AIRPORT OWNER'S

DIGITAL TWIN ROADMAP

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under the direction of AAAE Facilities and Technical Services Committee

This work product reflects the results of the AAAE Digital Twin Working Group's efforts spanning 2022-2023

Image courtesy of www.AirportDigitalTwin.org

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Introduction

This roadmap is meant to help airport owners and their technology solution providers take the right path towards achieving "Digital Twins" for **improving airport enterprise management – herein after referred to as an airport owner's digital twin (ARP-DT)**.

This roadmap's content was developed by the AAAE Digital Twin Working Group (DT-WG), consisting of approximately 70 participants, composed of both airport owners and technology solution providers. These contributing airport industry representatives are listed in the Appendix. This roadmap was commissioned by the AAAE's Facilities and Technical Services Committee; to be concise and practical, presented in layman's terms for airport managers to apply in their pursuit of continuous improvement.

Under the leadership of David Tamir, DT-WG founder and lead, and the guidance of Jeremy Valcich, AAAE's Director of Regulatory Affairs, the DT-WG met over Zoom on a weekly to monthly basis, primarily spanning all of 2022, researching relevant airport needs and examples, and developing the recommendations described herein. Moreover, the DT-WG organized two AAAE conference panels in 2022, supporting this work; at the Operations & Technology Symposium in San Antonio, and the National Airports Conference (NAC) in Orlando. Airports which presented their relevant examples to the DT-WG included AMS, YVR, MCO, DFW, SFO, CLT, and the PANYNJ.

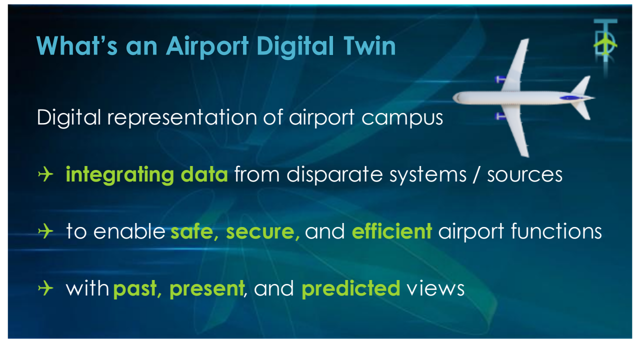
The DT-WG findings have been summarized herein and organized to include an explanation of what is an airport owner's digital twin, top business use cases with examples from various airports illustrating the needs and benefits of digital twins, how to gradually achieve a digital twin including an open system architecture and a maturity model matrix, recommended governance for sustaining the airport's digital twin, and funding approaches.

Background

"Digital Twins" is a relatively new term representing capabilities in various industries, which have been evolving over decades, such as digital twins of spacecraft and planetary rovers used by NASA. With the growing airport use of Internet of Things (IoT) (e.g., CCTV cameras, sensors, alarms, elevators, escalators, etc.), and corresponding business analytics and Artificial Intelligence (AI), airport management digital twins are now achievable using commercial-off-the-shelf technologies. In fact, digital twin software solutions are already being marketed to airports, and some implementations have begun. Accordingly, airport managers want to better understand what digital twins are, their justification, and the proper approach and required resources to successful implementation. This roadmap addresses these questions.

In addition to this AAAE roadmap, the Airport Cooperative Research Program (ACRP) is currently studying digital twins for airports as ACRP Project 03-66. The AAAE DT-WG's roadmap is being shared with the ACRP to assist their study.

Executive Summary



An **Airport Enterprise Management Digital Twin (ARP-DT)** is an <u>integration of airport information</u> (involving processes, data, and technologies) that provides visual multi-dimensional representation of the airport's ecosystem including its airspace, surroundings, infrastructure, facilities, assets, systems, flux (e.g., aircraft, vehicles, passengers, meeter greeters), staff resources, workflows, etc. The ARP-DT provides an integrated display/dashboard of correlated information from multiple systems/sources in the form of analytic graphs, tables, schedules, and maps. It also provides temporal analysis of past, current, real-time, forecast, and/or simulated data.

An **ARP-DT** is key to achieving **Airport Business Intelligence (BI)**.

It is fundamental to understand that an **Architectural-Engineering-Construction Digital Twin (AEC-DT)** has a significantly different mission than an **ARP-DT** and, therefore, <u>should not be confused with one another</u>. The AEC industry and its software vendors are evolving their terminology from Building Information Modeling (BIM) to "Digital Twin".

The **AEC-DT** essentially continues the mission of **BIM**: to improve design, construction, and activation of new facilities.

Airport owners should leverage data from project centric **AEC-DT** deliverables, to update their **ARP-DT** for the much larger airport campus-wide scope, spanning the entire aerodrome ecosystem. This **ARP-DT** scope involves optimizing airport enterprise business management including: landside operations with various types of vehicles, roadways, curbs, parking, and turn-around facilities; terminal operations with passengers, meeter-greeters, ticketing counters, security checkpoints, concessions, moving walkways, elevators, escalators, people movers, bathrooms, and aircraft gates; airside operations with aircraft and other vehicle locations, movements, airlines, and equipment; multiple on-going project types across the campus including capital improvements, tenant modifications, maintenance, information technology, environmental, and noise mitigation; security and life-safety situational awareness; and more…

The **ARP-DT** enables efficient collection, access, correlation, and understanding of quality information from multiple airport systems/sources to support faster and more confident decisions for improving airport enterprise business aspects:

- Levels of Service
- Safety & Security
- Operations & Maintenance
- Planning & Development
- Costs & Revenues
- Compliance & Risk Management

Top **ARP-DT** use cases, described in the roadmap below, include <u>optimizing</u>:

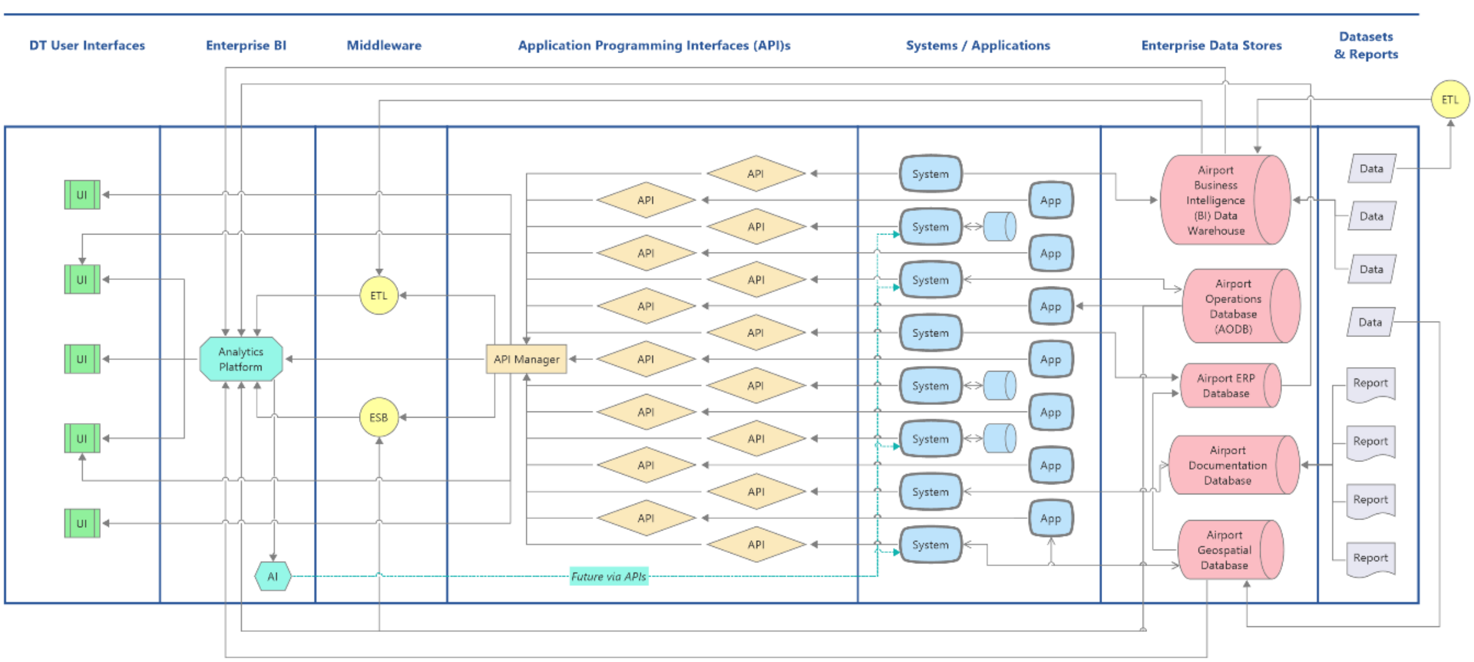
1. Landside Arrivals
2. Shuttle Bus Frequency
3. Security Checkpoints
4. Digital Content (i.e., on various electronic visual information displays including apps and web)
5. Automated People Mover (APM) Frequency
6. Concessions
7. Connecting Flights / Passenger Loads
8. Terminal Resources
9. Terminal Energy Management
10. Terminal Cleaning
11. Passenger Health
12. Safety Management System (SMS)
13. Security & Emergency Situational Awareness
14. Predictive Maintenance
15. Work Scheduling (e.g., O&M, CIP)

One of the best industry examples, presented to the AAAE's DT-WG, is shown below by the Vancouver Airport Authority, which has been developing its solution leveraging extensive in-house innovation resources.

Courtesy of Vancouver Airport Authority

Implementing an **ARP-DT** should involve an open systems architecture approach as illustrated below. This approach feeds multiple Digital Twin User Interfaces (UI)s serving different use cases.

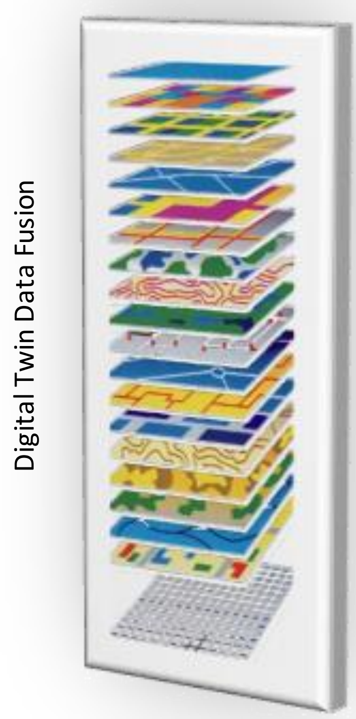
ARP-DT Open System Architecture

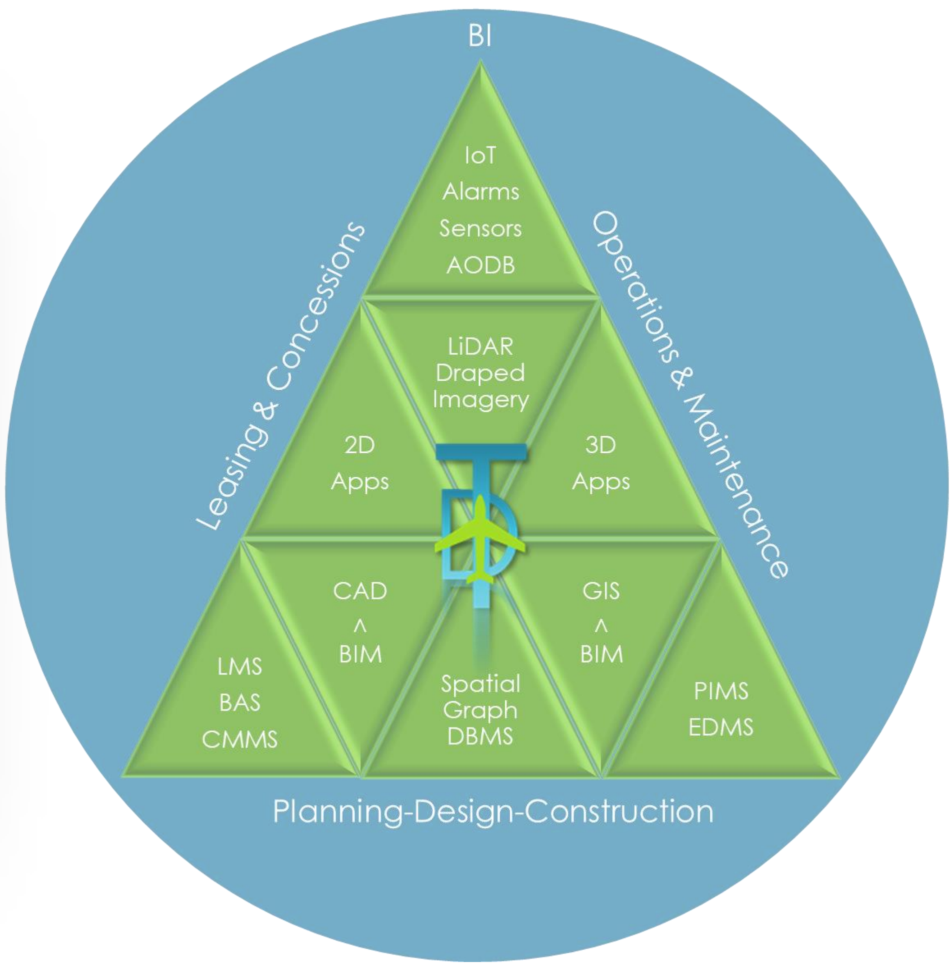


With the growing capabilities of Artificial Intelligence (AI), **ARP-DT** will gradually enable some autonomous operations and decision-making capabilities. The **ARP-DT** may be developed incrementally over time, increasing in capabilities gradually on an as needed basis per each airport's individual priorities. The following roadmap includes a maturity model, which allows the airport owner to ascertain their current digital twin capabilities and next steps on the path forward. This maturity model organizes **ARP-DT** capabilities into the following building blocks: staffing, business processes, data housing, metrics & analytics, data flow, spatial correlation, systems integration, and predictive simulation.

ARP-DT must be maintained current at a level of detail commensurate with daily airport enterprise management needs, leveraging the Internet of Things (IoT) including devices such as CCTV cameras with video analytics, various building automation sensors, passenger movement sensors, LiDAR scanners, etc.; all overlaid on a common-denominator, campus-wide basemap and indoor floorplans. Geospatial Information Systems (GIS) technology has effectively served airports over the past three decades, providing such a common denominator across the aerodrome, both outdoors and indoors. Airport Operations and Maintenance (O&M) systems often leverage GIS technology for safety inspections, work orders, situational awareness, lease management, etc. Moreover, GIS is best able to reference, overlay, and correlate BIM data, LiDAR data, draped CCTV and 360-degree imagery, and IoT sensor analytics data including historic, current (real-time), as well as future predicted data.

The following diagram illustrates key components required to assemble an **ARP-DT**.





Courtesy of
www.AirportDigitalTwin.org

Acronyms

AI	Artificial Intelligence
AODB	Airport Operations Database
API	Application Programming Interface
BAS	Building Automation System
BI	Business Intelligence
BIM	Building Information Modeling
CAD	Computer Aided Design
CCTV	Closed Circuit Television
CIP	Capital Improvement Program
CMMS	Computerized Maintenance Management System
DBMS	Database Management Systems
EDMS	Electronic Documents Management System
ESB	Enterprise Service Bus (middleware)
ETL	Extract Transform Load (middleware)
GIS	Geospatial Information System
IoT	Internet of Things
LiDAR	Light Detection and Ranging
LMS	Lease Management System
O&M	Operations & Maintenance
PAX	Passenger
PIMS	Projects Information Management System
SMS	Safety Management System
UI	User Interface

1. Explanation of Airport Owner's Digital Twin

The purpose of the following explanation is to help airport owners better understand what a Digital Twin is, in the context of their airport enterprise management. An airport owner's Digital Twin may be developed incrementally over time, increasing in capabilities gradually on an as needed basis per each airport's individual priorities.

An airport owner's Digital Twin is a virtual digital representation of the airport's real-world assets, intermodal transportation elements (e.g., aircraft, vehicles, passengers, cargo), and processes which may span the entire aerodrome ecosystem, including but not limited to:

- Air Transportation
- Ground Transportation
- Terminal Buildings
- Other Buildings
- Infrastructure
- Properties & Environment

An airport owner's digital twin transforms the airport business enterprise by accelerating holistic understanding, optimal decision-making, and effective action. It uses real-time and historical data to represent the past and present and simulate predicted futures. It is motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implemented in IT/OT systems.[i]

An **integration** of airport information involving processes, data, and technologies:

- **Data** (including spatial [ii], non-spatial, real-time, historic, forecast, and simulated)
- **Software** (including configurable COTS solutions, data maintenance, and business intelligence & analytics)
- **Hardware** (including servers, desktops, laptops, tablets, smartphones, and sensors)
- **Network** devices (including switches, routers, and hotspots)
- **Cloud** services (including software, data, databases, and infrastructure "as a service")
- **Staff** supporting non-automated data updates (such as airport configuration changes)
- **Governance** (including policies, standards, compliance, processes, and procedures)

That may provide

- **Visual multi-dimensional representation** of the airport's ecosystem including its airspace, surroundings, infrastructure, facilities, assets, systems, flux (e.g., aircraft, vehicles, passengers, meeter greeters), staff resources, workflows, etc.
- **Integrated display of correlated information** from multiple systems/sources (aka business intelligence) in the form of analytic graphs, tables, schedules, and maps
- **Temporal analysis** of past, current, real-time, forecast, and/or simulated data

To enable

- **Efficient collection, access, correlation, and understanding of quality [iii] data** from multiple airport systems/sources to support faster and more confident decisions to improve airport:
    - Levels of Service
    - Safety & Security
    - Operations & Maintenance
    - Planning & Development
    - Costs & Revenues
    - Compliance & Risk Management
- **Autonomous** operations and decision making

In support of all airport management disciplines

- Planning & Environmental
- Engineering & Construction
- Facilities & Asset Maintenance
- Operations (Landside, Terminal, Airside, Security, Fire, Police)
- Property Leasing & Concessions
- Business Development
- Public & Governmental Affairs
- Information Technology & Communications
- Finance & Procurement
- Legal & Administration

Addressing informational needs of various airport stakeholders

- Board members
- Management
- Staff
- Vendors / Consultants / Contractors / Service providers
- Tenants
- Passengers
- Meeters & Greeters
- Governing agencies (e.g., local, state, federal)
- Surrounding Community

An airport owner's digital twin is

- **NOT a single system**, but rather an integration of systems/data, which are assembled into a Digital Twin head-end system
- **NOT replacing existing airport systems**, but rather expanding their utility; some existing systems may become obsolete or consolidated as a result of a Digital Twin
- **NOT the Architectural-Engineering-Construction (AEC) Digital Twin** used to design-build-activate new facilities; however, the AEC's Digital Twin data may be leveraged by the airport owner's Digital Twin
- NOT a Building Information Modeling (BIM) nor a Geospatial Information System (GIS), although **BIM and GIS are parts of a digital twin**

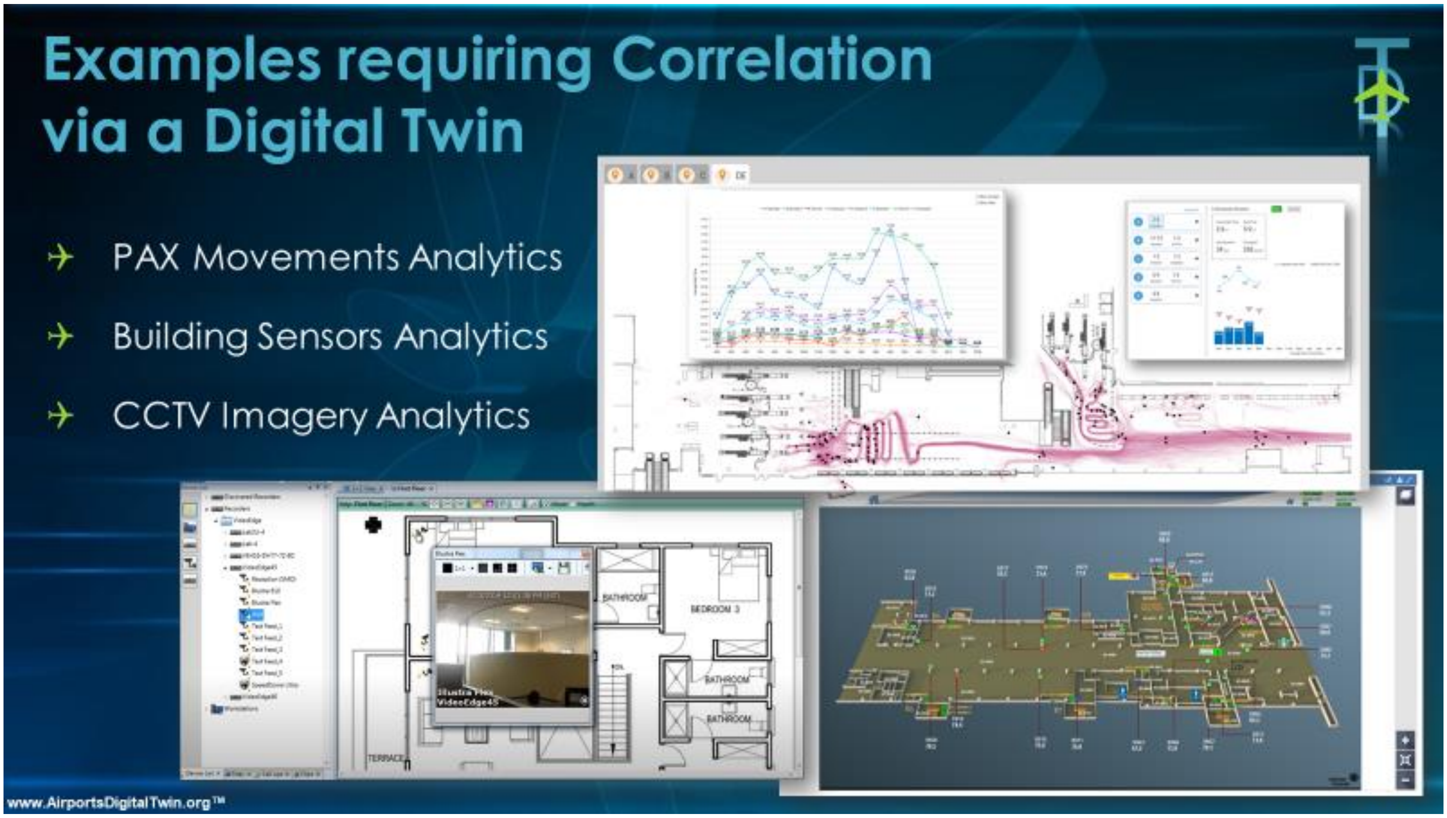
[i] Based on Digital Twin Consortium's Definition

[ii] Spatial data depicts the position and physical configuration of objects in two- or three-dimensional space. Spatial data can be diagrammatic or positionally accurate. Geospatial data is positioned in relation to a representation of the earth's surface.

[iii] Quality includes positional accuracy, currency, comprehensiveness, consistency, and correctness of the data, as well as the presence of metadata that describes the source, quality, and acceptable use of the data.

2. Value to Airport Owner

The value of ARP-DT to the airport owner can perhaps be best illustrated by the example below. This example shows the difficulty of correlating information from three typical airport systems providing passenger flow information, CCTV imagery, and building automation sensors, respectively. Each of these systems independently overlays the information on a different graphical depiction of a floor plan, which are not synchronized, nor up to date. With dozens and even hundreds of systems in use at airports, such correlation difficulty is multiplied beyond comprehension, impacting effective airport management. ARP-DT provides the needed correlation ability via combined analytics and consolidated spatial mapping. This may also be described as airport management "Data Fusion".



Examples of airport data sets which should be correlated via ARP-DT:

- ALP & Floor Plans
- 3D LiDAR with Draped Imagery Outdoors & Indoors
- Airspace / AOA Status & NOTAMS
- Aircraft Gate Turn-Around Status
- On-Airport Roadways / Curbs Status
- Parking Lots / Garages Status
- People Movers Status
- Elevators / Escalators Status
- Ticket Counters Status
- Security Checkpoints Status
- PAX Congestion / Queue Status
- Bathrooms Status
- Alarms / Sensors / CCTV
- Incidents / Complaints
- Inspections / Issues / Weather
- Projects, Work Orders, Outages…

Airport enterprise business elements, listed on this and the following page, may be correlated via ARP-DT's data fusion. The following are some examples of business questions that can be answered efficiently via ARP-DT data fusion:

Where are levels of service impacted across the terminal in terms of congestion, queue lengths, wait times, elevator/escalator outage etc.?

What does the passenger journey look like in one continuous view from the terminal entrance to exit (e.g., timing, shopping, dining, restroom use, etc.)?

Which concessions are most desired by passengers based on transactions, location, and flow levels?

Which airport concessions and corresponding locations are producing more or less revenue than expected and why?

How do gate changes, aircraft sizes per gate, irregular ops, etc influence concessions performance?

When should bathrooms/filters be cleaned based on number of passengers processed?

When should HVAC and lighting be minimized at which parts of the facility based on scheduled activity?

Which airport assets and corresponding locations are costing more or less than expected and why?

Which assets should be budgeted and when for renewal and replacement due to "traffic" levels (i.e., due to flux of aircraft, vehicles, passengers, baggage)?

What are our risk exposures and levels? Where is safety mitigation needed due to frequency and type of issues?

Which CCTV cameras cover access control alarm, smoke alarm, incident, etc?

ARP-DT data fusion is not limited to just large airports, but smaller ones as well. Today there are cloud-based ARP-DT offerings, which are an order of magnitude less expensive than traditional airport systems, that are now affordable for smaller airports.

- **Airline Activity**
  - Landing
  - Takeoff
  - Gate Turnaround
  - PAX Load

- **Levels of Service / Comfort**
  - Congestion / Queue Line / Wait Times
    - Entrance Roadways
    - Parking
    - Shuttle Busses
    - Terminal Curbs
      - Departure
      - Arrivals
      - Taxis/Shuttles/TNCs
      - Valet Service
    - Ticketing
    - Security Checkpoints
    - People Movers
    - Gates / Terminal Hold-rooms
    - Bathrooms
    - Food & Beverage
    - Re-booking (Airline Customer Service)
    - FIS
    - Baggage Claim
    - Rental Car Availability
    - Exit Roadways
  - Health
    - Congestion
    - UV Airflow Filtering
    - Cleanliness/Optimize Janitorial Service
      - Bathrooms
      - Trash cans
  - Visual Information
    - Wayfinding & Signage
    - Electronic Content Management
    - Irregular Operations
  - Concessions
    - Performance
    - Availability / Type
  - HVAC & Lighting

Costs & Revenues

- Minimizing Costs of Repairs/Issues
  - Predictive Maintenance
    - Pavement
      - Airfield
      - Roadways
    - Carpeting/Tile
    - Bag Belts
    - Jet Bridges
    - Elevators/Escalators/Moving Walkways
    - People Movers
- Lease & Concessions Management
  - Enhance Non-Aeronautical Revenue
- Cargo

Security & Public Safety

- Table-Top Exercises
- Situational Awareness/Alarms
  - CCTV
  - Access Control
  - Smoke/Fire
  - BHS
- Weather
- Cybersecurity
  - System Interdependencies

Projects

- Project Coordination
  - CIP
  - Tenant Mods
  - Maintenance
  - IT
  - Environmental
  - Operations
- Outage Coordination
- Asset Information
  - BIM Models
  - Record Drawings
  - O&M Manuals
  - COBie Data

Compliance & Risk Management

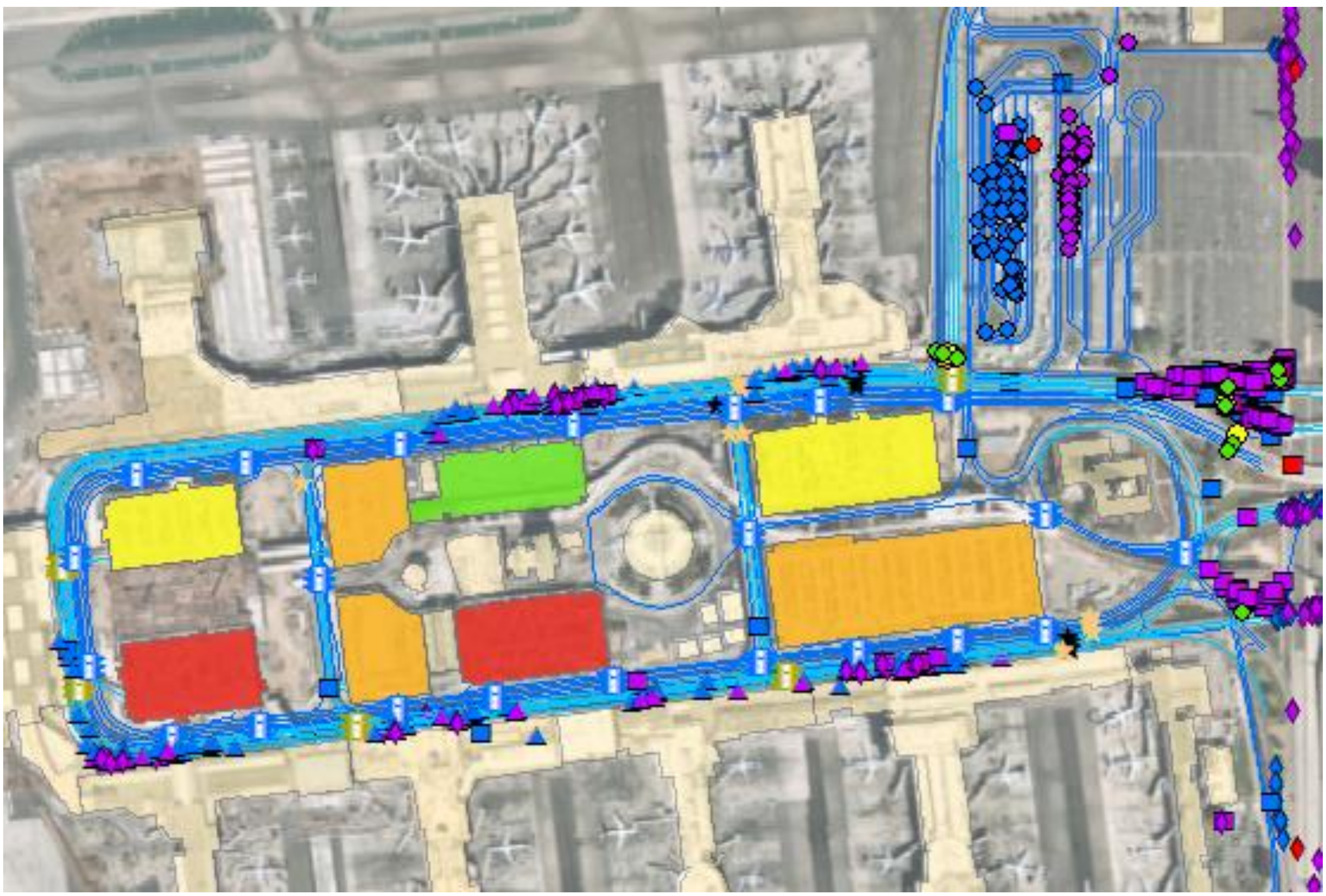
- Resiliency
- Sustainability
  - Energy Management
  - Electrification/Carbon Credits
  - Electric Aircraft
  - Electric Vehicles
  - Electric GSE
  - Solar Power
  - Geothermal Power
- Environmental
  - SWPPP
  - PFAS
  - HAZMAT
    - Fuel Tanks Inventory
    - Fuel Spills
- FAA Part-139 / ICAO
  - Inspections
    - Weather
  - Onboarding & Training
  - SMS
  - ADIP Updates (GIS, Survey, Imagery, ALP updates)
- Equity-Diversity-Inclusion
  - ADA
  - MBE/DBE
- OSHA
- GASB
  - 87 (Leasing)
  - 34 (infrastructure depreciation)

Top ARP-DT Use Cases

The following are examples of highly desired use cases for an airport owner's digital twin; organized from terminal curb to aircraft gate. Increasing airport passenger satisfaction, health, safety, security, revenues, and reducing costs, are all major business drivers shaping ARP-DT use cases. Each of the sample use cases listed below are described in more detail on the following pages. There are certainly other use-cases not included below, such as enabling airport-metaverse capabilities.

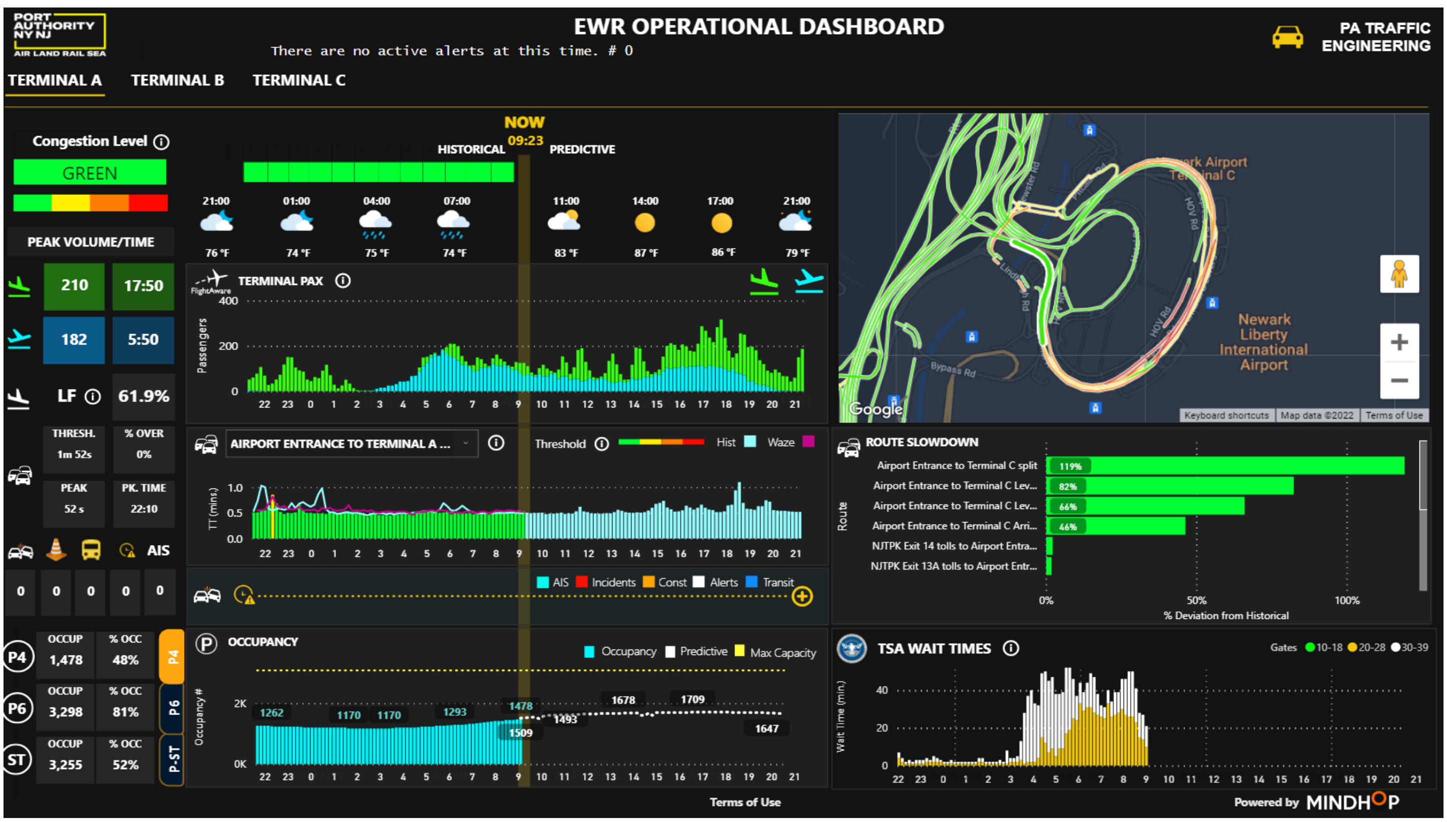
1. Optimize **Landside Arrivals** Mode of Transportation & Capacities
2. Optimize **Shuttle Bus Wait Times** vs. Terminal Congestion
3. Optimize **Security Checkpoints** for Landside PAX Arrivals
4. Optimize **Digital Content** Based on Terminal Activity
5. Optimize **APM Routing & Frequency** Based on Terminal Activity
6. Optimize **Concessions** for Flight Destination Gates
7. Optimize Extra **Connecting Flights/PAX Load** Effects on Terminal Congestion
8. Optimize **Terminal Human Resources** Planning
9. Optimize **Terminal Energy** Management
10. Optimize **Terminal Cleaning** for Flight Activity
11. Optimize **PAX Health** Monitoring and Improvements
12. Optimize **Safety** Management System (SMS)
13. Optimize **Security & Emergency Situational Awareness**
14. Optimize **Predictive Maintenance** of Facilities & Infrastructure
15. Optimize (minimize) **Work Scheduling** Impacts

Use Case Name:	(1) Optimize Landside Arrivals Mode of Transportation & Capacities
Type/Category:	Level of Service
Description:	Overlay entrance PAX transportation sources and respective quantities (i.e., from parking, TNCs, taxis, shuttles, curb drop-offs, etc.) to optimize parking/curb options
Contributing Systems:	AODB, parking management system, geofencing/automated vehicle identification, CCTV, PAX movement analytics/queue management, TNC data submittals, competitive parking submittals, GIS, etc.
Key Benefits:	Adjust landside curb/parking operations, plan and justify landside arrival transportation/parking improvements, etc.
Challenges:	Getting third party data submittals
Use Frequency:	Weekly / Monthly
Key Stakeholders:	Operations, Planning & Development



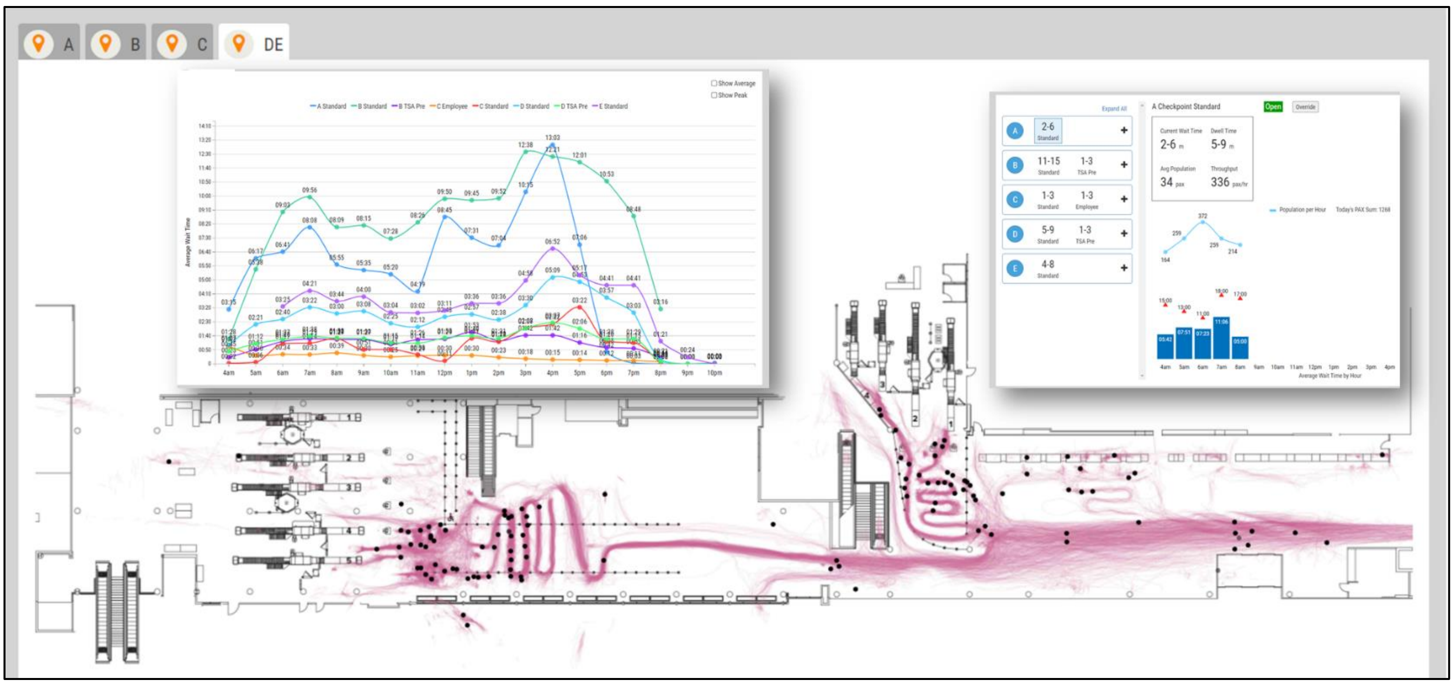
Courtesy of LAX using ESRI ArcGIS GeoEvent Server with x-Spatial's AEGIS

Use Case Name:	(2) Optimize Shuttle Bus Wait Times vs. Terminal Congestion
Type/Category:	Level of Service
Description:	Improve PAX wait times and drop-off to improve shuttle bus PAX flow
Contributing Systems:	Shuttle bus tracking system, shuttle bus CCTV analytics, AODB, PAX movement analytics/queue management, GIS, etc.
Key Benefits:	Improve PAX satisfaction, manage PAX expectations, manage wayfinding to reduce flight delays and/or missed flights
Challenges:	Cellular signal coverage to busses, frequency of location pinging (sub-minute needed), etc.
Use Frequency:	15 minutes
Key Stakeholders:	Operations, Airlines



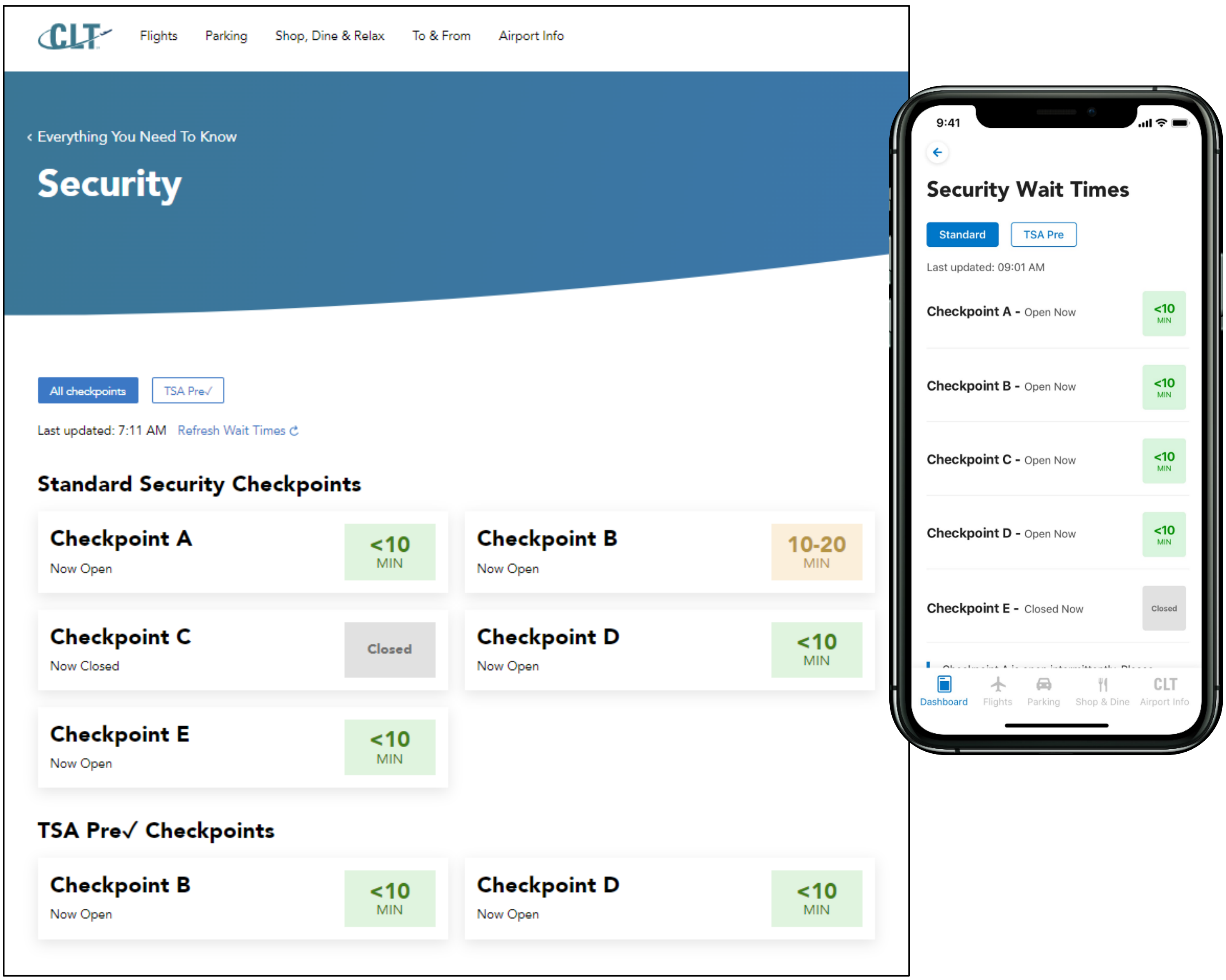
Courtesy of PANYNJ

Use Case Name:	(3) Optimize Security Checkpoints for Landside PAX Arrivals
Type/Category:	Level of Service
Description:	Measure entrance PAX throughput from parking, TNCs, taxis, shuttles, curb drop-offs, etc. that will arrive at security checkpoints and manage accordingly
Contributing Systems:	AODB, parking management system, geofencing/automated vehicle identification, CCTV, PAX movement analytics/queue management, TSA boarding pass flight data, GIS, etc.
Benefits:	Predict wait times and resource requirements, manage PAX time expectations, PAX distribution leveling across checkpoints, measure processing time from arrival to checkpoint for resource alerts, reduce flight delays and/or missed flights, plan and justify checkpoint improvements, etc.
Challenges:	Getting PAX boarding pass flight data from TSA
Use Frequency:	15 minutes
Key Stakeholders:	Operations, TSA, Airlines, Planning & Development



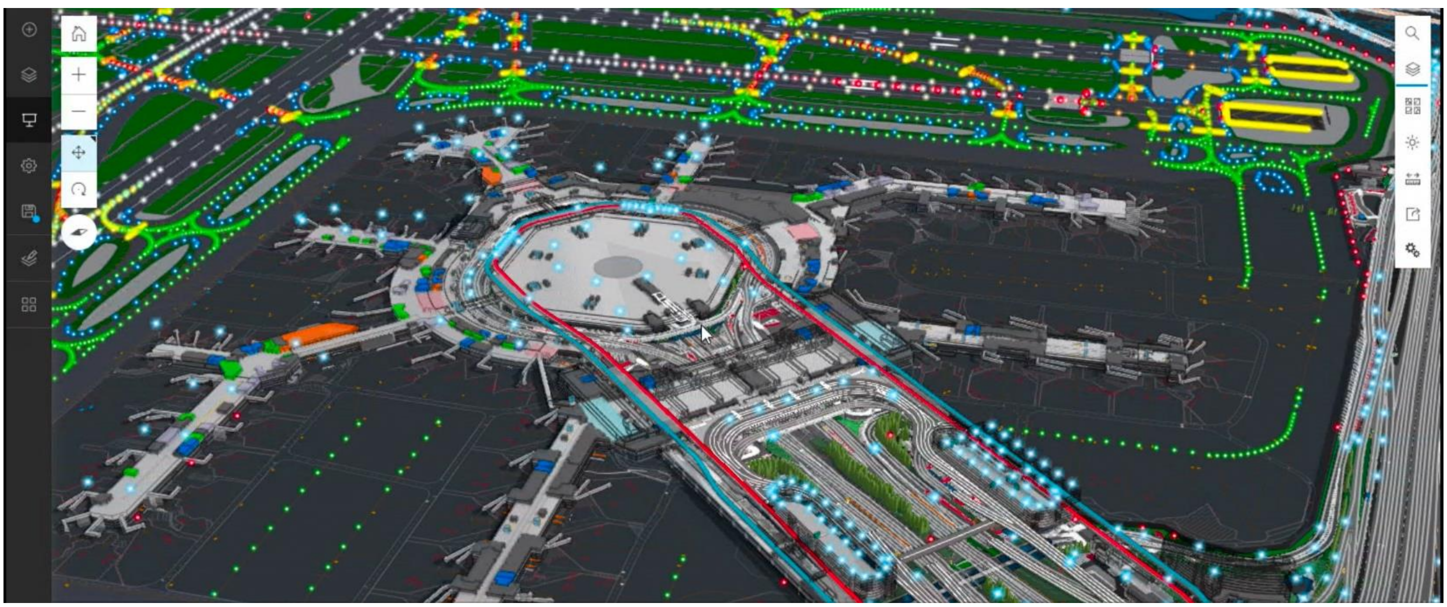
Courtesy of CLT using SkyFii's Crowdvision

Use Case Name:	(4) Optimize Digital Content Based on Terminal Activity
Type/Category:	Level of Service
Description:	Adjust digital content on airport web site, apps, digital signage/walls, information kiosks, etc. to improve PAX timing, way finding, awareness of concession opportunities, etc.
Contributing Systems:	AODB, digital content management, PAX movement analytics/queue management, elevator management system, APM control system, IROPs log, GIS, etc.
Key Benefits:	Reduce flight delays and/or missed flights, increase concession revenues, improve PAX satisfaction, etc.
Challenges:	Updated asset configuration management, etc.
Use Frequency:	15 minutes
Key Stakeholders:	Operations, Airlines, Concessions, Innovation, IT



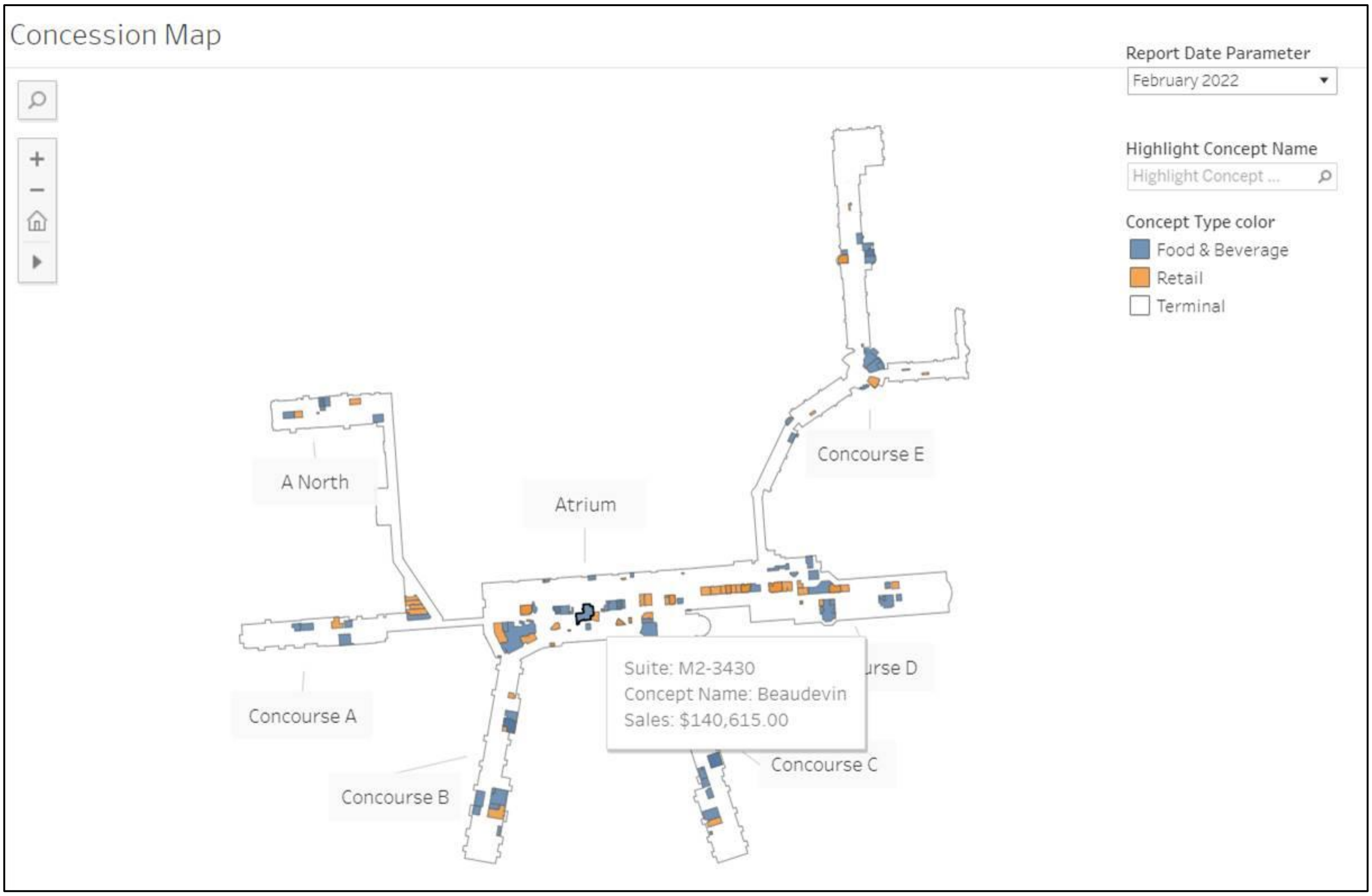
Courtesy of CLT

Use Case Name:	(5) Optimize APM Routing & Frequency Based on Terminal Activity
Type/Category:	Level of Service
Description:	Predict APM demands and manage its routing and frequency and PAX wayfinding accordingly, based on scheduled flight activity, late connecting flights, APM station queue lengths, etc.
Contributing Systems:	AODB, airline/TSA PAX destination data, PAX movement analytics/queue management, APM control system, IROPs log, EVIDS digital content and wayfinding, GIS, etc.
Key Benefits:	Improve PAX satisfaction, manage PAX expectations, improve wayfinding to reduce flight delays and/or missed flights, etc.
Challenges:	Reliant on airline/TSA PAX destination data
Use Frequency:	15 minutes
Key Stakeholders:	Operations, APM Operator, Airlines



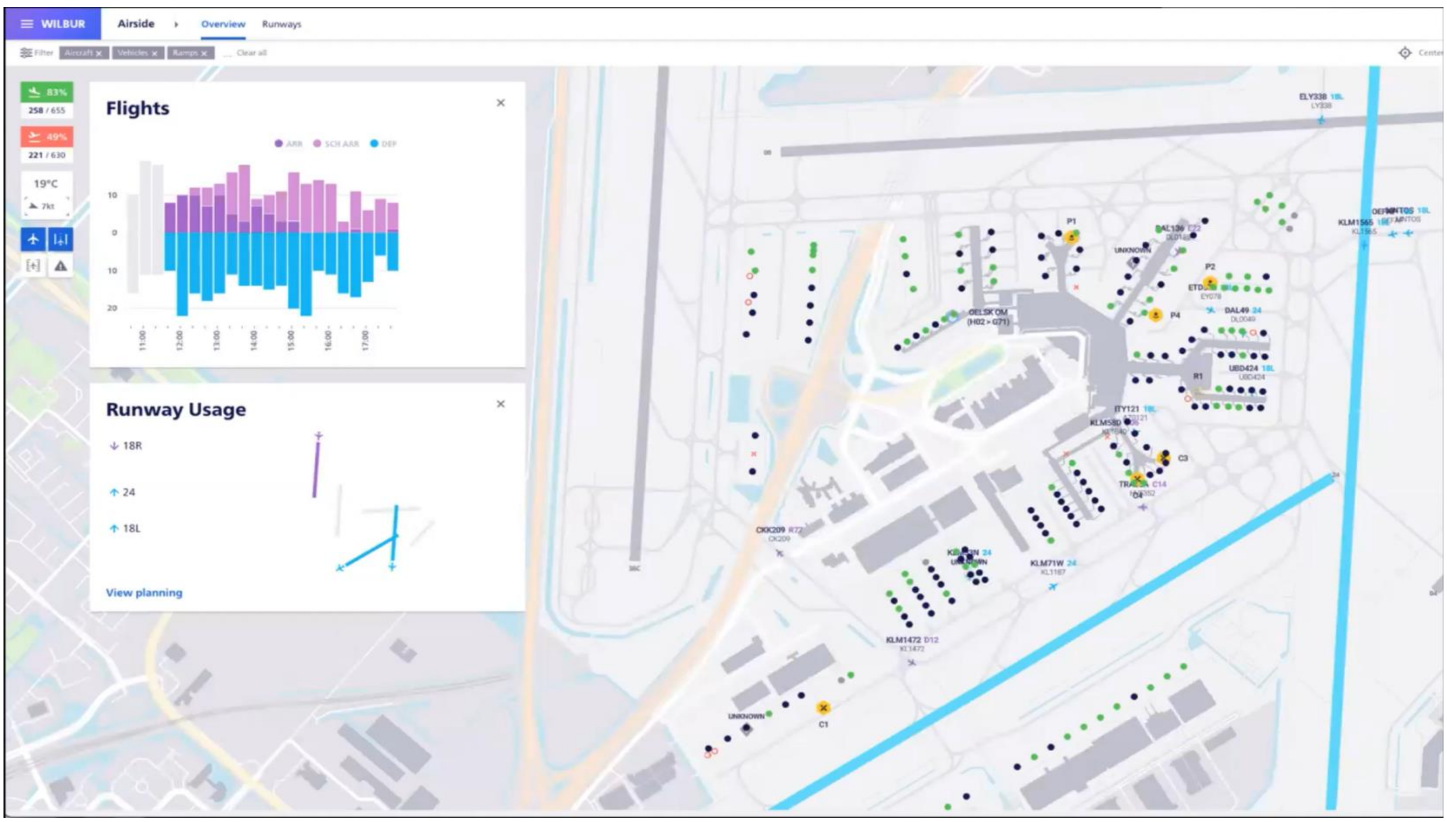
Courtesy of SFO using Esri software

Use Case Name:	(6) Optimize Concessions for Flight Destination Gates
Type/Category:	Level of Service & Financial
Description:	Aligning concessions to meet PAX demographic needs (e.g., family friendly, bar, golf, etc.)
Contributing Systems:	AODB, gate management, lease management, concessions point of sale (POS), CCTV, PAX movement analytics/queue management, GIS, etc.
Benefits:	Improve PAX experience, grow concessions revenues, minimize missed flights, plan and justify concessions modifications/improvement projects, etc.
Challenges:	Reliant on third party guarded data such as airlines PAX demographics data, concessionaires (POS) data; reliant on updated floor plans, etc.
Use Frequency:	Monthly
Key Stakeholders:	Concessions, Operations, Planning & Development



Courtesy of CLT using Tableau software

Use Case Name:	(7) Optimize Extra Connecting Flights/PAX Load Effects on Terminal Congestion
Type/Category:	Level of Service
Description:	Plan processing/wait times for extra connecting flight scenarios and consequent extra levels of PAX flux (based on flight quantity/size/gates) through restrooms, escalators, elevators, moving walkways, people movers, concessions, security, HVAC, boarding gates, etc.
Contributing Systems:	Flights/PAX flux modeling, predictive analytics, GIS, etc.
Key Benefits:	Resource planning/alerting, terminal capacity growth planning, etc.
Challenges:	Complex simulation of multiple modeling solutions for different aspects (e.g., PAX, aircraft, baggage), floor plan model updates, etc.
Use Frequency:	Quarterly, as needed for event preparation
Key Stakeholders:	Operations, Airlines, TSA, Planning & Development, Concessions

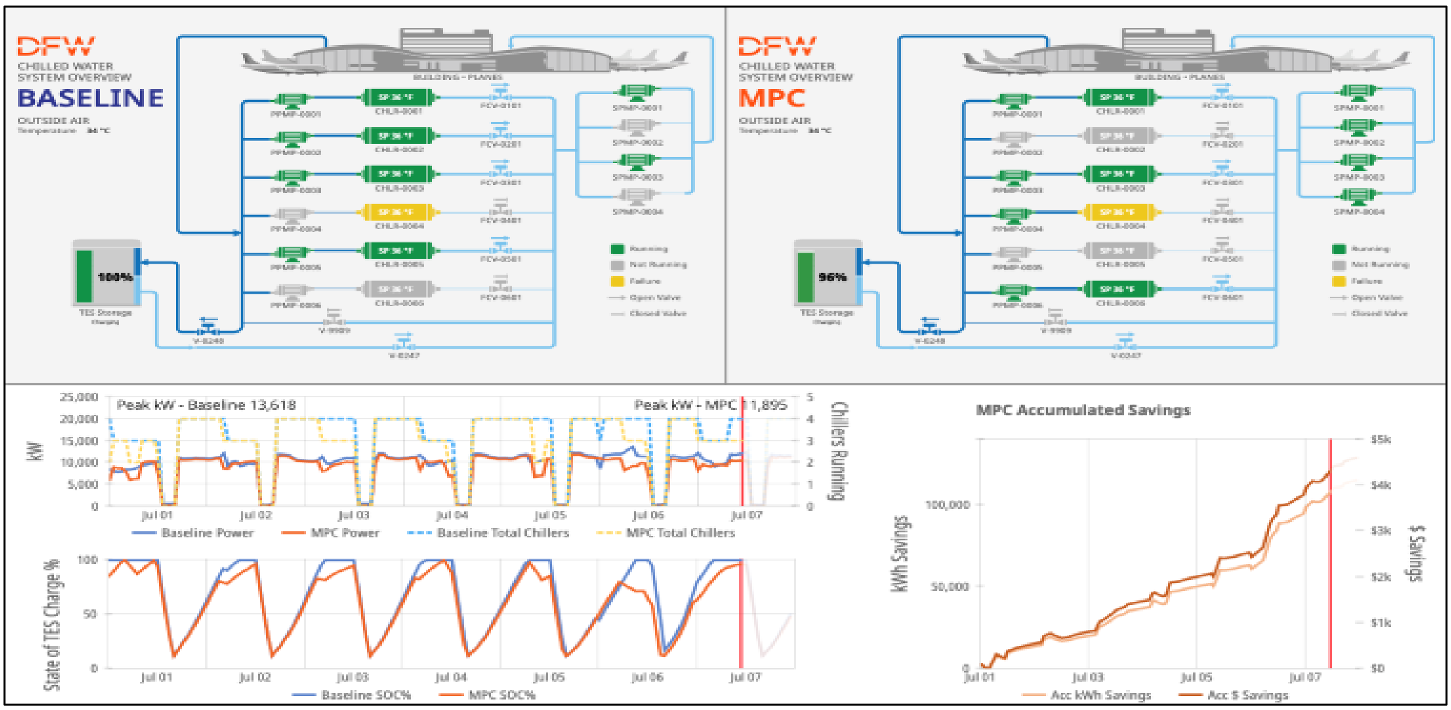


Courtesy of AMS

Use Case Name:	(8) Optimize Terminal Human Resource Planning
Type/Category:	Level of Service
Description:	Provide timely and appropriate levels of staffing for custodial, garbage, customer service, operations, supply techs, etc. based on anticipated terminal activity levels
Contributing Systems:	AODB, PAX movement analytics/queue management, GIS, etc.
Key Benefits:	Improved PAX satisfaction, improved tenant satisfaction, higher level of service, reduced flight delays and/or missed flights, etc.
Challenges:	Rules engine, establish metrics/KPIs, etc.
Use Frequency:	Hourly/Daily
Key Stakeholders:	Operations, Maintenance, Airlines, Concessions, TSA

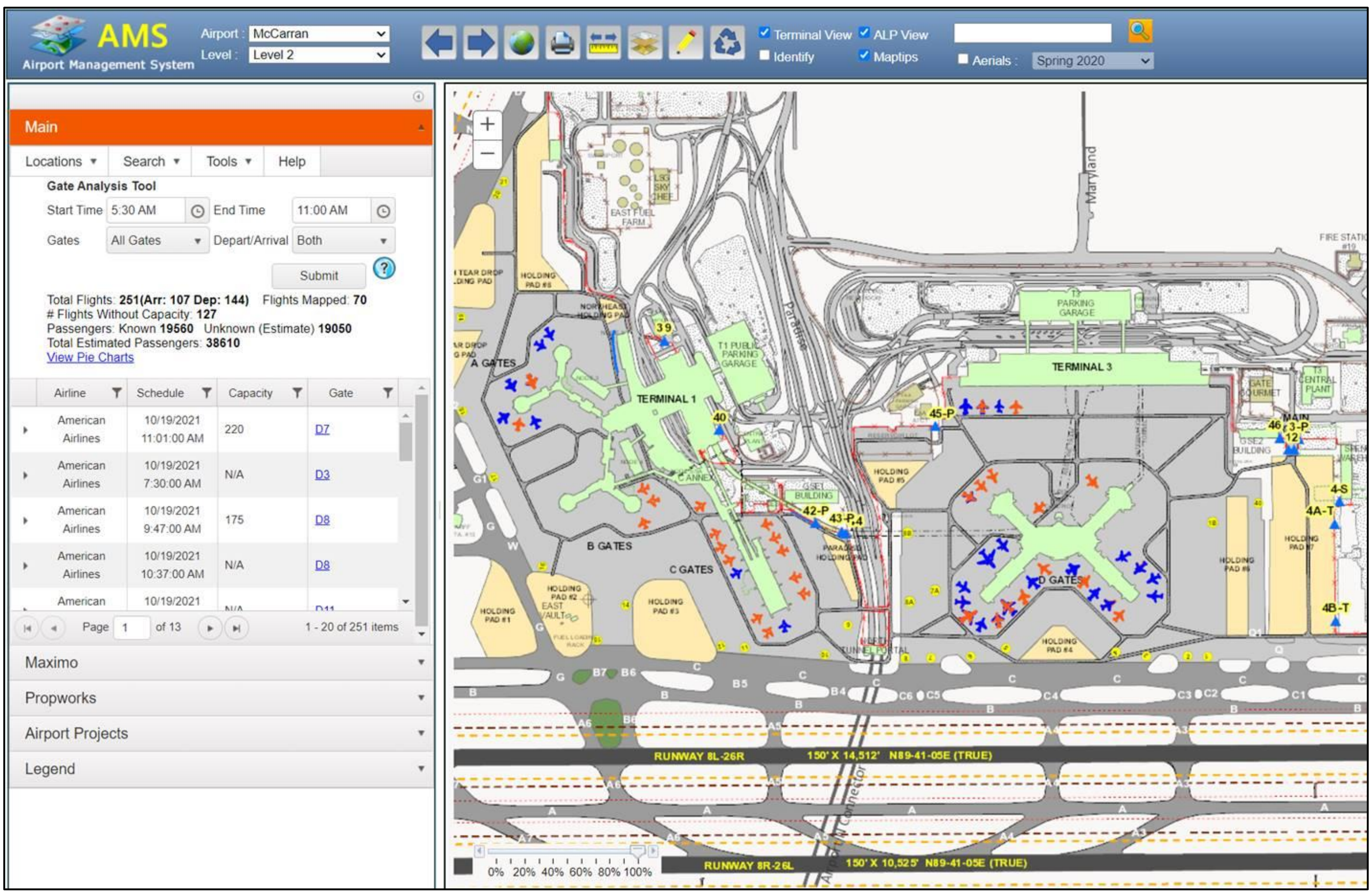
Courtesy of YVR

Use Case Name:	(9) Optimize Terminal Energy Management
Type/Category:	Financial & Sustainability
Description:	Correlating and analyzing data from disparate systems to minimize terminal energy costs, while maintaining comfortable PAX level of service
Contributing Systems:	AODB, BMS, HVAC/CUP SCADA, BIM, GIS, NREL Morpheus Analytics, etc.
Key Benefits:	Energy cost reductions
Challenges:	Integrating disparate systems data which traditionally have not been interoperable; transient to temporal; developing effective analytics algorithms
Use Frequency:	Monthly/Quarterly
Key Stakeholders:	Operations, Maintenance, Sustainability



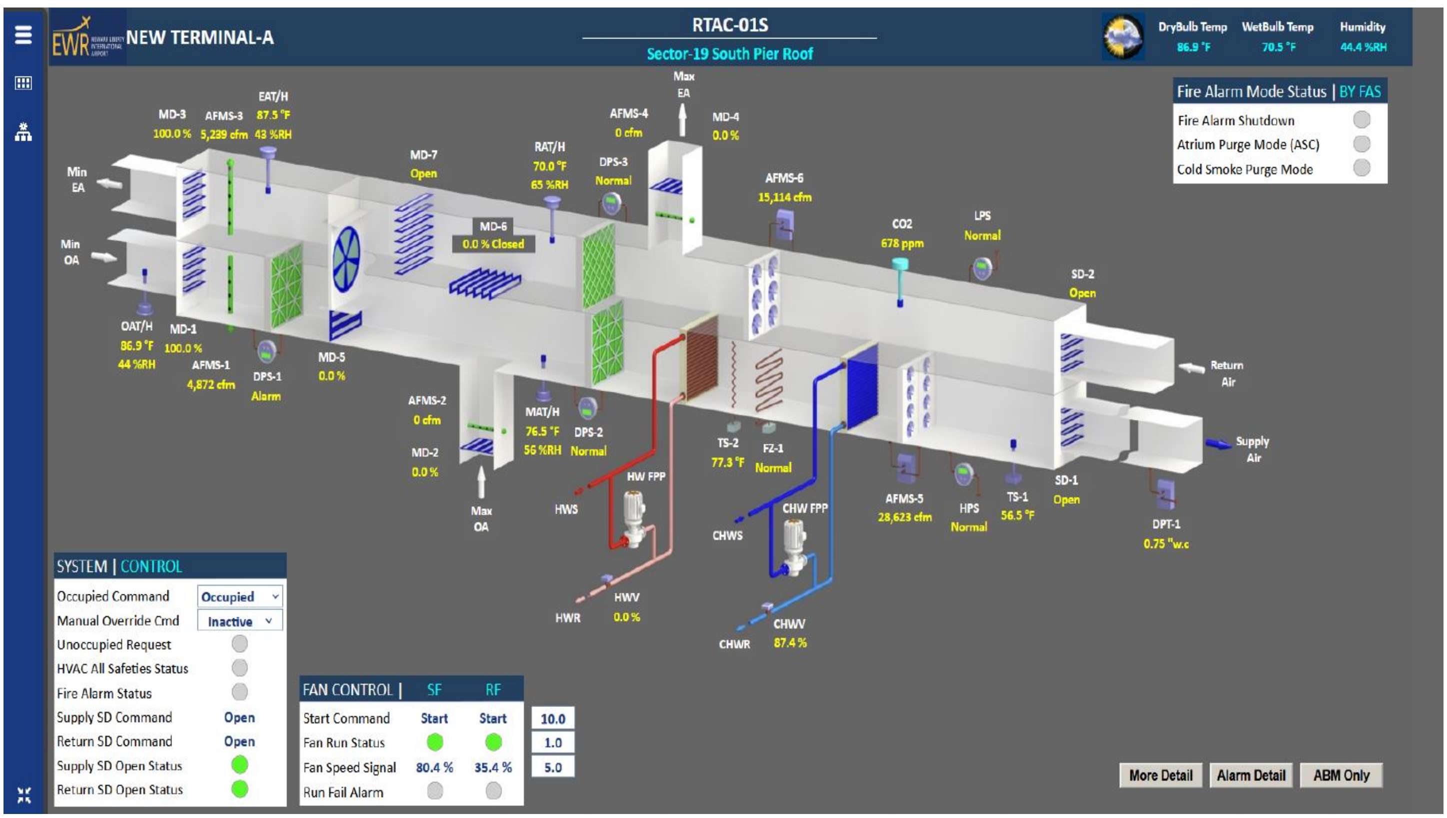
Courtesy of DFW

Use Case Name:	(10) Optimize Terminal Cleaning for Flight Activity
Type/Category:	Level of Service
Description:	Timely cleaning at required terminal areas based on use/foot traffic/incident information correlated from multiple systems; including bathroom queues/satisfaction surveys, gate seating, food/drink spills, smart trash cans, elevators, etc.
Contributing Systems:	AODB, aircraft gate management, PAX movement analytics/queue management, smart trash cans, CCTV video analytics, bathroom cleanliness surveys system, elevators management, GIS, etc.
Key Benefits:	PAX satisfaction, tenant satisfaction, health perception
Challenges:	Updated floor plans at large airports involving dynamic projects including CIP, tenant improvements, maintenance, etc.
Use Frequency:	Hourly
Key Stakeholders:	Maintenance, Operations, Airlines



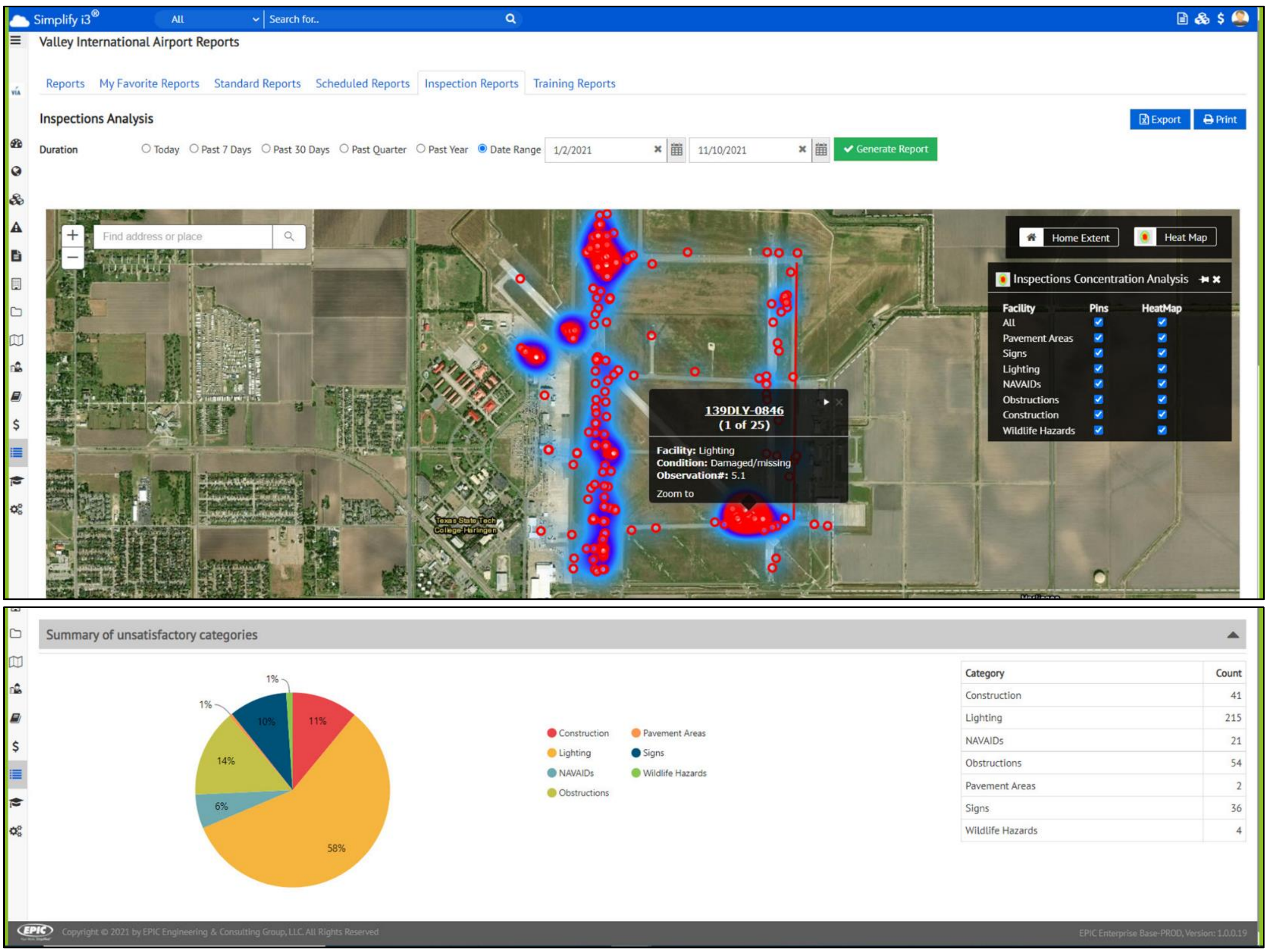
Courtesy of LAS using Esri, PROPworks, and Maximo software

Use Case Name:	(11) Optimize PAX Health Monitoring and Improvements
Type/Category:	Health & Safety
Description:	Map and correlate safety and health issues data to identify potential root causes which may be mitigated to improve productivity and reduce insurance claim costs
Contributing Systems:	HR, incident management, BI data warehouse, analytics, GIS, etc.
Key Benefits:	Improved employee productivity, reduced costs from insurance claims
Challenges:	Updated floor plans with assets/sensors layout
Use Frequency:	Monthly/Quarterly
Key Stakeholders:	Administration, Human Resources, Operations, Maintenance



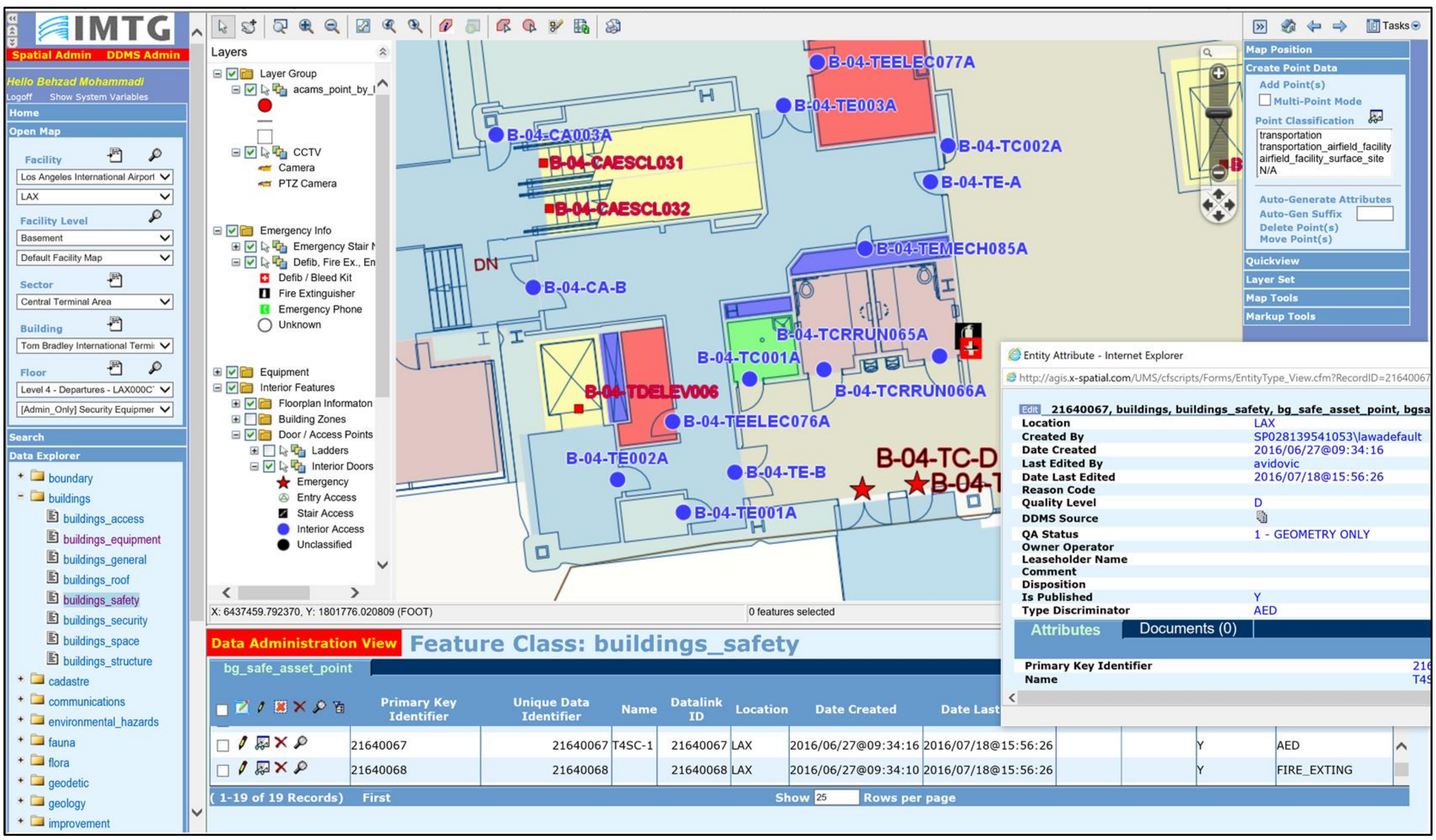
Courtesy of PANYNJ

Use Case Name:	(12) Optimize Safety Management System (SMS)
Type/Category:	Safety
Description:	Map and correlate various safety hazard data from hazard identifications, incidents, service requests, inspections, NOTAMs, workorders, etc. to improve root cause analysis and safety mitigation across airport campus
Contributing Systems:	SMS, inspections, NOTAM, CMMS/EAM, weather, AOA movement tracking, GIS, etc.
Key Benefits:	Improved safety, reduced operational impacts, reduced workorders, reduced costs
Challenges:	Collecting information feeds from disparate systems
Use Frequency:	Daily/Monthly/Quarterly/Annual
Key Stakeholders:	Operations, Maintenance, Construction



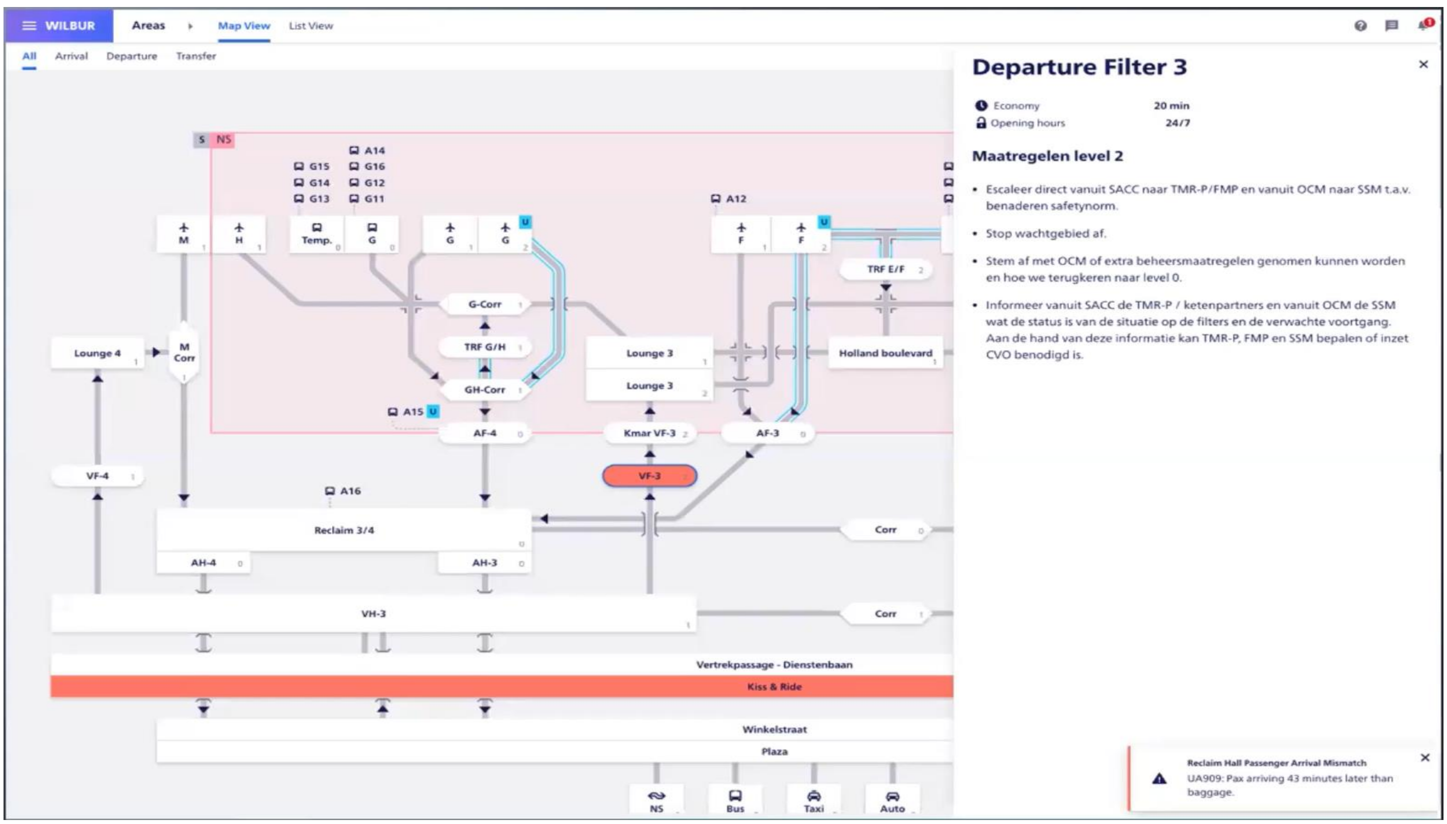
Courtesy of HRL using EPIC's Simplify i3 software

Use Case Name:	(13) Optimize Security & Emergency Situational Awareness
Type/Category:	Security & Safety
Description:	Airport Operations Center (AOC) and Emergency Operations Center (EOC) involve a myriad of systems used by the AOC/EOC operators to coordinate, assess, and respond to various situations; need to correlate various such system feeds/analytics to deal more efficiently with issues across the entire airport campus including cybersecurity
Contributing Systems:	Incident management, CCTV, video analytics, access control, smoke/fire alarms, temperature sensors, PAX movement analytics/queue management, elevator/escalator management, moving walkways, people movers, inspections management, work order management, project logistics management, AODB, GIS, cyber security, etc.
Key Benefits:	Faster and more accurate situational understanding, faster and more effective decision making, improved post situation analysis and reporting
Challenges:	Updated floor plans reflecting current location of assets, doors, CCTV cameras, sensors, etc., indoor tracking of personnel
Use Frequency:	Constant, 24/7
Key Stakeholders:	Operations, Police, Fire, Maintenance, IT, TSA



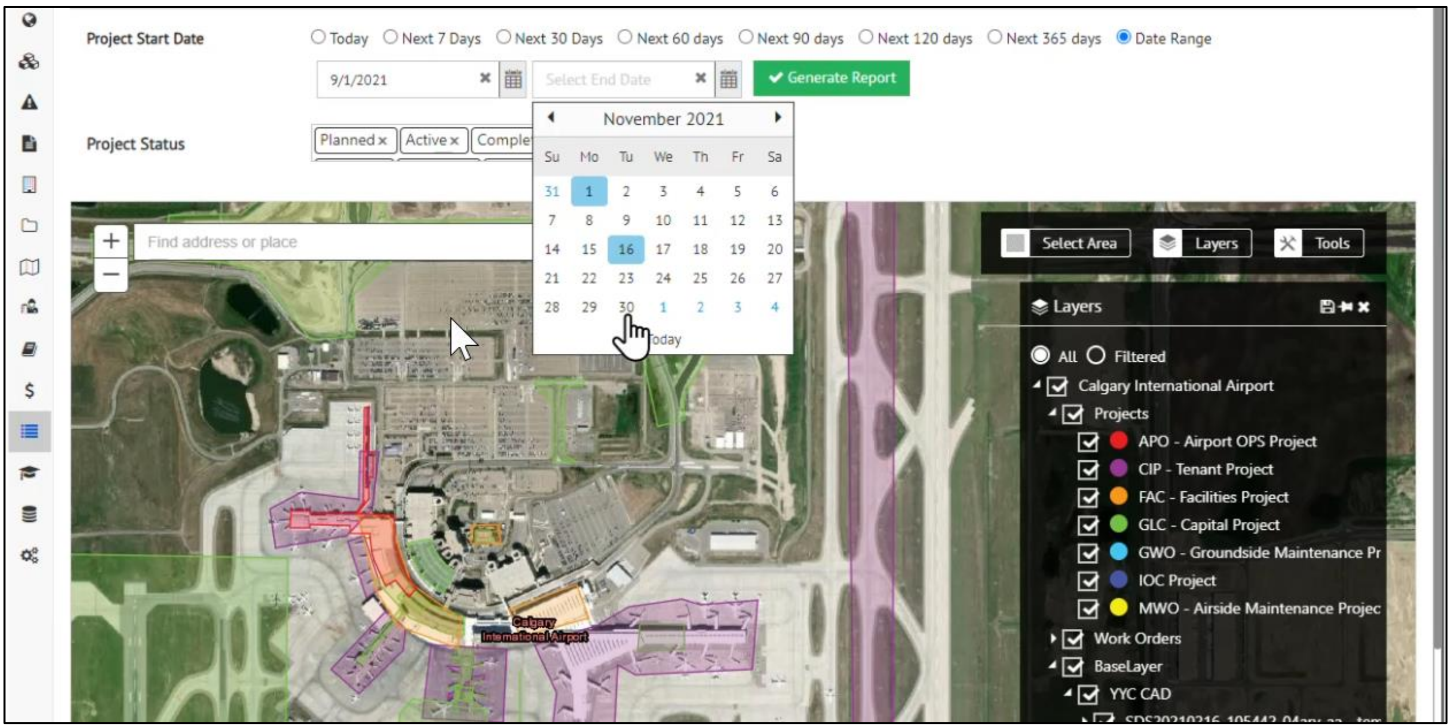
Courtesy of LAX using x-Spatial AEGIS software

Use Case Name:	(14) Optimize Predictive Maintenance of Facilities & Infrastructure
Type/Category:	Financial & Sustainability
Description:	Proactive maintenance of roadways, airfield, terminal (e.g., HVAC, lighting, elevators, escalators, roofing, carpeting, etc.) to reduce breakdowns, prolong service life, improve quality of service, and reduce costs
Contributing Systems:	AODB, PAX movement analytics/queue management, building automation/SCADA analytics, elevator/escalator/moving walkway/APM management systems, airfield movement tracking analytics, roadway vehicle counter analytics, inspections, GIS, etc.
Key Benefits:	Reduced interruptions to operations due to breakdowns/hazards, improved level of service, reduced costs
Challenges:	Variety of systems/vendors integration, updated assets data from CIP projects
Use Frequency:	Monthly
Key Stakeholders:	Maintenance, Operations, IT, Finance



Courtesy of AMS

Use Case Name:	(15) Optimize (Minimize) Work Scheduling Impacts
Type/Category:	Level of Service
Description:	Minimize power/water/HVAC outages and other disruptions to PAX and airline operations from maintenance work orders, construction projects (e.g., capital improvement, tenant modifications, facilities modification), inspections, etc.; optimize maintenance & construction windows; reduce revenue interruptions
Contributing Systems:	Maintenance management, project management/scheduling, AODB, PAX movement analytics/queue management, GIS, etc.
Key Benefits:	Avoidance of airline delays/penalty costs, avoidance of PAX complaints, accident avoidance
Challenges:	Multiple project management entities (e.g., CIP, tenants, maintenance, IT, etc.)
Use Frequency:	Daily/Weekly
Key Stakeholders:	Operations, Maintenance, Construction, IT



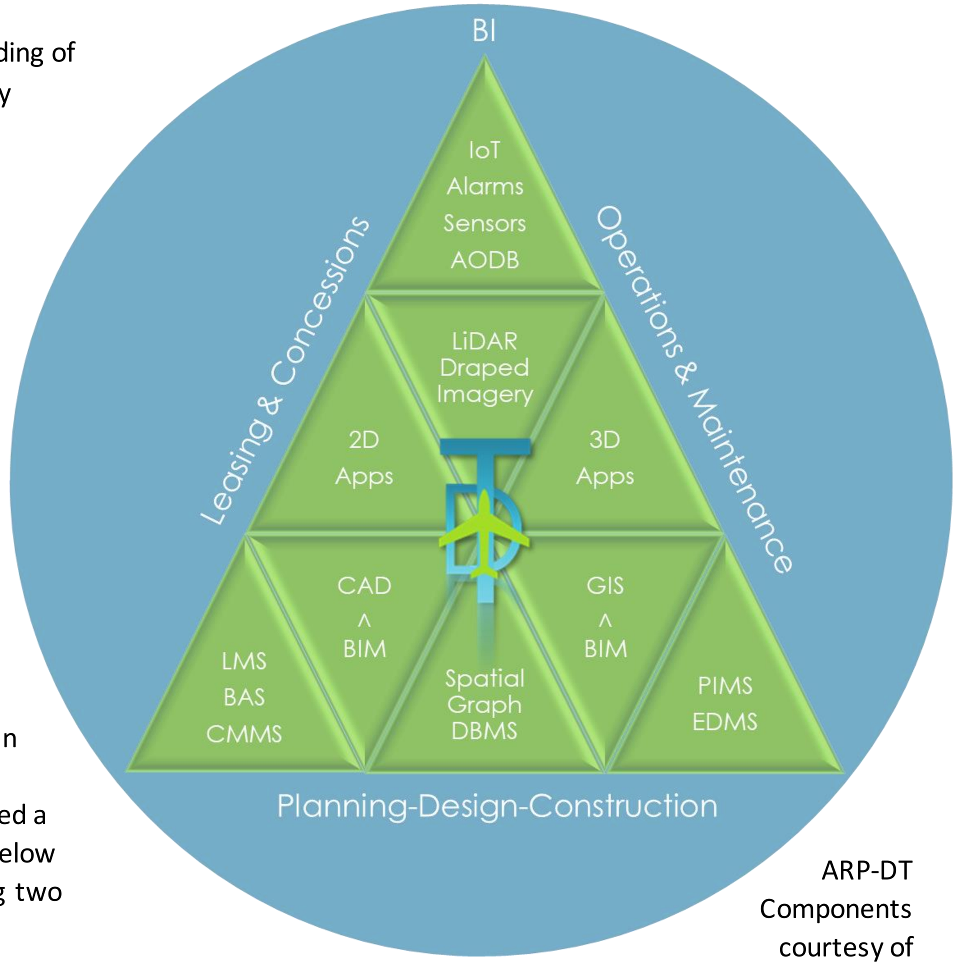
Courtesy of EPIC's Simplify i3 software

3. Implementation of Digital Twin

ARP-DT implementation requires understanding of the required components, a gradual maturity model, phased work breakdown structure, management, and skillsets.

3.1 Components

The triangular diagram, shown to the right, identifies key components needed to assemble an ARP-DT. The central components are spatial in nature, enabling a common denominator for correlating various data, all rolled up to an enterprise BI analytics platform.

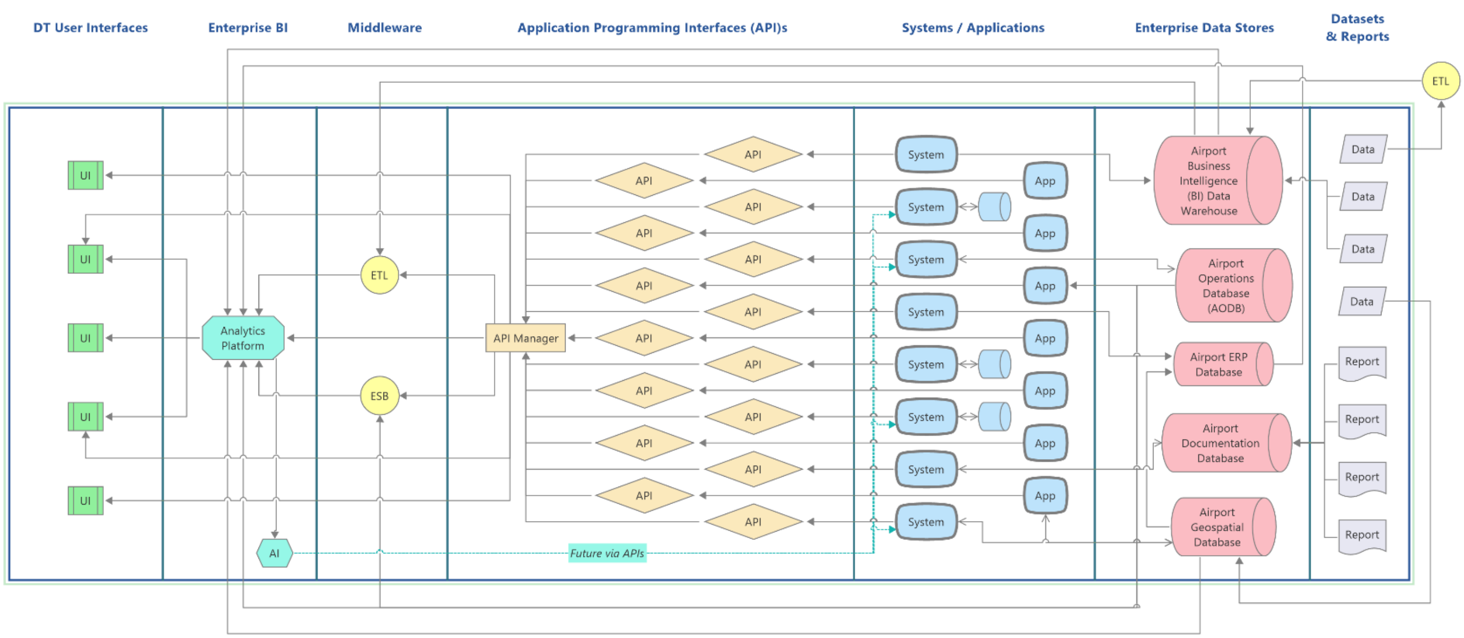


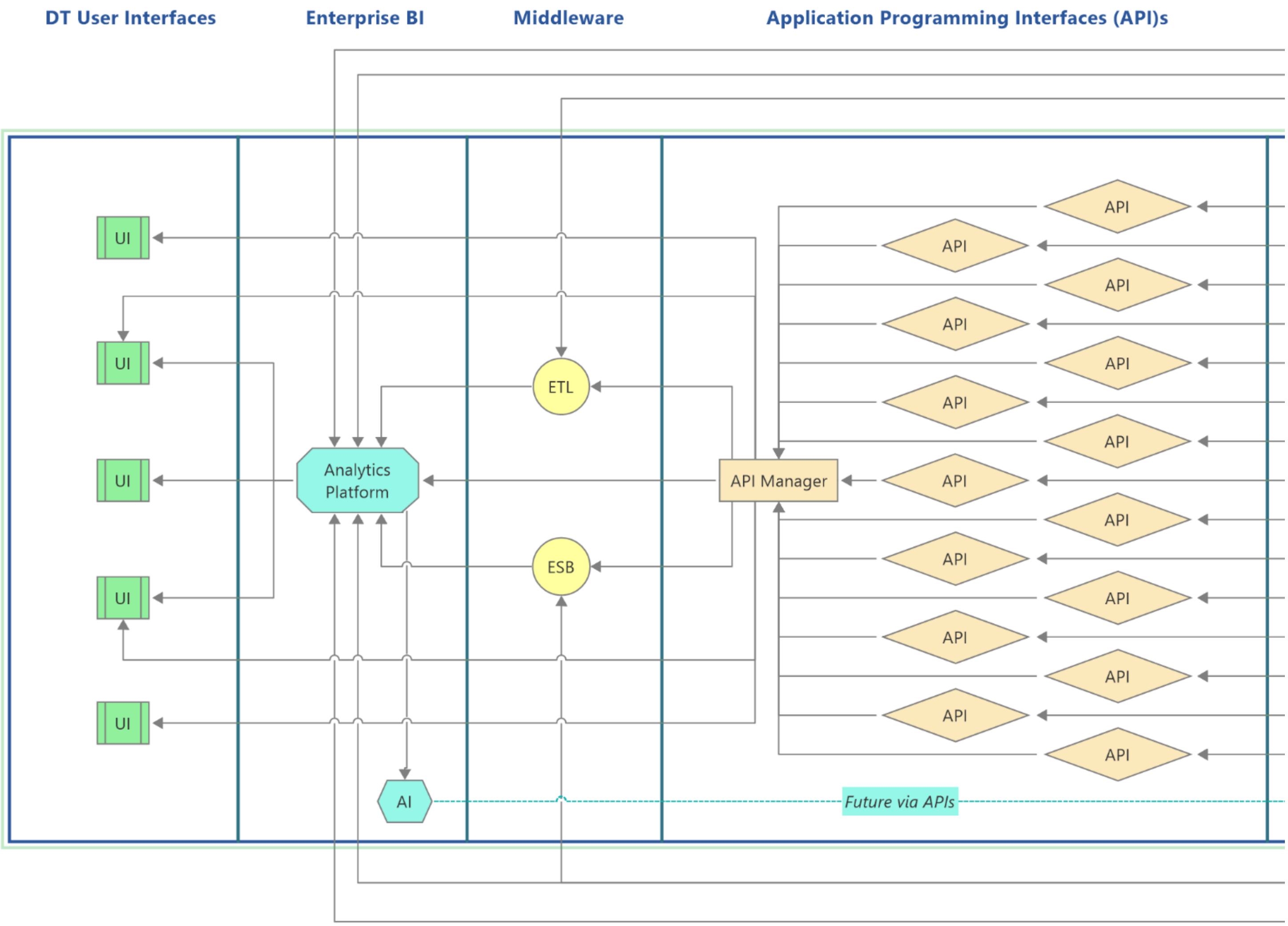
ARP-DT Components courtesy of www.AirportDigitalTwin.org

3.2 Open System Architecture

Since an ARP-DT involves an integration of various evolving systems and data sources, an open systems architecture approach is recommended. The AAAE's DT-WG developed a recommended system architecture shown below and described in more detail on the following two pages.

ARP-DT Open System Architecture courtesy of AAAE DT-WG (higher magnification provided on following pages)

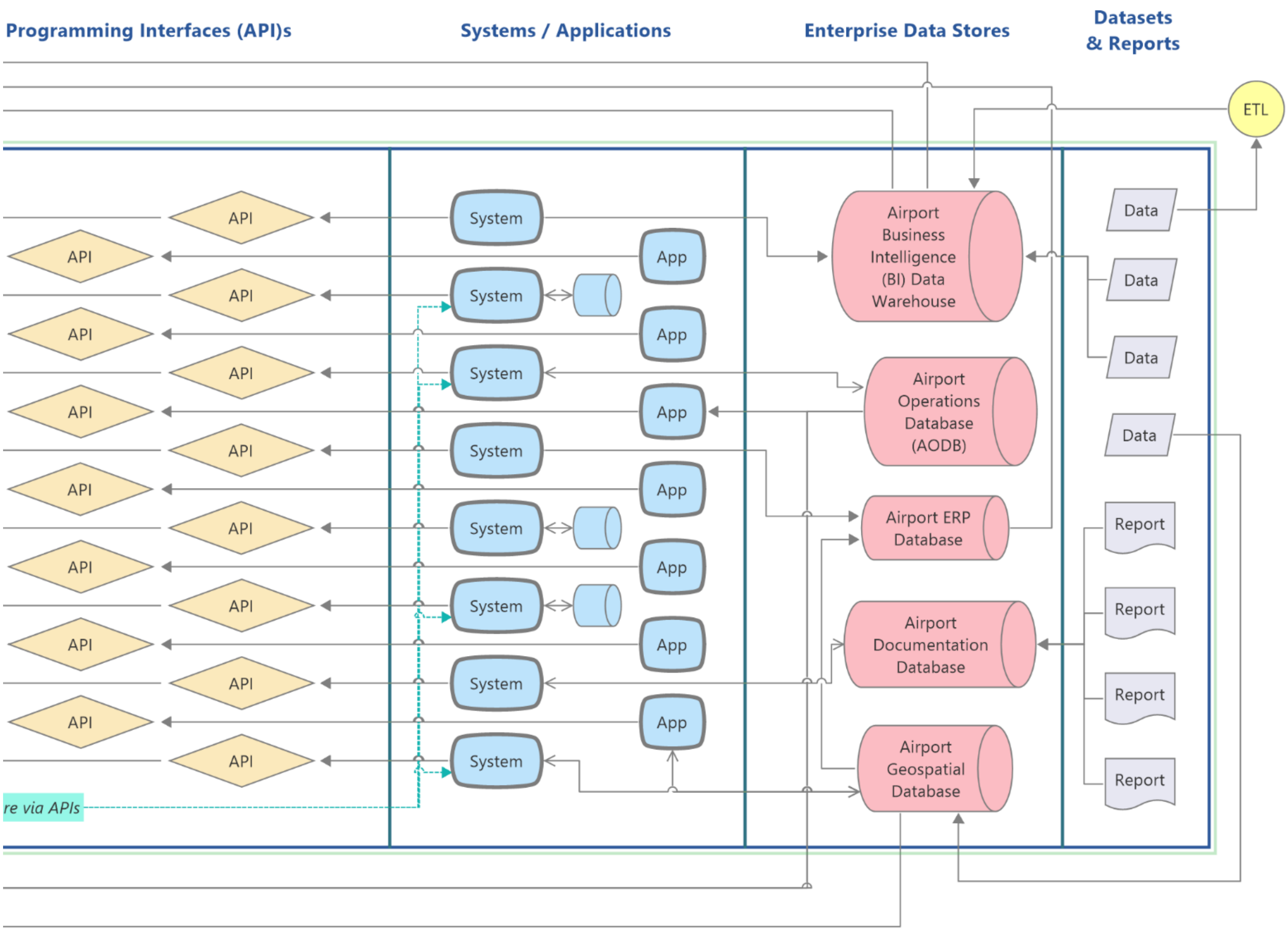




ARP-DT Open System Architecture courtesy of AAAE DT-WG
(left side of diagram)

The above portion of the ARP-DT system architecture diagram starts with the User Interfaces (UI) on the left side. Different airport management use cases, as described in the previous section, may require different UIs, respectively. Each use case will have relevant information to be displayed in a relevant layout. Various UI examples are shown in the previous section. The UIs are fed information from a combination of an enterprise BI analytics platform, an API manager facilitating integration with different systems, and major enterprise data stores shown on the following page. API data may require processing via middleware such as an Enterprise Service Bus (ESB) or an Extract-Transform-Load (ETL) mechanism.

Although most use cases for an ARP-DT are for one-way decision-support, where reactions needed would be invoked directly by respective control system operators, there may be opportunities for an ARP-DT Artificial Intelligence (AI) component to automatically provide feedback control to respective systems, based on correlated data; hence, a two-way information flow use case. For example, lighting control may be automatically scheduled based on planned AODB flights/passengers activity, Computerized Maintenance Management System (CMMS) work orders and preventive maintenance orders, and Project Information Management System (PIMS) all correlated by the ARP-DT via its GIS mapping of lighting zones corresponding to scheduled levels of activities.



ARP-DT Open System Architecture courtesy of AAAE DT-WG
(right side of diagram)

The number of APIs and systems and apps shown are merely representative. Airports may have hundreds of systems. Such systems may include their own respective databases or a shared enterprise datastore containing data needed by multiple systems such as an Airports Operations Database (AODB).

Another key enterprise data store is a BI data warehouse, which is needed to house various collected or ETL extracted datasets required for ARP-DT use cases; whether from other airport systems, or from discrete datasets or reports, including excel spreadsheets (e.g., airline self-reported passenger quantities).

Other key enterprise data stores include an ERP financial database, and an airport geospatial database including various spatial data types such as Computer Aided Design (CAD), Geospatial Information System (GIS), Building Information Modeling (BIM), and Light Detection and Ranging (LiDAR) with draped 360 degree imagery.

3.3 Maturity Model

The maturity model matrix was developed by the AAAE DT-WG as a spreadsheet, to enable airport owners to easily assess their current capabilities along the path towards achieving full ARP-DT capabilities. In essence, this matrix is a roadmap of capabilities to be achieved gradually.

This matrix is provided at a higher magnification on the following pages.

The matrix is divided into eight major aspects required to achieve and sustain ARP-DT capabilities:

1. Staffing
2. Business Processes
3. Data Housing
4. Metrics & Analytics
5. Data Flow
6. Spatial Correlation
7. Systems Integration
8. Predictive Simulation

	AAAE Airport Digital Twin Maturity Model					
	Lowest	>	>	>	>	Highest
	Entry Level					Utopia
Level	1	2	3	4	5	6
Staffing	Self motivated individual division staff conducting analysis	Division designated dedicated analyst	Proactive centralized Business Intelligence (BI) organizational function			
			Understaffed	Adequately staffed	Some machine learning automation reducing needed staff levels	Full machine learning automation
Business Processes	Not documented	Few documented	Few mapped with some workflow automation	Mostly mapped with some workflow automation	Completely mapped with some workflow automation	Completely mapped with full workflow automation
Data Housing	Siloed	Combination of siloed and centralized	Mostly centralized data hub/warehouse	Centralized & integrated data warehouse	Mostly aligned data	Full accessibility & alignment
Metrics & Analytics	Defining DT Vision & Path Forward					
	Measuring available data	Developing division metrics for key priorities	Developing centralized universal metrics	Build alignment of organizational measures into employee work tasks	Calibrate alignment of metrics to improve performance	Fully aligned enterprise with on-demand metrics
Data Flow	No automated data sharing flow (i.e., manual batch loading, not real time via API)	Manual and automated data sharing flow	Manual and automated data sharing flow	Priority external and all internal data flows automated	All data feeds automated with self reported validated	All data feeds automated (no self reporting)
	Some IoT device data flow within proprietary disparate systems	Some internal airport systems with automated data sharing	External partners data is partially manual (e.g., airlines, concessions, etc.)	Automated PAX demographics, POS, concessions data, airline activity overlay		
Spatial Correlation	Aerial/ALP/raster floor plan maps some georegistered	Manual shared CAD/GIS maps	Common basemap automated web services			
		Georegistered	Georeferenced with metadata / some surveyed	Some georeferenced LiDAR survey verified	Most georeferenced LiDAR survey verified	All georeferenced LiDAR survey verified
	Real-time sensor/analytics feeds (including video analytics) on static maps within respective siloed systems	Non-interactive analytics consumption of GIS mapping	Interactive analytics mapping overlay (i.e., can select layering and interrogate feature attributes)	Real-time sensor/analytics feeds overlayed on combined 2D map; CCTV imagery accessible from mapped cameras	Dynamic real-time CCTV imagery overlaid on 3D GIS/BIM	Augmented/virtual reality with all integrated data overlaid
	Accessible to individual system operators	Designated analyst access to mapped analytics	Enterprise distribution of mapped analytics			
	Ad-hoc updated indoor/outdoor basemaps in 2D GIS	Annual updated indoor/outdoor basemaps in 2D GIS	Semi-annual updated indoor/outdoor basemaps in 2D/3D	Monthly updated indoor/outdoor basemaps with LiDAR & draped 360 imagery integrated in 2D/3D GIS	Weekly updated indoor/outdoor basemaps with LiDAR & draped 360 imagery integrated in 2D/3D GIS	Daily updated indoor/outdoor basemaps with LiDAR & draped 360 imagery integrated in 2D/3D GIS
	Minimal GIS staff	GIS understaffed	GIS adequately staffed and minimal BIM staff	Spatial data updates partially automated in GIS; reduced GIS staff; more BIM staff	Spatial data updates partially automated in GIS/BIM; asset ID AI learning; reduced GIS/BIM staff	Spatial data updates fully automated in BIM/GIS with AI asset ID; minimal monitoring and staff
	"As-Built" BIM reference models available	"As-Built" BIM reference models linked to GIS with some BIM updating			High priority buildings updated in BIM and integrated with GIS	Updated BIM models campus wide and integrated with GIS
Systems Integration	Mostly disparate (non-integrated) COTS solutions	Mostly via flat file integration	Individually managed integrations via APIs; no direct sensor edge integration	Integration broker for some systems via APIs; no direct sensor edge integration	Major systems integrated via common hub; direct sensor edge integration	All systems integrated via common hub; direct sensor edge integration
		Uni-directional (1-way) integration into DT		Some bi-directional manual (DT control output) with non-critical systems	Manual bi-directional including critical Systems	Automated feedback bi-directional including critical systems
Predictive Simulation	Disparate simulation tools used as needed by consultants for defined studies; not part of DT		Predictive simulation of select flows (e.g., PAX, aircraft, bags)	Predictive simulation of high priority airport operations (e.g., aircraft, PAX, baggage, roadways, parking)	Predictive simulation of most airport operations	Full airport campus predictive simulation

	AAAE Airport Digital Twin Maturity Model					
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Level	**1**	**2**	**3**	**4**	**5**	**6**
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	Lowest	>	>	>	>	Highest
	Entry Level					Utopia
Level	**1**	**2**	**3**	**4**	**5**	**6**
			etc.)	activity overlay		
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		Georegistered	Georeferenced with metadata / some surveyed	Some georeferenced LiDAR survey verified	Most georeferenced LiDAR survey verified	All georeferenced LiDAR survey verified
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3.4 Phasing and Work Breakdown Structure

Achieving an ARP-DT should be a gradual, phased, evolution, as described by the maturity model matrix in the previous section. Starting or continuing, along the implementation path, with an ARP-DT program of projects should begin with a planning phase, as shown in the recommended Work Breakdown Structure (WBS) below. The Planning Phase should essentially prioritize the use cases to be implemented. For each use case, the Phase-n WBS should be used to design-build the use case in the ARP-DT. Once any use case has been implemented, O&M support should be in place for fine-tuning and updating both system and data, as needed.

Phase-1: Planning

1.1 Assessment of Current Relevant Capabilities & Gaps (including Data)

1.2 Ascertain Highest Priority Needs

1.3 Develop Corresponding Implementation Plan Phasing

Phase-n: Design-Build per Prioritized Use-Case

n.1 15%: Specify Requirements to Improve As-Is Process

n.2 30%: To-Be Business Process Modeling and Conceptual Layouts

n.3 60%: System/Data Configuration & Integration Development

n.4 90%: System/Data Testing

n.5 100%: System/Data Activation & Training

O&M Support Phase

- System O&M Fine-Tuning & Updates
- Data O&M Fine-Tuning & Updates

3.5 Implementation Management

An ARP-DT implementation program of projects can be managed via the airport's Information Technology (IT) division, or via the airport's Innovation/BI division, or via the airport's Engineering division. It is recommended that the airport outsource the Program/Project Manager (PM) position to a qualified consultant, serving as an extension to the airport's staff and reporting to the managing division.

Section 4, below, recommends which part of the airport owner's organization should serve as the lead "steward" for the ARP-DT. It is recommended that the optimum steward would be the airport's BI function, which would be the lead user of the system. Hence, it may also be most appropriate for the airport's BI function to manage the ARP-DT implementation program with close support from IT, Engineering, Operations, Facilities, etc. If an airport BI function does not exist yet, then it needs to be setup in preparation for the ARP-DT program.

3.6 Implementation Skillsets

The following outlines the types of individuals needed on the ARP-DT implementation team, composed of airport staff (listed in green) and consultant/solution-provider resources (listed in blue).

- **Airport Owner**
    - Executive Sponsor (for example the Chief Innovation Officer)
        - Steward (for example BI Manager)
            - Business Process Improvement Strategist
                - BI Analyst(s)
            - BI Data Warehouse & Analytics
                - BI Data Warehouse Technician
                - BI Analytics Platform Technician(s)
        - IT Support
        - Engineering Support
        - Operations Support
        - Facilities Support
        - Concessions & Real Estate Support
        - Finance Support
        - Etc.

- **Consultant/Solution-Provider**
    - Program Manager
        - Project Manager
            - Process Team Lead
                - Process Improvement Specialists
                - Business Process Modeling (BPM) Specialists
            - Technology Team Lead
                - Technology Platform Configuration Specialists
                - Technology Integration Specialist (i.e., leveraging APIs, ESB, ETL, etc.)
            - Data Team Lead
                - Facilities/Infrastructure
                - Operations
                - Tenant Leases
                - Financial
                - Environmental
                - Energy
                - Geospatial
                    - CAD
                    - GIS
                    - BIM
                    - LiDAR
                    - Imagery

4. Sustaining of Digital Twin through Governance

Just as the physical airport requires daily governance to sustain it, so does it's parallel digital twin. This section identifies key aspects of governance that are critical to sustaining an ARP-DT.

4.1 Airport Organization Lead Steward

An ARP-DT requires a steward group within the airport owner's organization to lead the program's development and manage its sustainment. The following are the top candidate divisions within an airport's organizations, listed by order of preference. The airport's Business Intelligence (BI) function, which is likely under the airport's Innovation division, is most recommended for such a role. If such a function does not exist yet, then it is recommended that a BI Manager be designated.

1st Innovation/BI Division

2nd Operations Division

3rd Engineering Division

4th IT Division

4.2 Configuration Change Management

The airport campus, its facilities, infrastructure, assets, systems, and processes continually evolve and change. Some examples of frequent common changes include the addition or re-positioning of CCTV cameras, tenant changes, facility modifications, etc. Such changes must be updated in a timely fashion on the digital twin side, in order to preserve its accurate functionality.

Configuration change management is a well-established governance practice, including at airports, especially with IT systems. Configuration management involves controlling any changes to an overall system's configuration, to preserve the system's proper operation. In other words, configuration changes can adversely affect the proper operation of a system. Hence, changes on IT systems are reviewed for compatibility prior to implementation, then tested offline to resolve any issues, and only after proper vetting and approval are implemented. A Configuration Control Board (CCB), involving various stakeholder disciplines, is often used to govern this practice.

With an ARP-DT, a CCB is also required, not only to preserve its IT operation, but also to update its reflection of the physical airport that is being digitally twin-ed. Maintaining the "twin digital reflection" to match the airport, involves not only the visual physical aspects, but also the various processes and data aspects. Any airport project, changing the airport, needs to include in its scope a task to update the ARP-DT as part of project activation. This task needs to be managed by the ARP-DT's CCB.

To achieve efficient ARP-DT configuration change management, leveraging established data standards is highly recommended both outdoors and indoors for asset identification, CAD, GIS, BIM, survey control, etc. Enforcing standards on airport project deliverables will save data processing costs for updating the ARP-DT. Millions of dollars have been spent developing such standards by the US government and other international entities. Airports should adapt these to their specific needs. Examples of such key standards for the foundation of an ARP-DT include EUROCONTROL/FAA Aeronautical Information Exchange Model (AIXM), FAA's 150/5300-18 GIS Standard, buildingSMART Industry Foundation Classes (IFC) ISO 16739-1:2018, DoD Spatial Data Standard for Facilities Infrastructure & Environment (SDSFIE), etc.

5. Funding Approaches

Funding of major airport improvement initiatives can be like "surfing waves". The airport owner ("surfer") has to navigate and leverage various airport funding opportunities for improving the airport and incorporate ARP-DT funding into these funded programs ("waves").

ARP-DT should leverage a Capital Improvement Program (CIP) to implement the platform and its use-cases, as well as leverage O&M funding for the airport staff and extension-to-staff for operating and sustaining the ARP-DT. However, major data updates to the ARP-DT, reflecting airport configuration changes due to CIP projects, should be funded as part of every CIP project's activation phase.

Other sources of potential funding may be special planning studies, including an airport's Master Plan, which would benefit from an ARP-DT to analyze airport capacity and safety improvement needs. Another source of potential funding may be an airport's Safety Management System (SMS) program implementation, which would leverage an ARP-DT for data integration supporting safety risk assessments, root cause analysis, and mitigation planning.

Essentially, every airport project should include a small percentage of funding to update the ARP-DT to reflect that project's changes to the airport. DFW has proposed an ARP-DT funding allowance of approximately 3% to be added to each project's budget.

Traditional airport management systems have been priced in the millions of dollars. Today, airports have cloud-based solution options priced 1-2 orders of magnitude less, with annual subscription costs ranging from $n0,000 to $n00,000. These options include ARP-DT platforms. For such Software as a Service (SaaS) solutions, there would be no other additional infrastructure costs. However, ARP-DT implementations do require on-boarding costs for different use-cases involving requirements specifications, platform configuration, systems/data interfacing, data processing, testing, fine-tunning, documentation, training, etc.

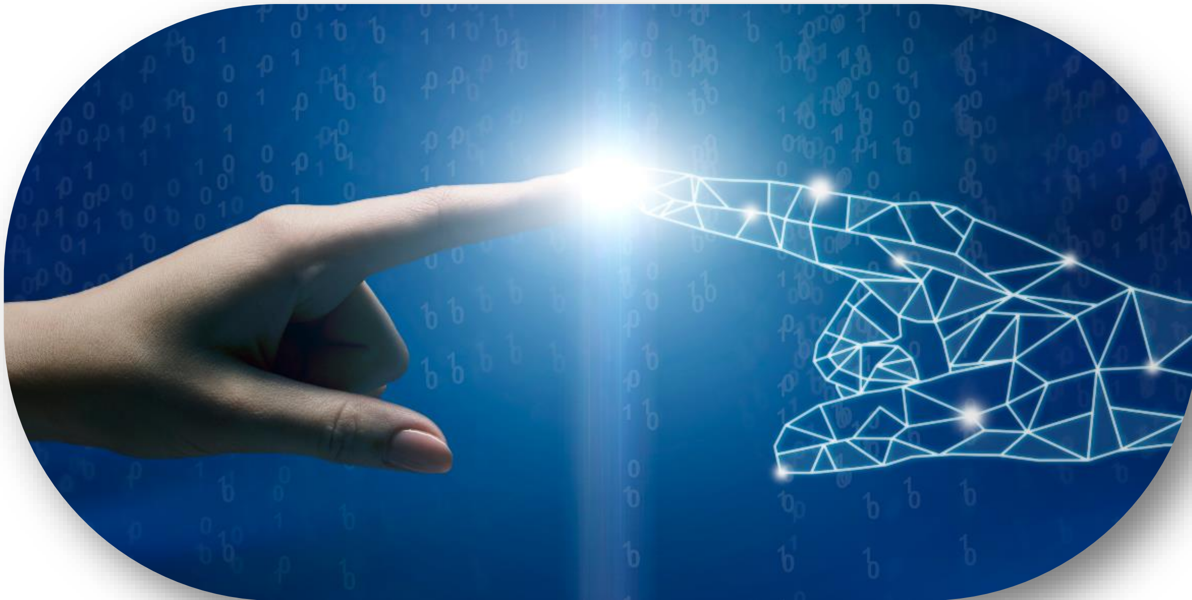

Image Courtesy of EPIC Engineering & Consulting Group

Acknowledgements

David Tamir formed and led the AAAE's Digital Twin Working Group, which developed the content of this roadmap for airport owners to achieve and sustain digital twins for airport enterprise management. Moreover, David has formed www.AirportDigitalTwin.org, combining key technology solution providers to enable airport owners to effectively achieve and sustain digital twins.

An aeronautical and space systems engineer, David brings 4 decades of relevant experience, including 1 decade from the Space Shuttle Program and 3 decades supporting over 30 airports, starting on the airport owner's side at Orlando International Airport. David's focus is airport business process improvements through technology applications, rolling up to digital twins.

David dedicates this work to Rear Admiral Lee Tillotson, who inspired him on this path starting at Orlando International Airport in the mid-1990s, where Tillotson at the time served as the Deputy Executive Director for Development of the Greater Orlando Aviation Authority.

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Last, but not least, David acknowledges his dear wife, Michal Yaminy-Tamir, for keeping their two young twin children at bay😊😊, so David can focus on his work.

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Appendix: AAAE Digital Twin Working Group Participants

The following listing provides the names of the AAAE DT-WG participants over 2022-2023. These are organized alphabetically.

Airports

- AMS
    - Gerben Tiemens
    - Frans van der Lek
    - Peter Kanbier
- ATL
    - David Wright
- BOS
    - Mark Ricketson
- CLT
    - Katie McCoy
    - Haley Cerri
    - Zach Yarbrough
- DEN
    - Brendan Dillon
- DFW
    - Pritpal Singh Roopra
    - Robert Brown
    - Dave Desanto (retired)
- LAS
    - Majed Khater
    - Rishma M. Khimji
- LAX
    - Anna Melikyan
- MCO
    - Joe Furnari
    - Mo Murnane
- MIA
    - Daniel Cinti
    - Mike Bryant
- MSP
    - Lydia Werner
- OMA
    - Patrick Kelly
- PANYNJ
    - James Mernin
- PHX
    - Jennifer Maples
- RSW
    - Joe Suglia
- SFO
    - Josephine Pofsky
    - Guy Michael
- Wisconsin DOT Aviation
    - Brenda Hanson
- YVR
    - Robert Leung
    - Andrew McFee
    - Carlos Silva

Technology Solution Providers

- AECOM
  - Brian Reever
  - Kyle Williams
- AirportDigitalTwin.org
  - David Tamir
- Amadeus
  - Danny Negron
- Amazon Web Services (AWS)
  - Tyler Subasic
- ARA
  - Kent Thompson
- Arora
  - Randy Murphy
  - Thomas Tiner
- Autodesk
  - Jon Monfred
  - Lewis Watts
- Bentley
  - Zubran Solaiman
- C&S Companies
  - Chuck Pietra
  - Posh Supupramai
- Dassault
  - Isaac Benzaquen
- EPIC Engineering
  - Prasad Chittaluru
- ESRI
  - Terry Bills
  - David James
- Honeywell
  - Basak Keskin
- IntellAct
  - Udi Segal
- Johnson Controls (JCI)
  - Ramsey Nuwar
  - Jason Pelski
- Magnasoft
  - Ganesh Deshmukh
- Microsoft
  - Eve Machol
- Mott MacDonald
  - Michael Salvato
- My Smart Plans
  - Dominick Armato
- NV5
  - David Grigg
- Parsons
  - Howard Shotz
- PDBM Consulting
  - Jorge Quiroz
- Pueblo Technology Group Inc (PTGI)
  - John Payne
- RS&H
  - Rob Grotefend
  - Julie Jernigan
- SAM
  - David Barron
- Siemens
  - Igor Starkov
- SITA
  - Sherry Stein
  - Brad Carufel
- Skyfii
  - Stephen Callender
- Skyline Software Systems
  - Jim Michel
- STV/CP&Y
  - James Duke
  - Jorge Suarez
- TransSolutions
  - Prasanna Kavaipatti
- University of Florida
  - Kofi Asare
- Willow
  - Jerry Schwinghammer
  - Chris Dusch
- Woolpert
  - Ed Copeland
- x-Spatial
  - Ed Maghboul

Others

- ACRP
  - Bill Jones
- FAA
  - Drew Goldsmith