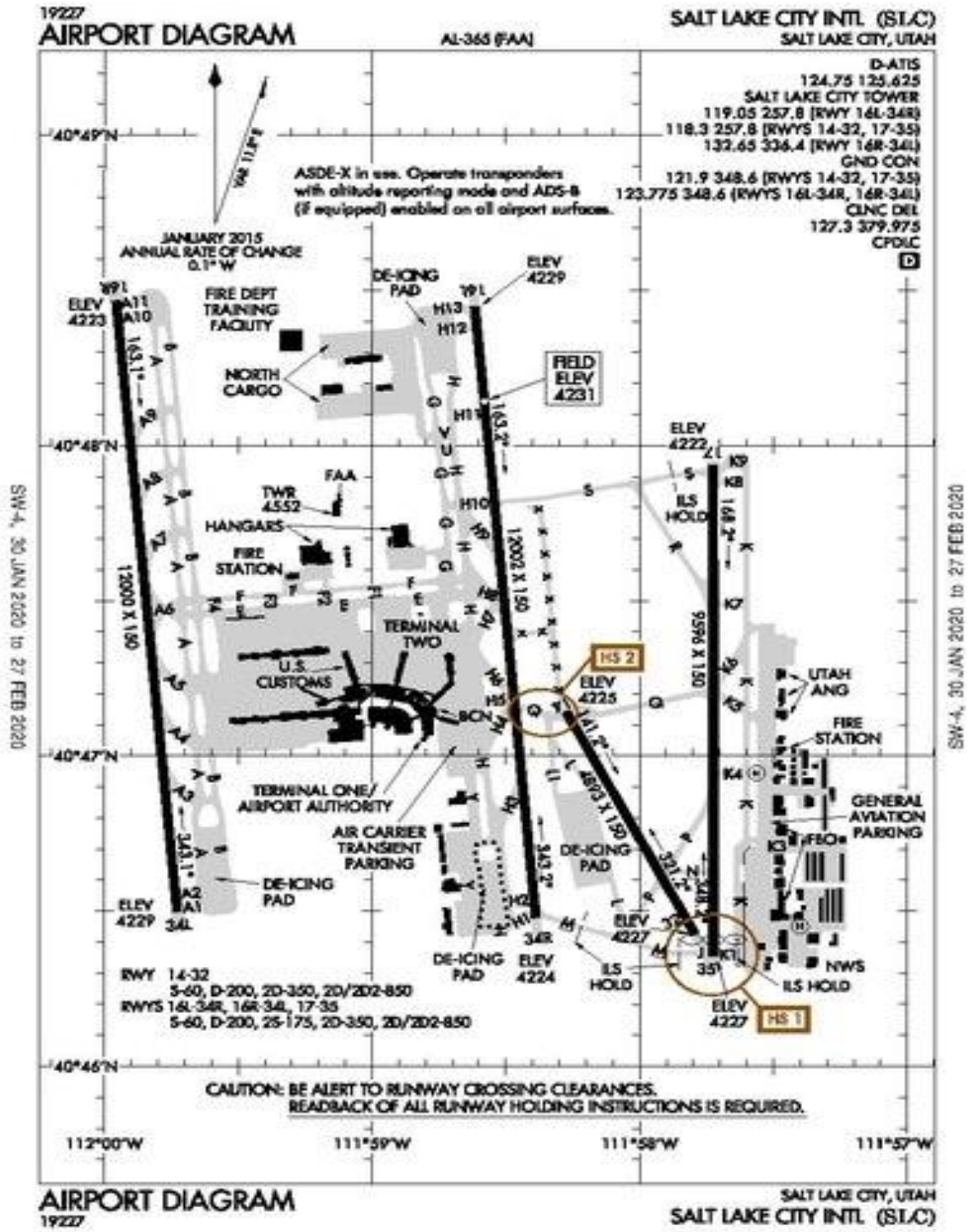
On-airport freight movement is prioritized both airside and landside. Airside, the surge of daily parcel flex requires at least two more parallel runways; by adding a runway to the west along/over where the Jordan River currently runs. Runway 17/35 would be realigned as 16/34; runway 14/32 would be eliminated. In a later stage, both runways would be eliminated and replaced by a new pair of parallel runways replacing the former General Aviation area.

Landside, the area between the present 16/34L and 16/34R runways north of the passenger terminals becomes a dedicated cargo area. Both the east and west sides of the airport have cargo-oriented development. The land along the fenceline would be leased to distributors, specialty manufacturing, prototyping, repairs, assembly, and other light industrial land uses reliant on rapid transportation or just-in-time delivery of parts, that can pass cargo through the fenceline or that merely value the added security of an on-airport location. Circulation within the airport would require the construction of an airport ring road connecting the peripheral buildings along the fenceline to cargo areas north of the passenger terminals.

While much of this scenario is specific to Salt Lake City International Airport, this scenario has relevance for smaller airports. For reliever airports as well as larger general aviation airports, this would include a focus on freight and industrial development along the fenceline of the airport with a preference for firms with an erratic but pressing need for air cargo: prototyping, repairs, samples/displays, and customized manufactures, such as 3D printing or laser sintering. Accordingly, firms with irregular freight or passenger visit needs (i.e., using business jets) would also be tenant candidates. Additional fenceline tenants might include security-conscious firms (payroll/medical billing), military/law enforcement agencies, or may simply provide secure storage.

In this scenario, airports become freight and manufacturing activity centers, connected to the rest of the region by a network of specialized freight surface transportation infrastructure intended to maximize: 1) access to the airport (through multiple runways); 2) access from the airport (for delivery vehicles), and; 3) access to the airport (for truck freight used to stock warehouses and distribution centers). It maximizes connection in multiple directions and across multiple modes, facilitating intermodal transfers. It leverages both passenger activity and Utah's historic trucking legacy as Crossroads of the West.

Finally, COVID-19 has hastened a technological change in retail, increasing the dominance of Amazon, online shopping, and rapid delivery.



Airport City

This scenario focuses on turning airports into self-contained airport cities, building sub-centers by conglomerating convention centers, convention hotels, business hotels, and business offices and shopping/dining within airports. The exemplar for the scenario is the Atlanta Hartsfield-Jackson Airport (ATL), where an automated people mover links the airport to the Georgia International Convention Center, providing 24-hour access to hotels: the Marriott Gateway, Renaissance Atlanta Airport Gateway, and SpringHill Suites Gateway [128]. In this scenario, on-airport convention capacity (meeting rooms, seminar rooms, and auditoriums) would be matched with existing airport dining and shopping opportunities, providing the capacity to fly in, meet, and fly out within a single day. Some airports already contain such facilities [129]. For multi-day events, the presence of an adjacent convention center and multiple hotels provides a package that minimizes the friction of travel. Even for multi-day events, time inside the airport (dining or drinking) becomes integrated into conference programs. While hotels (and entertainment) may be located outside the security cordon, activities within it remain part of the conference. In both contexts, airport shopping and dining become an essential part of the experience of traveling, moving beyond the provision of convenience retail (Advil, snacks, replacement headphones) and toward experiential retail: shoes, product showrooms, fashion—things which require in-person engagement to evaluate. Federal limitations on tarmac delays mean that more passengers are being kept inside the airport for longer. The unknown and variable amount of time it takes to get through airport security also causes passengers to spend more time in terminals. Retailers have not been slow to recognize the possibilities of a captive population of affluent travelers, and indeed Denver International Airport, perhaps the most recently constructed, resembles nothing so much as a high-end mall, a pattern echoed by Salt Lake International [130]. Further, the dining options offer a local microcosm, providing outposts of notable local breweries and restaurants: Uinta, Wasatch, Pago, Squatters, Gourmandise, and Market Street Grill, sending the message that there is no need to venture beyond the airport because the experience is contained within the airport.

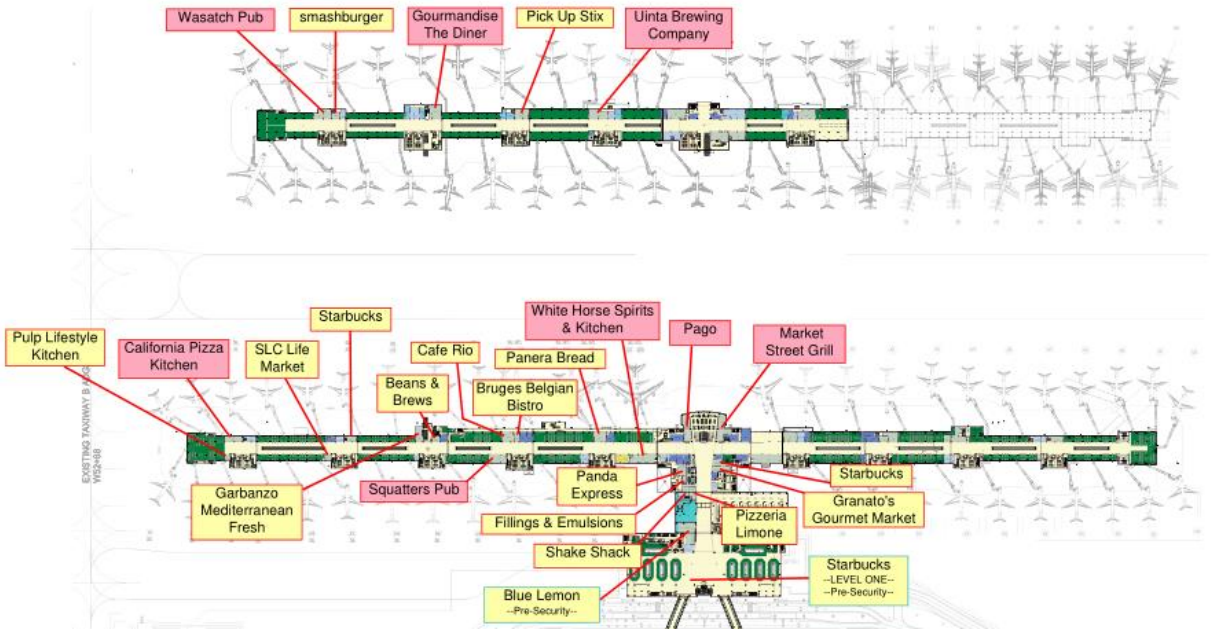
The second element of the airport-city scenario is the development of business offices near the airport. Any business that relies on regular face-to-face contact to coordinate with employees, suppliers, partners, venture capitalists, potential clients, or other collaborators relies on air travel to link together geographically scattered operations. An airport location makes it simple to coordinate; businesses are no longer located near the airport but at the airport. At the same time, the logic which drives the need for convention hotels near the airport also drives the need for business hotels as multi-day engagements require overnight stays. But the hotels would need to do more than offer a place to sleep for aircrew,

128 https://martaguide.com/things-to-know-about-the-atlanta-skytrain/

129 Lindsay, G., & Kasarda, J. D. (2013). Aerotropolis: The way we'll live next. Farrar, Straus and Giroux.

130 https://slcairport.com/dining-and-shopping/the-new-slc-restaurants-and-shops/

the hotels would also offer cater to stranded passengers or business travelers catching an early morning flight. For an increasing number of workers, an office is now any location with a place to sit and a wi-fi connection. Knowledge workers can be seen perched over laptops and phones in coffee shops, cafes, and bars across the world. Correspondingly, properly configured hotels have become an effective place



to do work. In a COVID-19 world, a private hotel also offers an escape from public spaces and mask use.

An airport city is also well positioned to take over the central-place functions of gathering people from scattered locations into a central location for company get-togethers. Essential to both the convention aspects and the business office aspects of an airport is connecting locations to the airport. While the Freight-Hub scenario is about expanding airport access by improving mobility to and from the airport, this scenario is about improving airport access by bringing more activity near the airport. Everything necessary to accomplish the purpose of a trip can be obtained within proximity of the airport. In some cases, it may be possible to include specially designed residential areas at the periphery of the airport city for frequent fliers and other heavy users of aviation.

For airports to function as connected activity centers in this scenario, connections between locations must be quick, direct, and obvious, as simple as walking down the street. Several airports (Atlanta included) rely on airport people movers to provide this service. In other airports, the same train that connects the terminals connects to off-terminal locations but provides a one-way exit-only gateway. High-speed moving sidewalks have been used for this purpose [131]. Given the rate at which vehicle automation is advancing, and the capacity to provide controlled access on and adjacent to airport property, it may soon be possible to supply automated on-demand shuttles connecting different destinations: climb in, select a destination from an elevator-like panel, and enjoy the ride. Each

131 Lindsay, G., & Kasarda, J. D. (2013). Aerotropolis: The way we'll live next. Farrar, Straus and Giroux.

destination is structured as a walkable pedestrian pocket wrapped around the autonomous shuttle drop-offs, with parking and freight/commercial delivery access at the periphery. Like the airport people-mover example, convention centers, hotels, business offices, and car rentals are all available and accessible through an airport-centric circulation system.

For non-hub airports, it is less a matter of an airport city than an airport district, where the intention is to create an activity center capable of providing a unique experience in association with the airport. As smaller airports lack the development capacity of hub airports, co-location may not be possible but could be replaced by creating tightly coupled transportation linkages. Minimally, this includes mapping and promotion of nearby amenities, knowledge of ground transportation options to hotels and dining as well as for destination retail such as major malls or specialty stores. This may include maintaining on-site ridesharing parking and designated pickup spots, partnering with a carsharing or an hourly car rental enterprise (instead of a full rental car service), or simply maintaining a loaner car. Whenever feasible, the airport itself should offer experiential amenities such as a patio or an observation deck. Options for airport tenants may include non-aeronautical uses such as unique restaurants, breweries/wineries/distilleries. Novel recreational opportunities (paintball/airsoft/shooting ranges) may also enrich airports. In all cases, the scenario for small airports focuses on creating an activity center with attractive amenities, so that an airport becomes a desirable location to fly to.

In this scenario, airports function as connected activity centers by engaging central-place functions of being the most convenient place for gathering people from scattered locations into a central location, creating an activity center around the airport, and then using specialized transportation infrastructure to integrate that center more closely with the airport, in addition to activities that take place within the security cordon. This development scenario is about improving airport access by bringing more activity near the airport.

Airport Resort

This scenario focuses on general aviation rather than scheduled passenger service. The exemplar is Jackson Hole Airport (JAC). Located within the Grand Teton National Park, its footprint is extremely constrained with total facilities consisting of some hangars, one Fixed-Based Operator (Jackson Hole Aviation), a charter service, and a terminal containing a rental car center with associated parking. In this scenario, a general aviation airport would not grow and expand to serve as a reliever airport to serve jet aircraft, but rather would focus on serving as an access point to the broader region for smaller general aviation aircraft, thus connecting a region of tremendous natural beauty and protected lands (such as Moab or Park City) to distant population centers.

In addition to tremendous natural beauty, essential to this scenario is the presence of a pedestrian-scaled walkable entertainment district providing dining and high-end shopping (clothing and fine arts) within a short drive of the airport as well as essential goods and services sufficient to make part-time or full-time residence feasible (typically through second home ownership).

In this scenario, the role of the airport is to provide a casual, comfortable, friction-free travel experience linking a resort community with the wider world. Travel is more casual because general aviation travel occurs under a ‘know your customer’ basis rather than the institutionalized screening associated with commercial passenger service. Travel is more comfortable because the amenities provided while making

the intermodal transition are greater, and the combination of the two reduces both the hassle and discomfort.

Central to this experience is the airport terminal. Airport terminals are nodes where intermodal transfers take place; mismatches in arrival times mean that waiting is an inevitable part of the experience. The airport facilitates the intermodal connection by reducing the time experienced by making the terminal a comfortable place to wait in a way analogous to the lobby of a resort hotel—well designed, beautifully decorated, with comfortable seating, food, and water readily available, and entertainment (television, newspapers) provided. In effect, the terminal is the lobby for both the FBO and the charter aviation service.

Depending on conditions, an airport may or may not include long-term automobile storage on site—this scenario is most applicable where it does not do so because that circumstance increases the dwell time of general aviation passengers and hence the importance of comfort while waiting.

The second core element in this scenario is quality surface transportation connectivity. Regardless of how comfortable waiting is, it remains a liminal state. In addition to on-site rental cars, the airport should facilitate taxi or charter services to either second homes or the entertainment district. (Before the advent of Uber, over 30 licensed taxi firms were operating at Jackson Hole airport).

The land-use planning associated with this scenario focuses on preventing encroachment on the airport. The scenario relies on unrestricted general aviation service at the airport to drive second home ownership and tourism in the associated entertainment center. Over time, as an area develops, increasing conflicts will develop between part-time residents, who rely on the airport for access to the area, and full-time residents, who experience only the nuisance value of the airport and none of its benefits and who engage in campaigns to either limit aviation activity at the airport or relocate the airport to a more remote location. The attractiveness of the area for second homes ensures high property values, limits the capacity of airports to restrict encroachment through land purchase, and leaves airports dependent on land-use regulation to limit encroachment.

Larger airports with extensive general aviation activity would slowly replace propeller-craft with more light jets, and they will develop special general aviation terminals with an elevated level of amenities and special surface transportation options. Scenario adaption may include satisfying the needs of business travelers by providing lounges suitable for work or rooms suitable for private phone calls. However, in a COVID-19 context, business aviation is being driven by the desire to avoid potential infections, which may result in an additional emphasis on moving as rapidly as possible between an aircraft and a surface vehicle.

In the airport resort development scenario, airports function as connected activity centers by using aviation to connect a remote region characterized by tremendous natural beauty and a thriving tourist economy to distant population centers, often facilitating second homeownership. Rather than focusing on becoming a jet-capable airport, the focus remains on providing casual, comfortable, and friction-free general aviation travel by facilitating the intermodal interface between air and surface transportation modes.

Conclusions & Implications

Developing an airport as a connected activity center is difficult. Airports are often a forgotten major land use because they are insular. They are more likely to represent a barrier to surface travel than to facilitate it because airports represent a walled compound with controlled access. Secondly, on-airport improvements tend to be self-funding through a mix of fees and federal grants, mitigating the need to engage with regional planning activities to receive infrastructure funds. Eventually, the need for congestion-free transportation access to airports drives engagement with both transportation and land-use planning. As Prins (2008) notes, "Airport authorities themselves are no longer mere transport suppliers but full-fledged economic actors," so the era of splendid isolation, in which airports merely provide infrastructure for airlines, is over. The "review of the features of and trends at airports reveals that when airports change from transport node into a full-fledged hub, they seem to come at a turning point; they transform from an infrastructure facility to an economic system" [132].

For airports to operate as connected activity centers, cooperative planning between airports and land-use agencies is required. This cooperation is often difficult to begin. Many airport engagements can be characterized by obedience to their sponsoring government and Federal Aviation Administration regulations; they can convey a pugnacious attitude toward other jurisdictions. Kasarda's writings about attempts to create an aerotropolis make clear that jurisdictional fragmentation and conflict underlie most efforts. (Although evidence also suggests that even autocratic control of development is subject to sudden reversals in policy and funding.) Cooperative planning and development of airports rely on a sustained and shared vision; the scale of infrastructure investment associated with the development (or redevelopment) of a new airport is too large to be accomplished quickly.

As long as networks of aviation routes exist, the hub-and-spoke network pattern will emerge. As long as it does, hub airports will continue to exist and represent a supermajority of enplanements. Accordingly, a small number of airports will continue to experience increasing activity (barring the vagaries of fuel prices, economic conditions, and disasters such as the September 11th terrorist attacks and COVID-19). Increasing activity at those airports will require continued development and redevelopment of existing airports; the foundation of new hub airports (necessarily at the periphery of urban areas) will continue to be a rare event. Denver International Airport was the last example, which occurred over 15 years ago. Upgrading smaller reliever airports to commercial service standards and displacing general aviation to small airports with shorter runways offers a temporary respite from the problem.

While improvements in air traffic control, artificial intelligence, and automation will improve the safety and efficiency of aircraft operations over time, the need to continue to expand hub airports will remain. Consequently, as airports expand, they will no longer be able to use space to buffer themselves, and there is a real need to ensure that airports 'fit' into the urban fabric with compatible and airport-oriented uses in proximity. The best development practice for all scenarios is managing the relationship between an airport and its surrounding urban area, along both the fenceline edge of the airport and along the surface transportation network connection to and from the airport.

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132 Prins, M. (2008). Landing an airport? Airport development and strategic land use planning in the EU. na.

Appendix A: Trends Shaping the Future of Aviation

Two trends and their convergence are explored here: electrification and automation. Electrification changes the economics of air transportation, offering a reduced range in exchange for lower fuel costs. Automation offers the promise of replacing expensive pilot labor with automated vehicles with a consequent reduction in the cost of transportation.

Electrified Aircraft and Air Transportation

Electric aircraft are quieter and require less maintenance than fuel-powered aircraft [133,134]. They also suffer from both payload and range restrictions [135]. While battery technology has improved substantially and seems likely to improve, electric aviation faces substantial barriers. The energy density of jet fuel is currently 43 times that of batteries. Hence, the weight of batteries represents a critical limitation to electrified aviation. Research and development are ongoing with battery technology improving at 5 to 8% a year [136]. The suggested threshold for competition for jet fuel for commercial aviation is that batteries must become five times as efficient, suggesting that commercial electric operation is 30 years away [137]. Electric aviation development efforts are focused on smaller aircraft (regional jets, business jets) whose use is characterized by shorter flights and smaller flight distances [138] as well as flight training and air taxi. The immediate future in electric aviation may not be in long-haul aviation but in short flights, such as air taxi operations and/or shuttle routes [139,140]. “Short-haul regional services have been on the decline in the United States for a variety of factors; the advent of low-operating-cost electric aircraft could reverse this trend” [141]. With current technology, the maximum possible endurance is 200 to 400 miles [142], a limitation offset by operating costs. Electric aviation could be expected to offer a 30% reduction in operating costs [143]. It may also revolutionize pilot training by reducing the associated costs [144,145].

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133 https://psmag.com/environment/cop24-electric-aviation-is-poised-for-a-revolution-and-its-about-time

134 https://www.economist.com/science-and-technology/2015/09/17/electrifying-flight

135 https://evtol.news/2019/08/29/the-potential-of-ectol/

136 https://techcrunch.com/2018/07/08/the-electric-aircraft-is-taking-off/

137 https://www.wired.com/2017/05/electric-airplanes-2/

138 https://techcrunch.com/2018/07/08/the-electric-aircraft-is-taking-off/

139 https://spectrum.ieee.org/aerospace/aviation/cheaper-lighter-quieter-the-electrification-of-flight-is-at-hand

140 https://psmag.com/environment/cop24-electric-aviation-is-poised-for-a-revolution-and-its-about-time

141 Short-haul regional services have been on the decline in the US for a variety of factors; the advent of low-operating-cost electric aircraft could reverse this trend.

142 https://www.wired.com/2017/05/electric-airplanes-2/

143 https://www.economist.com/science-and-technology/2015/09/17/electrifying-flight

144 https://byeaerospace.com/

145 https://byeaerospace.com/electric-airplane/

"As technologists have shown time and again, if you bring down the cost of a product dramatically, you effectively create an entirely new product. Look no further than the $300 supercomputer in your pocket" [146].

Electric Vertical Take-Off and Landing (eVTOL)

Electric Vertical Take-Off and Landing (eVTOL) is an area of active interest. Electric helicopters have existed for a decade [147], but as helicopters are less energy-efficient than fixed-wing craft, they have even more limited range endurance; the current world record stands at about 30 miles [148]. Suggested use for this technology includes transporting high-value cargo, such as transplant organs [149]. Electrical helicopter battery weight currently stands at 1,100 pounds, with an expected useful payload of 600 pounds and an hour of flight time.

Improvements in battery technology and cybernetic controls mean that multi-rotor drone aircraft have gone from being toys to industrial workhorses in less than a decade. Multi-rotor aircraft emerging from the 'drone' paradigm are entering commercial deployment. The recent feasibility of eVTOL is thanks to the rapid convergence in technologies "including advances in electric motors, batteries, power management systems, fly-by-wire flight controls and lightweight composite structures" [150]. Many eVTOL vehicles are still in the demonstration phase [151,152,153,154,155,156]. An experimental application is underway in Dubai [157]. The single-seat EHang 184 began demonstration flights in 2016 [158], and the two-seater EHang 216 has received a special 'specific operational risk assessment' to permit it to carry passengers; it began making deliveries in 2019 [159].

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146 https://spectrum.ieee.org/aerospace/aviation/cheaper-lighter-quieter-the-electrification-of-flight-is-at-hand

147 https://en.wikipedia.org/wiki/Sikorsky_Firefly

148 https://cleantechnica.com/2019/01/26/electric-helicopters-are-coming-new-guinness-world-record-for-farthest-flight/

149 https://www.verticalmag.com/news/why-an-electric-r44-helicopter-makes-more-sense-than-you-think/

150 https://www.verticalmag.com/press-releases/vfs-reports-more-than-200-evtol-aircraft-now-in-development/

151 https://robbreport.com/motors/aviation/bell-air-taxi-concept-2772624/

152 https://en.wikipedia.org/wiki/Airbus_CityAirbus

153 https://mashable.com/article/surefly-workhorse-octocopter-drone/

154 https://cleantechnica.com/2019/05/06/electric-aircraft-will-help-save-the-world/

155 https://www.theverge.com/2019/1/7/18168814/bell-air-taxi-nexus-uber-flying-car-hybrid-ces-2019

156 https://evtol.news/2019/08/24/first-turkish-evtol/

157 https://www.airspacemag.com/articles/fly-through-air-greatest-ease-180962272/

158 https://evtol.news/aircraft/ehang/

159 https://evtol.news/2019/08/24/ehang-operational/

Experiments in developing such vehicles are ongoing; in May 2019, Airbus tested a ducted-fan vehicle [160] and the NEC corporation provided a testbed for eVTOL in Tokyo [161]. Quantum is currently building traffic on routes by using conventional aircraft for commuter routes but plans to replace them with VTOL craft later. It anticipates four years before the general advent of VTOL and five to seven years before it becomes endemic [162]. Interim applications for eVTOL include delivery for hard-to-reach or remote locations [163].

Rotorcraft may be slower to market for reasons of certification, as the distinct characteristics of electric motors imply a different type of airframe. Electric motors are smaller, lighter, and have higher low-end power input. These characteristics affect the design of airframes, the distribution of engines, and the size and shape of wings. Resultant aircraft are unlikely to resemble existing typologies and may more closely resemble drone aircraft. Historical forms, such as autogyros [164] or gyrodynes, may also be more feasible.

Fixed-Wing Electric Aviation

Fixed-wing electric aviation is closest to realization, simply because using existing airframes reduces certification difficulties, as only a Supplemental Type Certificate (STC) is required [165]. Electrified vintage floatplanes flying routes of about 30 minutes are already in operation within the Pacific

160 https://www.aviationtoday.com/2019/05/06/city-airbus-evtol-prototype-makes-first-flight-germany/

161 https://evtol.news/2019/08/24/nec-flies-testbed/

162 https://evtol.com/features/meet-quantum-xyz-electric-aircraft-startup/

163 https://spectrum.ieee.org/cars-that-think/aerospace/aviation/japan-on-track-to-introduce-flying-taxi-services-in-2023

164 http://sustainableskies.org/electric-autogyro/

165 https://evtol.news/2019/08/29/the-potential-of-ectol/

Northwest [166]. Small one-and two-seater planes used for training [167] or air racing [168] are already feasible.

In 2017, Slovenian-based Pipistrel released a purely electric aircraft, the Alpha Electro, which was the first aircraft to be FAA certified in the Light Sport category. Pipistrel began selling the 4-seat electric Panthera plane in early 2020 [169]. Pipistrel was recently acquired by Textron [170], whose deep pockets and expertise in developing and certifying aircraft, will accelerate development. Flight training may be a highly viable market for electric aviation, as neither range nor load requirements are substantial. Bye Aerospace is taking deposits for both 2- and 4-seat electric aircraft, for plans to use both as trainers, noting the heavy fuel use otherwise associated with the activity [https://www.newdelhitimes.com/us-textron-to-acquire-slovenian-electric-aircraft-pioneer/ 171]. Ampaire plans to retrofit an existing nine-to-19-seat commuter/cargo aircraft with electric motors [172]. Quantum Air has purchased an all-electric four-seater for Bye Aerospace for use in Air Taxi. Other virtues

166 https://psmag.com/environment/cop24-electric-aviation-is-poised-for-a-revolution-and-its-about-time

167 https://www.wired.com/2017/05/electric-airplanes-2/

168 https://cleantechnica.com/2019/02/09/welcome-to-the-era-of-electric-airplane-racing-airbus-becomes-official-founding-partner-of-air-race-e/

169 https://www.flyingmag.com/pipistrel-four-seat-panthera-first-us-flight/

170 https://byeaerospace.com/eflyer/

171 https://byeaerospace.com/eflyer/

172 https://www.ampaire.com/news/press-release-hybrid-strategy-071719

of eSTOL are cited as having lower operating costs, development costs, and noise production than eVTOL [173].

In contrast, electrification is unlikely to affect long-range passenger aviation: “The bigger and faster an electric airplane gets, the greater the number of batteries it needs and the greater the share of its weight those batteries constitute” [174]. It is unlikely but possible that it could be achieved by returning to a flight stages style of operation that characterized early aviation transcontinental flight, with aircraft making repeated fuel stops to charge up along the way. Swapping batteries rather than waiting for charging has been suggested as a mechanism to reduce turn-around time [175]. Lithium-sulfur batteries offer the promise of higher energy density but remain years from production [176]. Hydrogen power aviation remains in the conceptual phase [177]. In contrast, Israeli-based Eviation has an electric nine-seat V-tailed airframe that will begin making its first flights this summer [178].

Electric Short Take-Off and Landing (eSTOL)

STOL aircraft are characterized by the ability to take off and land on very short runways and are characterized by large power/weight ratios and a high rate of climb to clear obstacles [179]. In addition to rough fields or harsh environmental conditions, this makes them capable of operating at smaller airports with shorter runways, including some close-in urban airports such as the London City Airport [180]. Characterized by runways under a mile in length, past cases of these specialized airports (STOLports) had a service pattern characterized by short-range shuttle flights, but public opposition to noise typically spelled their demise [181]. The combination of high power and low noise suggests that electric aviation might be able to overcome this limitation to provide commuter or shuttle service. AirFlow is in the process of developing an eSTOL cargo vehicle for the 250-mile range to serve same-day logistics needs, noting lower development costs than a comparable vertical take-off and landing cargo vehicle [182]. Airflow claims a 500-pound payload is feasible, and that runways as short as 300 feet will be possible [183]. MetroHop is a prototype aircraft capable of take-off and landing on a 300-foot runway able to carry payloads up to 1000 pounds; low RPMs make the aircraft extremely quiet [184]. The

173 https://evtolinsights.com/2020/07/market-opportunities-for-estol-technology-discussed-at-electric-aircraft-symposium/

174 https://spectrum.ieee.org/aerospace/aviation/cheaper-lighter-quieter-the-electrification-of-flight-is-at-hand

175 https://www.aviationtoday.com/2019/10/08/urban-air-mobility-coming-focus-two-companies-present-alternative-visions/

176 https://spectrum.ieee.org/aerospace/aviation/with-ultralight-lithiumsulfur-batteries-electric-airplanes-could-finally-take-off

177 https://spectrum.ieee.org/energywise/energy/environment/airbus-plans-hydrogenpowered-carbonneutral-planes-by-2035-can-they-work

178 https://evtol.news/2019/08/29/the-potential-of-ectol/

179 https://en.wikipedia.org/wiki/STOL

180 https://en.wikipedia.org/wiki/London_City_Airport

181 https://en.wikipedia.org/wiki/STOLport

182 https://www.avweb.com/recent-updates/evtols-urban-mobility/airflow-unveils-estol-cargo-concept/

183 https://www.ainonline.com/aviation-news/business-aviation/2020-06-10/airflow-launches-estol-electric-cargo-aircraft

184 https://evtolinsights.com/2020/07/market-opportunities-for-estol-technology-discussed-at-electric-aircraft-symposium/

proposed use is connecting fulfillment centers to hospital campuses, as hospitals have limited storage and make extensive use of express delivery [185]. Pyka has a prototype designed for crop dusting [186].

Advanced Air Mobility

Advanced Air Mobility is the combination of electrification and automation, where "highly automated aircraft that will operate and transport passengers or cargo at lower altitudes within urban and suburban areas" …using…" existing helicopter infrastructure such as routes, helipads, and Air Traffic Control services" [187]. The premise suggests that the economics of electric aviation will make VTOL rotorcraft both safer and cheaper to operate thus making helicopter taxis economically feasible beyond a small pool of high-income individuals they currently serve.

Distributed electric propulsion reduces costs, emissions, & noise

Pilot assistance systems reduce pilot demand & increase safety

Powered lift allows close-in access at new locations

On-demand service allows seamless integration into ground mobility services

The promise of automation suggests a catalytic effect by replacing expensive pilot labor with capital investment, thereby further reducing prices and increasing demand. Increased demand then supports a broader rollout of the service, and the network effect supplies a reduction in associated waiting time and further expansion of demand. This model is premised that the model of surface transportation ridesharing companies is a) sustainable and b) generalizable to air transportation.

Autonomous aircraft are promising but uncertain. Autonomous cars have proven significantly more difficult than anticipated, and autonomous vehicles remain unable to operate outside of controlled environments, making them unsuitable for use in complex urban environments. Generalizing this to aircraft suggests that autonomous aircraft providing friction-free point-to-point transportation for either passengers or cargo is a long way off. In contrast, the intermediary status, with autonomous aircraft flying controlled paths between controlled locations, is technologically feasible today. The public acceptance of the noise and perceived risk of VTOL delivery or travel remains uncertain, as does the economic viability. Unable to provide point-to-point service, VTOL delivery will require endemic depot facilities. Ridesharing services in surface transportation enjoy access to a network of public streets, an

185 https://www.aviationtoday.com/2019/10/08/urban-air-mobility-coming-focus-two-companies-present-alternative-visions/

186 https://evtol.com/features/pyka-autonomous-electric-stol-planes/

187 https://www.faa.gov/uas/advanced_operations/urban_air_mobility/

advantage not shared by aerial transportation. Public opposition to VTOL delivery depots is likely to be fierce due to noise impacts limiting the widespread penetration necessary for a sufficient network effect to make it economical. Heavy users of delivery services may represent a bridgehead for an urban air mobility delivery network, as might noise-insensitive light-industrial districts.

Aviation requires space to maneuver. Space in urban environments (where demand for transportation is greatest) is scarce, suggesting that future landing sites will likewise be difficult to obtain and hence scarce, thus limiting their utility, and casting doubt on the future of urban air mobility [188]. Further obstacles include regulatory constraints, long approval times, and concerns around noise pollution [189]. Increasing their prevalence will be slow: helipads atop buildings require specialized construction and their safety record is poor. An effective solution may lie in making use of the (often underused) top deck of urban parking garages. While a combination of safety and noise issues limit point-to-point operations in an urban context, point-to-point flight by quadrotors in a suburban context using low-traffic streets and backyards as landing points is being explored by FLUTR Aviation [190].

Electra.aero suggests that eSTOL is preferable to eVTOL, given that "the very high energy costs of VTOL devices and the low energy-storage capacity of batteries will likely limit such vehicles to ranges of 50 miles or less…not enough to change the paradigm of regional travel" [191].

Hybrid Electrics

There are a larger number of efforts underway to develop electric aircraft, including hybrid electric systems. Hybrid-electric aircraft enjoy range and load advantages over purely electric aircraft, as they enjoy both the benefits of electrified engines and the energy density of fuel, with ranges of 100-1000 miles [192]. Electric aviation offers an opportunity to revolutionize airframe design. "Electric motors are substantially smaller and lighter than jet engines of equivalent power. This allows them to be placed in different, more favorable locations. In this case, the engines are to be mounted above and distributed within the wings rather than suspended below them" [193]. Further, the capacity of an electric motor to provide power on demand at low speeds may also reduce the necessary wing size. Pipistrel has a 19-seat hybrid-electric model on the drawing board. Another firm, Ampaire, has developed a novel hybrid in the form of a pusher-puller configuration with one electric and one gasoline motor in a Cessna 337 Skymaster, with flight trials for Hawaii-based Mokulele Airlines in 2019. Zunum Aero was developing a 12-seat hybrid but has since folded [194]. Airbus had a plan for a 90-seat regional jet, the E-Thrust, but has shelved work on it, in favor of the E-Fan project to convert a British Aerospace BAe 146 regional jet to hybrid electric [195].

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188 https://www.aviationtoday.com/2019/10/08/urban-air-mobility-coming-focus-two-companies-present-alternative-visions/

189 https://www.aviationtoday.com/2019/10/08/urban-air-mobility-coming-focus-two-companies-present-alternative-visions/

190 https://www.aviationtoday.com/2019/10/08/urban-air-mobility-coming-focus-two-companies-present-alternative-visions/

191 https://www.electra.aero/

192 https://psmag.com/environment/cop24-electric-aviation-is-poised-for-a-revolution-and-its-about-time

193 https://aviationweek.com/technology/nasa-tests-distributed-electric-propulsion

194 https://evtol.news/2019/08/29/the-potential-of-ectol/

195 https://evtol.news/2019/08/29/the-potential-of-ectol/

Implications for Airports as Connected Activity Centers

If electrification lowers the operating cost of flying, it will increase the demand for flying. Long-haul jet flights are the most resistant to electrification; even short-haul jet flights remain some distance in the future. Electrification (and hybrids) seem most likely to revitalize the General Aviation market for fixed-wing aircraft. Yet electric aviation will impose the 'range anxiety' of early electric automobiles to a whole new degree, and it is reasonable to expect an increase in the number of events analogous to 'ran out of fuel' due to variabilities in battery capacity with age and weather. This suggests that the presence of a network of 'reliever' airports may become necessary. At the same time, a reduction in operating costs may revitalize general aviation and make general aviation touring feasible once again, such that visiting aircraft could outnumber based aircraft for more airports. It thus represents an opportunity for airports to leverage themselves as destinations, rather than just way-stations. After decades of rising, the median age of pilots is starting to fall, and Millennials are strongly oriented toward 'experiential' tourism—go someplace and do/see something, rather than go someplace and buy something. Conspicuous consumption now requires things that cannot be bought on Amazon. To that end, general aviation airports might co-locate with a unique restaurant, brewery, art establishment, or other activity, on airport property.

Electric aviation will change the nature of fixed-base operators at airports—battery charging remains slow, and the provision of substantial amounts of electricity requires a different infrastructure than providing fuel. Remote installations disconnected from the power grid may become less feasible. Airport Rescue and Fire Fighting (ARFF) will need to develop the capacity to put out lithium fires--something that proved exceedingly difficult during an electric vehicle crash [196].

Changes in the infrastructure associated with airports have implications for on-airport uses. In an age of electric aviation, heavy users of electricity, such as some classes of light industrial, could be expected to co-locate with airports. Example uses might include data centers, greenhouses, or refrigerated storage.

eVTOL/eSTOL Implications

Electric rotorcraft capable of VTOL have quite different implications for airports, for the form of airports, and for airports as connected activity centers. Many of the proposed uses for eVTOL are last-mile services from major airports, providing a costly but high-speed connection to and from the airport. Multiple rotor eVTOL has the potential to be revolutionary. Helicopters have existed for 75 years, and multi-rotor aircraft have only been viable for about five years. For short intra-urban trips, the range limitations of even current batteries are less significant. A technology capable of offering a fast and reliable (congestion-free) trip between two points within an urban area for a small multiple of the cab fare for the journey could revolutionize urban transportation. Lacking the need for an approach path, any location with sufficient clearance for VTOL could emerge as a node in the transportation network, including parking lots, parking decks, and the tops of buildings. The future that the dirigible mast atop the Empire State Building was designed for might finally have arrived.

The effects of the 'Uberization' of surface transportation provide general guidance on the effects. Trip ends are likely to remain tightly clustered, with service provision focused on a small number of districts

196 https://www.reuters.com/article/us-tesla-crash-ntsb/u-s-opens-probe-into-fatal-tesla-crash-fire-in-california-idUSKBN1H32OT

where it is most profitable. This would include transportation terminals, mass gathering spaces, and major employment centers. But these places will require the necessary space for eVTOL operations, not only for vehicle movement but also for approach paths. Rotorcrafts are noisy; even if eVTOL vehicles are quieter, expanded operations will represent the imposition of noise nuisance to a much wider variety of locations. While not 'airports' per se, they will need to exceed the historic role of the helipad, providing much more capacity, space for parking, and charging stations. Such helicopter stages will hence have more people staying for longer and will need additional hospitality facilities (waiting rooms, bathrooms, retail, and personal services). They are also a natural location for hotels to locate. The helicopter stages will also require surface transportation access, in the form of ride-hailing lots or parking lots. The increased use of eVTOL for urban transportation will affect connectivity to exurban locations. While major mountain ranges may remain impassable, rivers, hills, freeways, bridges, and smaller mountain ranges will cease to be a barrier. The creation of a network of eVTOL nodes also makes a system of air ambulances more feasible, suggesting co-location with major emergency hospitals. Before the establishment of such a network (and after), the role of air stages will likely be placed upon existing general aviation airports within the urbanized area. Point-to-point aviation seems unlikely.

Fixed-wing eSTOL will require greater footprints but offer a greater range. The likely effect will be a substantial increase in air taxi operations, due to reduced fuel costs, with an accompanying emphasis on maintaining efficiency through rapid turn-around and limited downtime. Consequently, eSTOL could result in an extremely high demand for operation capacity. This suggests the private provision of STOLports might be feasible: shorter runway lengths and quieter operations imply lower real estate needs and associated costs, as well as increased capacity to fit them into an urban context. (Most current 'urban airports' were rural before urban expansion). Smaller in size than many rapid transit stations, STOLports could support Aviation-Oriented Development in much the way rapid transit supports Transit-Oriented Development.

Advanced Air Mobility Implications

When (and if) aviation can be successfully automated, and that automation is demonstrated to be safe, and certified accordingly, it would represent a completely new mode of transportation. Automated cars have long been predicted to be the heralds of 'Mobility as a Service' where on-demand services substitute for personal vehicles. Unlike automobiles, urban air mobility would have far less competition for space and would be free of the roadway capacity constraints that have proven a decisive limitation on the triumph of automobility. This could herald another iteration of sprawl development by making longer commutes feasible in much the same way that partial automobile automation already has.

Even if eVTOL/eSTOL can operate at low speeds and make use of small landing strips, it will not change the operational characteristics of traditional aircraft. Accommodating prior users of the airspace, such as passenger jet aircraft and military airspace will significantly limit operations, especially in urban areas. Air Traffic Control systems and regulations designed for a different era will prove difficult to adapt.

Changes in mobility (however extreme) will do little to alter the distribution of already existing structures in the built environment, suggesting that dense areas will still generate many trips. Consequently, vehicle storage would still be a problem, both for boarding and alighting, but also for storage of vehicles waiting on new passengers. Urban air mobility would still suffer from the taxi-stand problem, where curb management is key, necessitating the aerial analog of a ride-hailing lot.

Conclusion

Electric aviation has a real potential to revolutionize air transport because it changes the economic fundamentals, offering dramatically lower fuel costs but dramatically lower endurance. The combination of the two suggests a substantial increase in the feasibility of short-distance flying. Flight training and air taxi operations will represent the initial adopters. It seems likely electric aviation will spread widely through the single-engine general aviation fleet, a feat made possible by supplemental-type certificates modifying existing airframes. It may likewise revolutionize short-distance jet travel, by making short hops sufficiently economical to be common. It seems unlikely to change the economics of long-distance passenger jet aviation, due to the comparative energy density of batteries and jet fuel.

The primary impact of electrified aviation will be a resurgence in general aviation activity, with concomitant demand for runway capacity. Meeting this may require either expanding existing airports or opening new airports. Electrified aircraft will likely be capable of shorter ascents on shorter runways such that small private airports will be more feasible.

While promising, autonomous aviation is in its infancy. Where it exists, it consists entirely of prototypes of uncertain and unknown effectiveness, let alone economic feasibility. For Advanced Air Mobility, efforts to integrate the new airframe designs induced by electric aviation and new business models associated with ride-hailing suggest a bumpy road with uncertain success. For freight applications, Advanced Air Mobility relies on the assumption that high-value, low-weight, and time-sensitive freight will be endemic; that demand for next-day fulfillment will continue to grow. Drayage/cartage of freight over short distances will require offering a competitive advantage in time or cost over delivery trucks. Longer distances energetically favor eSTOL over eVTOL. Urban Air Mobility is further constrained. Even if these limitations are overcome, public acceptance of noise and safety impacts of a massive increase in aviation activity in an urban context suggests difficulties for Urban Air Mobility, and an extensive lead-in and adoption period.

Transportation takes space. Aviation does not benefit from an existing network of landing zones the way ride-hailing companies benefit from curb space. Advanced Air Mobility will require the widespread provision of helipads or landing strips, where no such network currently exists. Accordingly, they will likely be (at least initially) integrated into or at the edge of existing airports. Long term, the small footprint of eVTOL and eSTOL may permit the private sector provision of small airports, contingent on effective noise management.