Technological Standardization in the Horizontal Skyscraper Airport

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Abstract

As hubs, airports serve to connect the movement of millions of citizens across local, regional, state, national, and global boundaries. To facilitate the rapid access to these movements through airspace, airports design airport buildings and space horizontally as one large unit that integrates multiple stakeholder needs, information and communication systems. Along with these various stakeholders and their needs comes the application of innovative technologies that deliver increasingly granular data on the day-to-day operations. The current impetus for airports is to synergize their own internal needs with their stakeholders by building bridges between internal and external systems and technologies in order to improve the flow of passengers and ensure increasing revenues and enplanements, while protecting proprietary or personal information.

For example, Las Vegas Airport, which serves as a destination location for many countries across the world, created an evolving technology architecture born in the 1990s and iterated successfully into newer versions to present day. This airport operational database and architecture has enabled them to establish a deep historic archive of data flows reporting out from multiple aspects of airport operations such as baggage systems, ticketing, ground transportation services, into a central integrated information system. By gathering this data, performance metrics and improvements were made to how passengers were processed from check-in, through security and on to gates. This resulted in increased revenue for the airport as a result of the increased time for passengers to stop and shop at airport vendors. Specific technologies applied in the Las Vegas architecture include sensors, networks, standards, and a method to convert and connect data into information on how a passenger moves across various staging areas of the airport. By developing an architecture, the Las Vegas airport effectively created a standard for how it procured systems, favoring those that were more modular and worked within the umbrella airport integrated information system developed in-house by Las Vegas airport. This research delves into how international standards and current technology developments affect the degree to which airports serve as efficient hubs of passenger, and freight flows.

1.1 Introduction

Airports serve as regional, and international gateways through use of a variety of subsystems connected to airline, retail, and passenger stakeholders and their associated needs. As new technological advances lead to increased communication and reliance on emerging data sources in daily operations, there has been a push to establish standards and protocols for system-of-systems based management processes within airports.

In the 1990s airports and airlines began installing more complex information system architectures and databases recognizing the capability to leverage deeper insights arising from connections between operational subsystems. Examples of these subsystems include: Southwest Airline's use of engine telematics on fuel use and financial information systems with procurement/market price forecasting (1); and Las Vegas McCarran International Airport's databases capable of integrating baggage flow and financial data to arrive at baggage system operational costs that incorporate service standards for lost or damaged luggage (2). The success of these efforts establishing greater connectivity through use of needs-driven information system architectures resulted in a competitive advantage from exploiting them, and a proliferation of similar investments in IT and communications architectures in other airports and airport stakeholders.

In the mid-2000s freight and supply chain systems associated with Amazon and Wal-Mart derived similar advantage by using Radio Frequency ID Tags (RFID) to emit real-time location data and cargo monitoring which further improved delivery schedules and enabled operational benefits associated with reduced warehouse spacing and improved customer order/market needs assessments (3). This use of wireless technology filtered into airports that installed RFID on high dollar asset systems such as luggage carts to monitor their locations in real time (4). At the same time, data emerging from these monitoring systems began to connect with smart phone devices carried by passengers and airport personnel providing real time locations via Wi-Fi and Bluetooth sensor data. These connections also fed into airport operations architectures and databases enabling greater operational visibility and revenue potential for airports. As the use of internet-connected devices, sensors, and equipment proliferate, airports may obtain competitive advantage when they develop flexible, and modular information technology architectures to advance new operational concepts that address challenges and shifting customer demands associated with these new technologies. For example, figure 1 displays the concept for an airport bathroom that is connected in real time to maintenance information systems displaying the status of the bathroom.

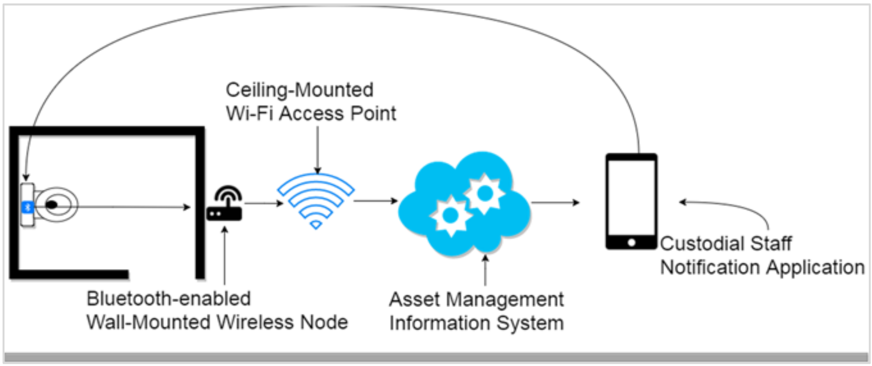

Figure 1- Smart Bathroom Pilot Concept

In the following sections, the paper will examine key airport stakeholder and customer needs. Following this the paper will discuss system-of-system communications standards in connection with new airport technologies. It will cover an expected need of airport systems to integrate broader navigation systems associated with ground transportation and pedestrian foot traffic, and it will illustrate considerations for adding value to data mining and information integration efforts in the current airort environment

1.2 AIRPORT KEY STAKEHOLDERS: AIRLINES, RETAIL, AND PASSENGERS

International standards for communication and internet technology development and deployment have evolved over the past 30 years based on market needs and relatively recent technological advances. An understanding of retail, airline, and passenger markets as airport customers and key stakeholders is important to understanding the development of international standards in the context of how it affects airports and their place as regional, national, and international gateways.

1.2.1 Airlines

Commercial aviation is rapidly developing new big data systems that interconnect data sources and information flows from internal and external systems. For example, the Fly Dubai airline is seeking to develop a scheduling system that integrates airport-based delay data in a real time input-adapt relationship, while the Qantas airline is integrating real time sensor data from airplane engine maintenance systems to on-the-ground maintenance services (5). As customers, airlines will increasingly rely on airports to provide greater integration of communication and data transfer capabilities from weather information systems on the ground, delay and gate capacity data from airport operations (6). Some airlines install after-market sensors onto their aircraft engines because of proprietary telematics data blockage between airlines and engine manufacturers who do not want to connect their internal engine data systems to airlines maintenance systems. Engine telematics data also represent a new potential source of information that could help airports improve gate scheduling, and routing functions within airport operations. If an aircraft scheduled for a gate alerts airlines and airports about an engine maintenance requirement in flight that could lead to a delay, this information provide for a schedule and gate reassignment update in advance, which would help improve gate operations.

In 2000, Airlines for America developed iSpec2000 standard to guarantee airplane manufacturers develop flight control systems that quickly communicate clear technical information and data transfer protocols to pilots and central flight monitoring systems with all airlines (7). iSpec2300 makes additional improvements to how technical data is conveyed to airlines for operational system integration, but it does not open all engine telematics and associated data on engine performance to airlines (8). Airplane manufacturers rely on engine manufacturers like Rolls Royce to provide engines on their airplanes. The internal data systems associated with airplane engines are thus, one manufacturer-removed from proprietary control and the iSpec2300 standards.

Much as the same reason airlines guard their scheduling systems and maintenance systems as proprietary data from connecting with airport operations and federal system-wide information management system (SWIM), engine manufacturers prevent their engine telematics system from connecting with airlines and airplane manufacturers. Presently, intermediary operations service providers like SAAB use SWIM in conjunction with other data systems to operate its departure management system at JFK (9). The SAAB approach serves as a work around in conjunction with integration of other FAA and non-FAA data sets to bridge the data gap between airline and airport systems and improve gate and terminal and gate operations.

One potential path forward is the use of smart data contracts that stipulate use restrictions and result in the conveyance of reformatted data scrubbed of proprietary information but still useful for airport operations. This technology path is tied to data vending block chain applications, which help give greater control over what source owners deem proprietary information. Figure 1 illustrates how this type of blockchain approach works (10).

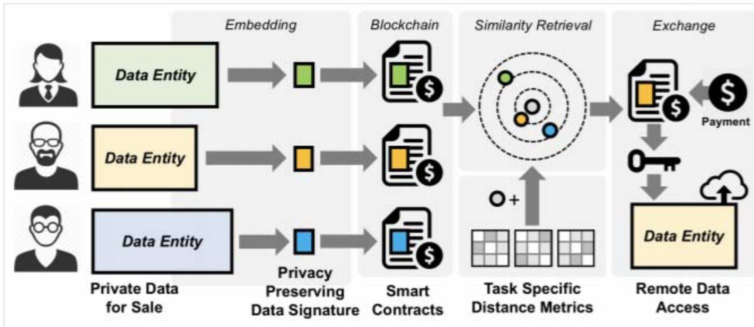

Figure 2-Data Vending Blockchain Concept.

1.2.2 Retail

When considering airports as destinations, the current public perception is to provide high marks for airport retail and concessions. For airports, the ability to attract the right mix of regionally flavored retail for place and national retail with brand recognition for good quality often comes down to availability of specific locations within the airport and the quality of supporting IT and communications infrastructure (11). Retail vendors increasingly bring new technologies and service innovations to their storefronts in order to gain competitive advantage, which may include location-based marketing, reservation, and payment based systems tied to wireless networks, Internet-of-Things (IoT) sensors/devices, and smartphones (12).

In the 1990s airports began using private vendor management companies (VMCs) to run-in-terminal programs for retail. VMCs were involved prior to this in large mall management operations and brought with them greater information on which stores fit in given locations and performed well region-to-region. In the 2000s, VMCs established connections to airport schedule and operational databases that provide approximate passenger volumes by time of day, some in real-time and some using historic counts (12). This relationship between VMCs and airport operations resulted in greater demand for high-speed internet at retail locations to accelerate faster payment processing as well as offer a coordinating presence for brand management and new technology adoption.

VMCs served in this role in the 2000s and to this day as the interface for vendors, retail, and their brand and quality standards in retail locations and as key stakeholders in communicating retail needs to the airport. At the Columbus International Airport in Ohio active relationship building and data exchange on passenger volumes has facilitated shifting schedules and store locations to better accommodate passenger traffic (13). For example, using passenger traffic data, the concessions manager at the airport had a nationwide coffee vendor's schedule extended and then moved the storefront to the baggage departure terminal area to accommodate late arrivals in passenger traffic. This move resulted in increased revenue for arrivals traffic who wanted coffee and food options before collecting their baggage and departing the airport.

Since 2009, retail sales at airports have grown at 12% per year, with greater information exchange between airport operations and retail vendors as to when optimal "golden hour" will take place in any given day (14). Retail at airport takes place in a data rich environment and because retail revenue pays dividends in non-aeronautical income to the airport, it becomes clear why this exchange has been so ensconced.

According to a major VMC, a key standard update driving airport retails is the February 1st, 2018 payment card industry data security standard, PCI DSS 3.2 enforced by major credit card companies (15). Presently, 85% of airports are moving towards airport application-based purchases for all airport services such as parking, luggage carts, etc (16). This airport application approach potentially exposes airports to the risk of data breaches as their applications age, or PCI non-compliance because of aging code within their airport applications (17). On the airport retail side, in response to this standard, VMCs are presently evaluating the development of a central application-agnostic middleware platform, which would serve to connect and verify PCI DSS 3.2 standards in use by all vendors in their retail group and vet their coding before accessing payment processing through the platform (12).

1.2.3 Passengers

Passengers bring wireless and IoT devices like iPhone, and Fitbit into an airport environment. These devices switch operational profiles to adapt to the airport infrastructure and the web of communication layers. For example, on approach to an airport, prior to entering the airport property, a passenger may rely on their smartphones and navigation applications on the roadway. The smartphone may encounter the first airport communication boundary as it enters the airport property and a geo-fence, which is a virtual fence, put in place by some airports to mark when a vehicle or passenger enters the airport grounds. In some airports the airports' ground traffic management department in conjunction with the airport IT department uses a geo-fence. The San Francisco International airport deployed a geo-fence to count Uber and Lyft users to assign fees to these companies for their access to the airport initially, but now have the option to also count passengers with smartphones as they cross the virtual boundary (18). Figure 3 details a map used by the ground transportation management department at SFO.

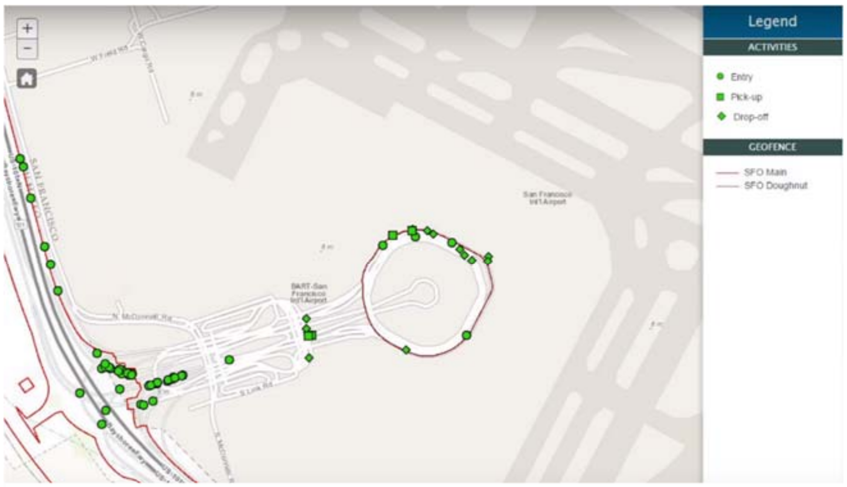

Figure 3- San Francisco International Airport- Transportation Network Company Geo-Fence

Passengers then depart their vehicle and enter the check-in area. In many airports, this is the extent of where their vehicle navigation application ceases to provide navigation details. The passenger may switch to an airport application for navigation or rely on analogue wayfaring and signs to move about (19). Some airports maintain facility maps in digital format, which interface with the smart phone either through navigation applications or a website address, effecting a transition from vehicle to building without requiring passengers to change their application service (20). All of these geo-fence and navigation options require a combination of cell towers, Wi-Fi access points, and Bluetooth sensor points. The web of communication and related infrastructure must then condense to ensure seamless coverage and intermodal transition of passengers across the terminal and airport grounds.

1.3 Systems-of-Systems and Communications Standards Past and Present

Communication standards ensure different devices and systems connect and work together across multiple styles of communications networks. In the early 2000s, the web of communications described above was entering a period where conflicts arose between two major wireless device standard-bearers (21). The primary reason these different standards were proposed had to do with different approaches to security countermeasures, and the different needs of devices, which would connect, to wireless networks using the associated protocols. Manufacturing and automation drives some of the needs for one set of devices and ease of transition and use of more open-facing consumer products by the public drove the other.

In a single airport, these needs and the reason for the diverging standards is close to the surface, especially when taking into account the various devices and their owners within the airport environment. Airports operate at a massive scale, using massive spaces, buildings, and a plethora of owners, communications devices, information systems, and networks. They serve almost as miniature scale cities, some often having their own power sources and utilities management groups with differing degrees of autonomy. Corralling all of the associated network operations under a security standard with strong countermeasures is a critical need. What often transpires is the development of a unified framework from the information and technology department, which serves as a system-of-systems map to which various entities, like airlines, passenger devices, government agencies, and retail can connect their systems. Figure 4 displays a diagram of airport operations as related to various staging gates for passengers.

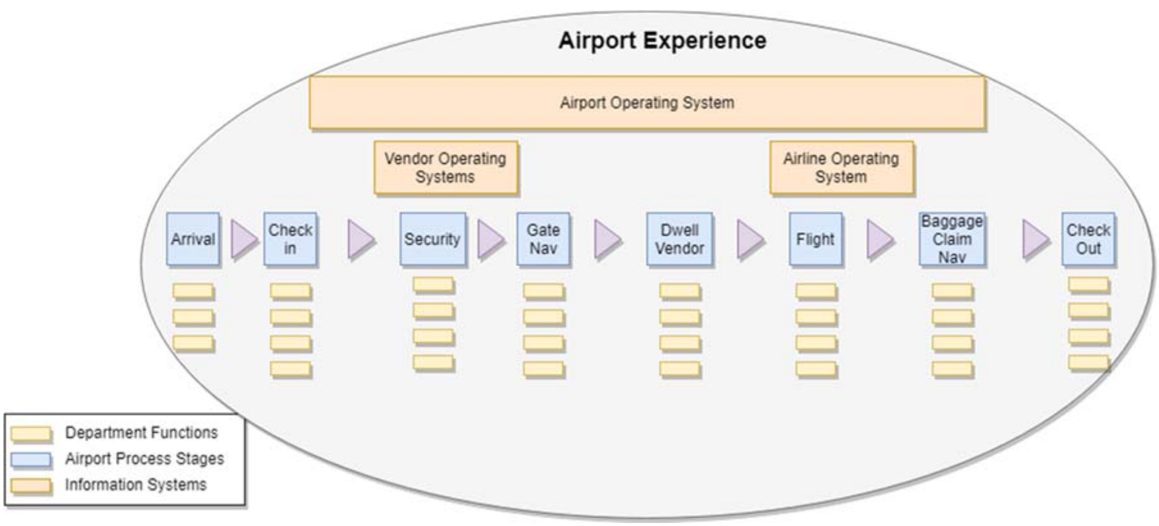

Figure 4 - Airport Stage Gates and Operational Information Systems

In 2003, IEEE 802.15.4 developed as a base standard to connect devices to the internet, and subsequent standards expanding into the wireless network domain derived from this standard

(22). IEEE 802.15.4 provides blueprints for the physical and media access control layers of future networks deployed across the globe and in airport environments. Figure 2 displays potential network configurations based on the 802.15.4 standard using either peer-to-peer configurations or a star configuration (21).

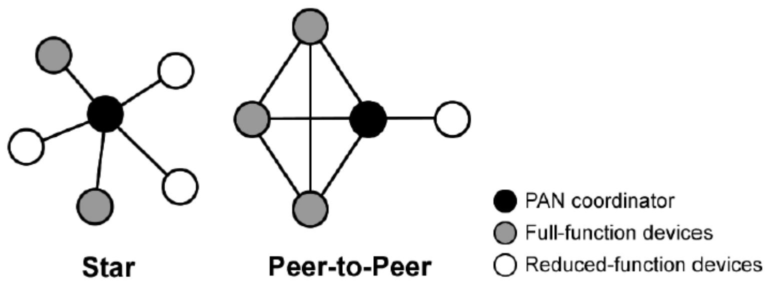

Figure 5- 802.15.4 Standard Network Configurations

Since that time, WirelessHART and ISA 100.11a standards depicted additional configurations for: network gateways; security managers; network managers; access points; field devices; hand-held devices; backbone routers; input/output nodes; with still more underdevelopment(21). These two new standards effectively expand the wireless network to provide increased internal controls and modular connections across former proprietary silos and lays the ground work for IoT systems development. These two subsequent standards have been battling it out for market dominance ever since and new proprietary standards have entered the fray using a variety of network and device configurations that deposit entire swaths of market devices onto 802.15.4 (21).

The three use cases for these various networks and their configurations include:

- Process and monitoring control (i.e., passenger throughput and bottleneck identification across journey stages in check-in, security, terminal, and gate)
- Asset monitoring and analytics (i.e., real time bathroom maintenance needs, and escalator gear telematics for maintenance related service predictions), and
- Safety alerts (i.e, alerts for pressure control valves, weather, wind, etc.)(21).

Wireless networks and associated information systems currently oriented toward airport uses provide greater internet connectivity, and also serve as potential bridges to other external information systems like transit, and roadway traffic operations. These connections could potentially improve the efficiency of airport ingress and egress activities associated with these modes and associated traveler information and operations systems. According to a recent study, departure delays are often associated with airlines waiting for missing passengers in order to facilitate flight transfer, maintain load factors, reduce rebooking, and opportunity costs. A departure delay of ten minutes at the beginning of the day can result in a 60 minute delay in the final departure of the day for the airline. Active monitoring of passenger locations through the connection of transit, and road to cover their arrival and then subsequent pedestrian journey through the airport to the gate is one proposed solution to provide the airlines with better cost and departure analysis data. This could reduce the scheduling departure padding that airlines inject into their schedule if they have greater awareness of where their passengers are in relation to the gate (23).

1.4 Merging Ground Transportation Services and Navigation with Building Information Services and Pedestrian/Transit Airport Navigation

To navigate the cavernous interiors and multiple levels of airports requires solving the challenges associated with line-of-site connections to satellites via GPS locations technology. Depending on cell tower coverage, to navigate from parking facilities to locations inside the terminal building may require a combination of facility mapping that merges with a switch from GPS to other communications networks like Wi-Fi, or Bluetooth (24). As evident in figure 3, disconnects for transfer from vehicle to pedestrian mode as well as errors in internal store locations and addresses can add inefficient routing to a navigation request.

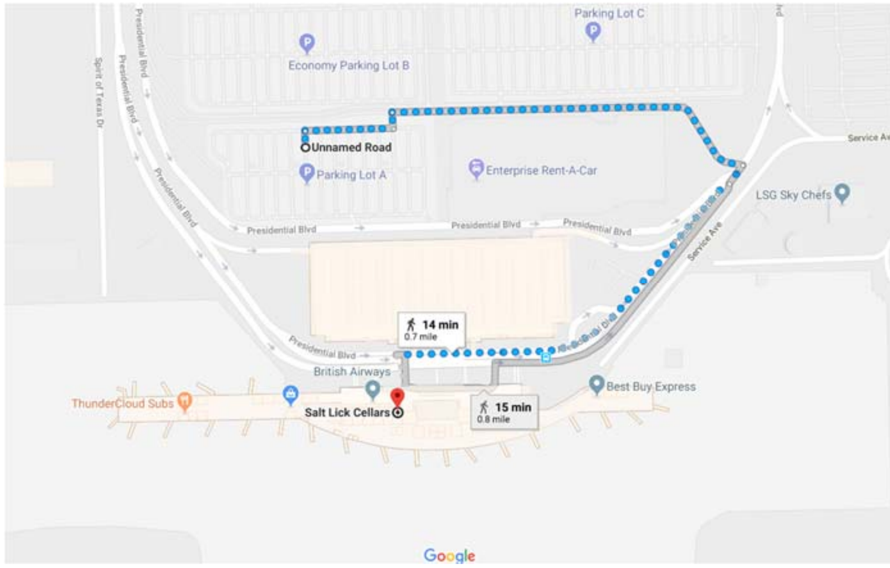

Figure 6- Pedestrian Routing Function Disconnects Between Parking Facility Maps and Indoor Maps (Source: Google Maps)

There is also an information component for retail/vendors as input to building information management systems. Updates to building indoor maps must be coordinated with vendors to ensure accuracy for navigation. One potential path to achieve seamless updates to an indoor map is to connect smartphone navigation applications using an open application-programming interface (API) (25). This API would be available for all smartphone navigation applications to use and it would effectively connect them with a database that maintains facility geometrics and vendor locations known as a building information management system (BIM). This BIM contains a 3-D map/model of the building and levels, and pedestrian, vehicle, and other paths preset. This solution, could address the complexity of navigating on multiple levels through use of the BIM. San Francisco International Airport is in the process of sharing a catalogue of open-source APIs that it has developed that with other airports to use in their own wayfaring and ground transportation management systems.

1.5 Making Sense of Data Mountains

Not all data is equal. Given suitable investments in IT infrastructure, resources, and computing power, some data sources provide high priority inputs or represent outsized opportunities to improve airport efficiency in comparison to other data sources. Activities and explorations need to accompany any data and associated system procurement, which includes asking the standardization question on whether the investment plays well with other systems. Creating and maintaining a data map of all sources with clear input, output, priorities and risks catalogued would go a long way to managing the increasing amounts of data and assignment of constrained resources to ensure the quality and use of the gathered data (26).

In the flow of data most difficulties arise at transition points where data transfers either between departments or from one organization to another. Airports may situate parking data, within information systems associated with vendors or with ground transportation operations departments. The priority assigned to these parking systems for data collection may be for fare reporting for revenue analysis and capacity monitoring for notifications and alerts to the traveling public. The database may reside within the ground transportation management department, with simple reporting functions to finance department systems. Upon further review, strategic analysis may reveal the need to connect this parking and revenue data with vendor retail management so that they can estimate demand for different customer paths across the airport to customize service delivery.

Efforts are underway at San Francisco International Airport to, in the words of their Chief Information Officer, "put all the data legos onto one board." This effort entails the development of an airport integrated information system (AIIS). Currently, efforts to reduce airport carbon emissions has their asset management department pilot testing data collection in buildings down to the level of electrical outlets and light bulbs to drive reductions in energy expenditures. What occurred at SFO in 2013, was agreement on a plan to integrate all of the airport's data into a single system. However, what the IT department soon realized was that there was a lack of cyberinfrastructure to support this integration across airport departments and airport stakeholder groups. In the interim between 2013 and 2017, preparation for AIIS procurement involved a lot of re-engineering of data flows across the airport by the IT department. This paved the way for SFO to layer a single system over what would formerly have been information disconnects which wouldn't be solved by a single procurement of an AIIS (27).

This effort at SFO places them in a position to convert data from a singularly focused context, within a departmental or organizational silo, to a broader data paradigm, which can be used for further analysis and business value accretion. It required thoughtful consideration over a four-year period of what are essential functions performed by the various airport information systems as the base layer requirements to the procurement of a broader integrated information system.

1.6 CONCLUSION

Airports are a microcosm of the regions they serve, providing elements of road, transit, and pedestrian networks with a particular emphasis on revenue and economic demands pushing decision-making. As gateways, airports reveal the values, challenges, and vision of their region. Solutions often come from homegrown resources and service providers. A variety of jurisdiction and ownership interests control how airports operate, including municipal, county, port, and public-private partnerships. Airports may have access to student and university resources through city internship programs, or they may face increased or relaxed regulatory and procurement constraints depending on their position within county/city policy environments.

Technological changes and new market forces in commercial aviation and transportation in general are affecting how airports operate (28). New "Uber-of-flight" business models are in development, which threaten high-end first class business traveler markets. Uber and Lyft is having a noticeable impact on parking revenues. New national system deployments such as the U.S. Federal Aviation Administration NextGen satellite-based air traffic control may lead to increased air traffic and passenger throughput which applies capacity pressures to traveler markets, and opens opportunities for increased inter-airport coordination for new aviation routes through traditionally smaller markets and airports-less-travelled.

Based on pre-existing regional advantages and constraints, airports are scaling up approaches to IT infrastructure investment, services, and solutions that approximate loose standards in response to market and technological pressures. Key takeaways from the research are:

- **Investment in open information flows confers competitive advantages.** Ground transportation system managers at SFO can draw on TNC APIs to improve traffic flows for arrivals and departures, and gather increased revenue for TNC airport access where formerly there was a net loss in terms of parking revenue.
- **Investments in cyberinfrastructure do well to keep central, data information processing and archiving modular and flexible enough to include new emerging data sources.** In the 90s Las Vegas McCarran International Airport started with a modular oracle database capable of integrating a wide array of data, but in the 2000s this system converted to a sequel database format to accommodate real-time data flows with higher automation processes and rates. SQL is now, in the late 2010s, considered outdated.

Systems couched in the Big Data arena such as Spark and Hadoop have greater capacity to facilitate on-demand analysis and data explorations of what were formerly SQL data batched into data silos and isolated by conflicting metadata references. The next time a connection is made between TNC data obtained from APIs and bathroom maintenance data in building information management systems, the use of systems like Hadoop may provide the communication protocol.

- **New standards and technologies like block chain/smart contracts are progressively opening up greater insight and control of data flows from formerly siloed proprietary systems.**
- **Information sharing between airport operations and vendor management is driving increased sales and revenue, while new payment processing standards are bringing online vendor-agnostic middleware platforms that leverage this information exchange.**
- **Passengers with smartphones and other devices engage multiple communications layers across their airport journey.** Standards are in flux as tech giants like Google and Apple issue different standards to capture as much of the IoT device market and enable seamless connections across cell tower, GPS, Wi-Fi, and Bluetooth communication layers.
- **Airport IT departments are responsible for the framework that outlines the system of communications and information exchange across the entire airport space and all of its stakeholders.** IT departments use IPv6 network standards, which are incomplete at this time.
- **As a key regional and international gateway and nexus point for multiple modes, airports represent a unique opportunity to serve as a regional model for the integration of operations systems across transit, road, and pedestrian networks.**
- **The connection of building and facilities management information systems to wayfaring and passenger navigation can bridge the transfer of passengers from roads and transit systems into indoor airport spaces.**
- **Data standards and related transfer protocols improve data flows across departments, devices, information systems, and communication layers.** In the absence of standards and protocols, preparing for and deployment of integrated

information systems often serve to provide the groundwork for improved data flows and other work arounds until the standards “catch up”.

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