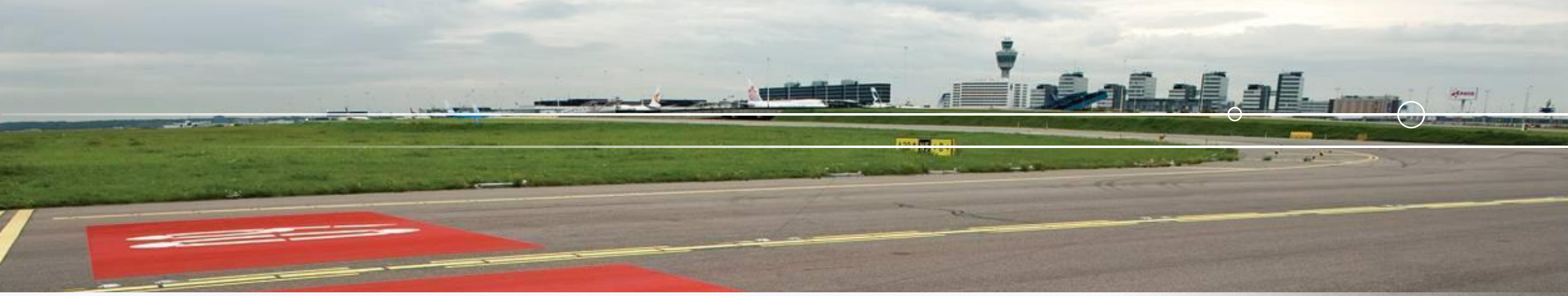


RFI Aircraft Flow & Capacity

View on the platform

Version : 9 April 2018

Schiphol
Amsterdam Airport

Table of Contents

Scope of this document

This document contains Schiphol's view on the architecture and requirements for the aircraft flow and capacity management platform. It describes the architecture we envision, what part of this solution we desire and what functionality we need in our view.

Please note that these are our initial thoughts and we want to elaborate, validate and develop them together with a protentional partner. Please view this document as a starting point for the discussion.

Organization:
Continuous improvement of processes, technology & people

1. Continuous Improvement Teams

We need to develop the capability/skills to continuously improve; move from traditional planning / execution towards process optimization, fact-based decision making and root cause analysis on disturbances.

2. Partnerships

We need to partner with industry leaders that share our vision and have the drive, skills and tools to jointly achieve our business goals as expressed in our ambition and participate in the continuous improvement teams.

3. Platforms

Instead of purchasing turn key solutions, the IT systems in this area should not be set in stone, but be open and enable continuous improvements (platforms).

Agile development

- Mixed team (Schiphol & Partner)
- Within Value Stream for Planning & Forecasting

Process Groups

We identify five process groups:

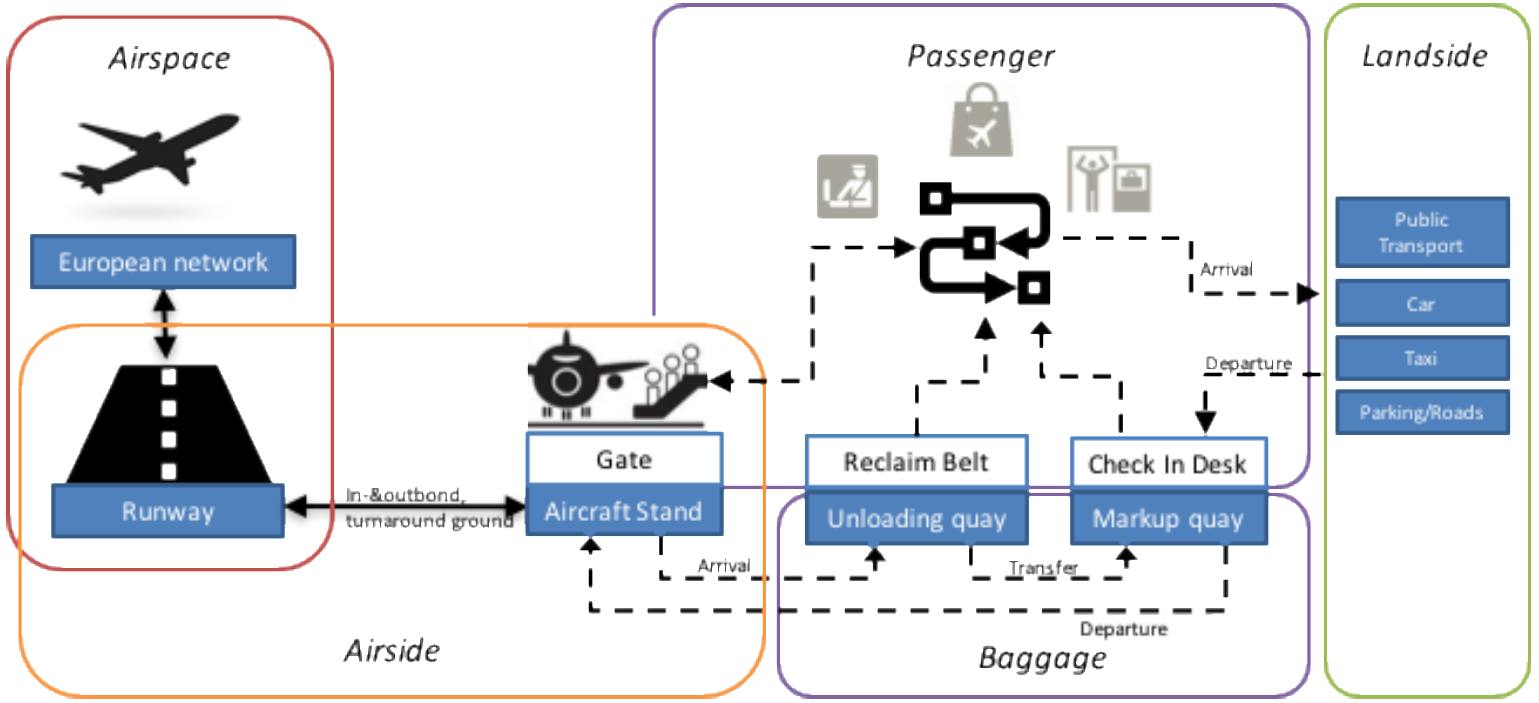
1. Airspace; all travel patterns/flows between the European airspace and runway

2. Airside; all travel patterns/flows between runway and aircraft stands including all other airside traffic.

3. Passenger; all travel patterns/flows between the gate and check-in desks, reclaim and other gated, including non standard processes e.g. PRM, VIP.

4. Baggage; All travel patterns/flows between the aircraft stands and markup/unloading quays.

5. Landside; All travel patters/flows between check-in desk and the various transport options.



Process groups are linked via a transfer point.
For example, the aircraft stands are linked to the gates. Check-in desks are linked with the markup quays.

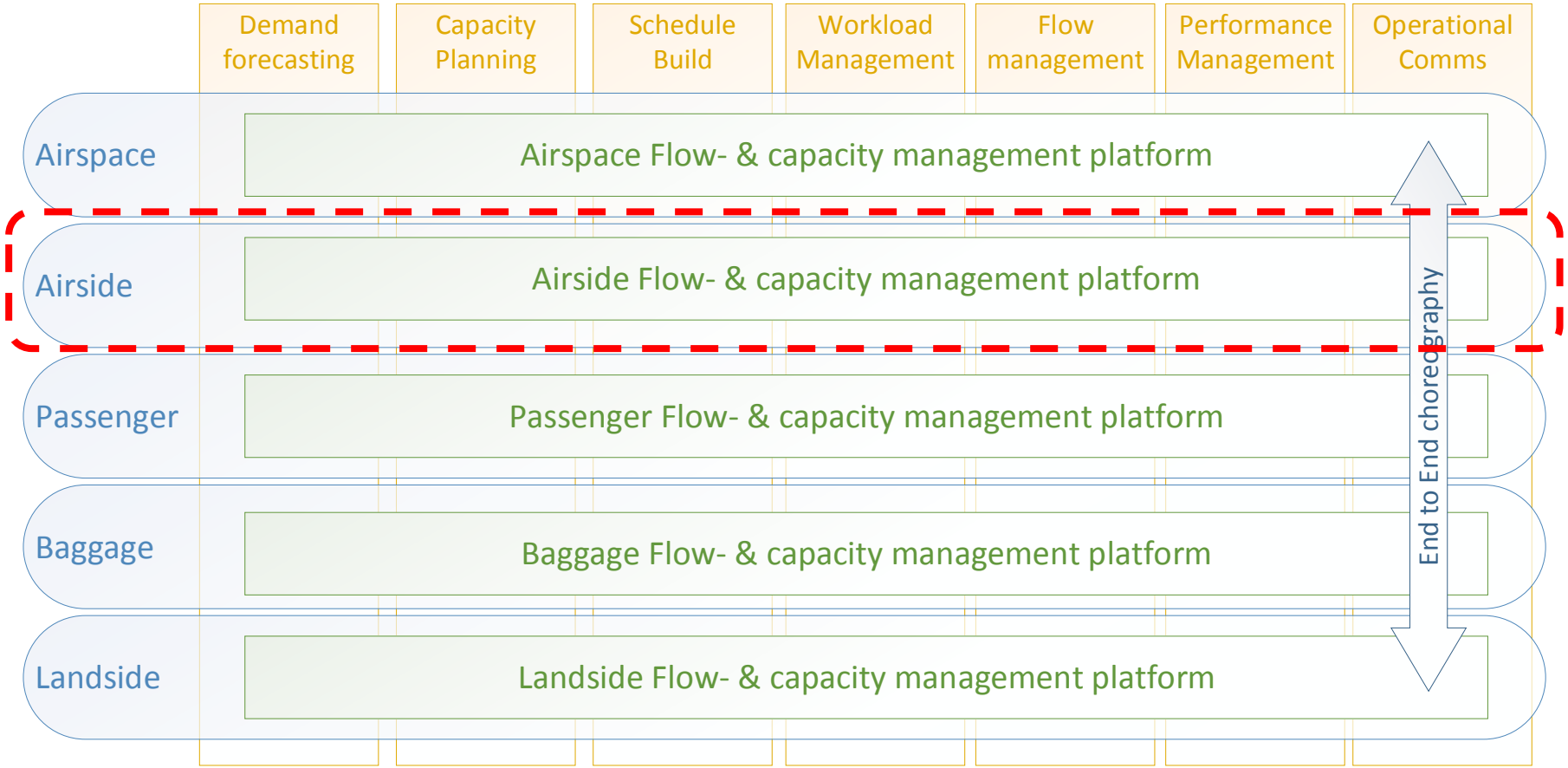
The scope of this RFI is Airside. In this process the planned items for Schiphol are aircraft (Gate/ramp assignment) and busses.

Schiphol Amsterdam Airport

Flow & capacity domain architecture

- At a high level, each of the five process group (i.e. flow) needs similar capabilities[1] (top axis) within the flow & capacity domain.
- We need however to group the processes and supporting software in such way that that he solution space is more manageable and has clear transfer points.
- We expect a platform to have the functionality to support all capabilities needed to perform flow & capacity management for a specific process group/flow, e.g. for Passengers.
- This would be for all tactical and operational time horizons (5 years till day of operation).

  The platform will consist of a cohesive toolset supporting all capabilities.
- Finally there is a layer across all platforms for end to end choreography that ensures the principle of end to end optimization is met.

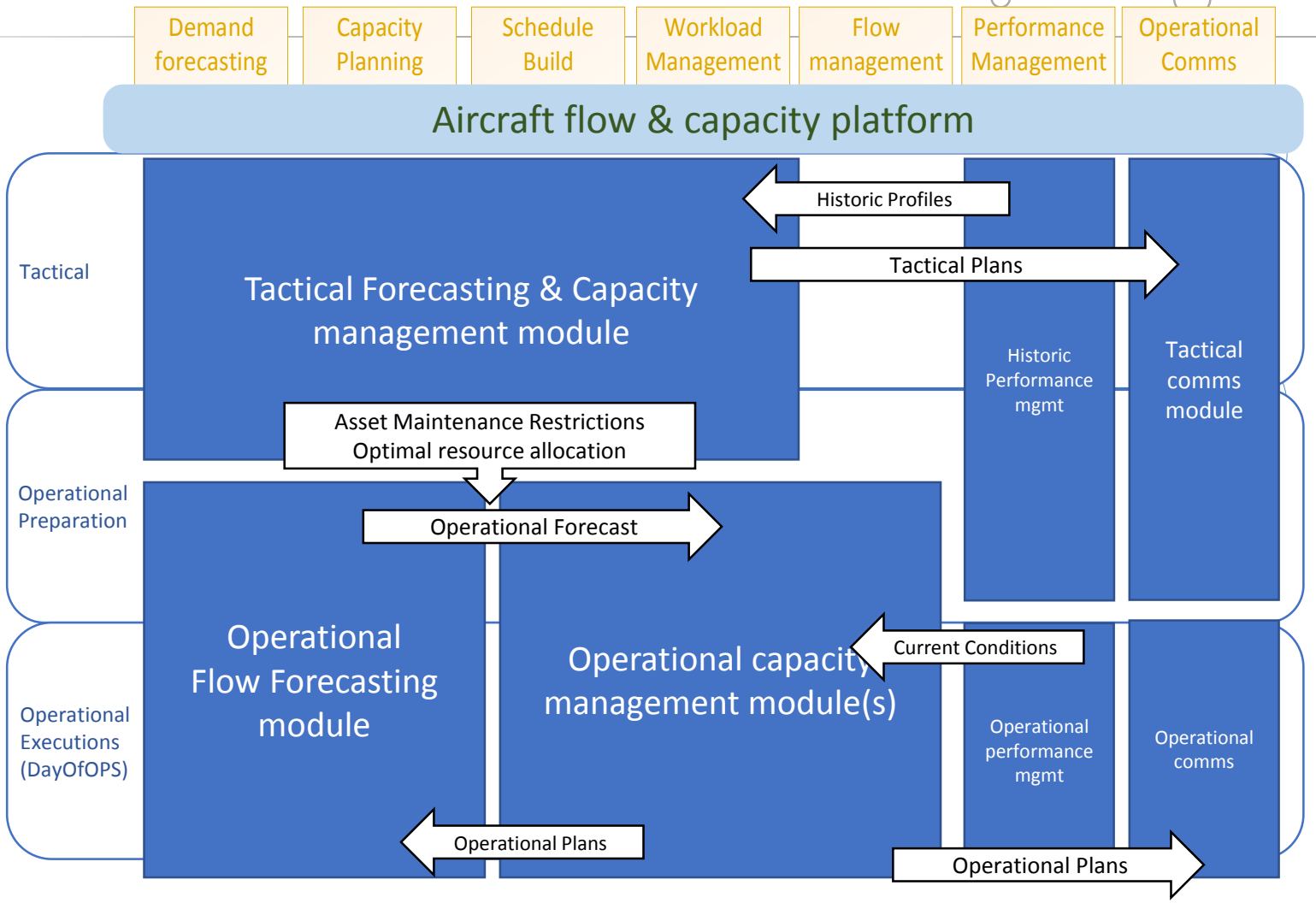


1. A description of the capabilities is available in the appendix
2. A overview of touchpoints in the passenger process is available in the appendix

Aircraft Flow and Capacity platform architecture

This picture depicts the logical modules we foresee for the Aircraft flow & capacity platform.

- The modules should be loosely coupled and highly cohesive. The modules should be changeable and have clearly demarcated inputs and outputs.
- If a module does not perform or reaches the limits of complexity, but the others work fine, we need to be able to change the unfit module.
- This results into a solution space that for tactical planning all the processes can be forecasted and planned in one big cycle, while the operational forecasting and planning is an interaction between various stakeholders (internal and external) that act within an agreed mandate.
- This configuration fits the dynamics of the processes at Amsterdam Airport best. Execution at the day of operations is netcentric (choreography), while at tactical level it is command and control (orchestration).



Scope of the RFI for the Aircraft flow & capacity platform

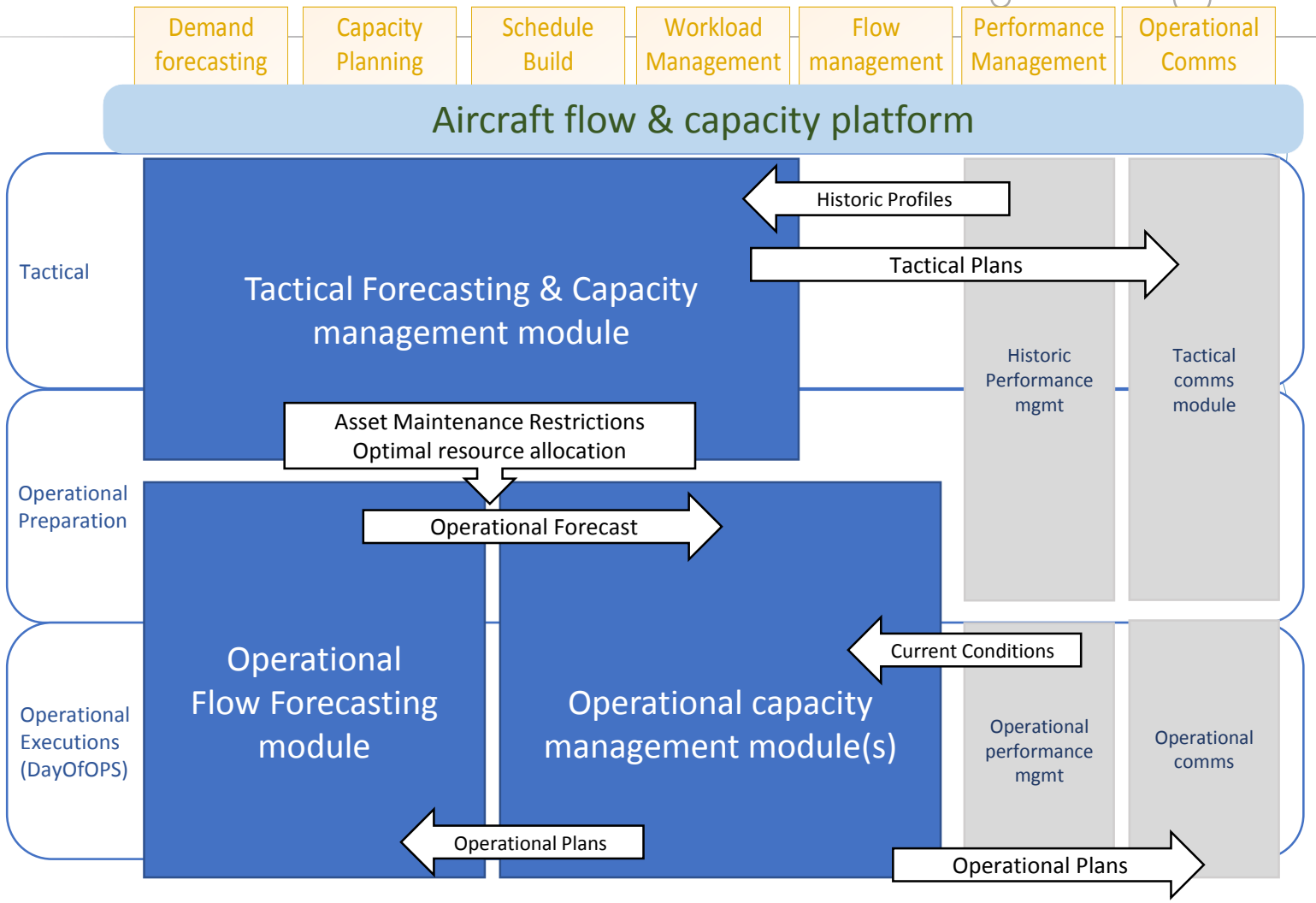
Schiphol is looking for a platform that can support the functionality defined for the modules as highlighted blue on the right:

- Tactical forecasting & capacity management
- Operational Flow Forecasting
- Operational Capacity management

For the modules highlighted grey, Schiphol already has systems in place, but we do want to learn what the vendor has to offer and its experiences with integration of these systems:

- Operational & historical performance management
- Tactical and operational communications

Our first views on desired functionality is included in the following slides.



Airside process overview

- The handling of aircraft at Schiphol is in itself similar to any airport
- The process responsibilities differ per airport. At Schiphol the situation is as follows:

Process	Responsible	Comments
Take off and landing	LVNL*	Note: Capacity/availability management is responsibility of Schiphol
Taxi from and to gate	LVNL	Note: Capacity/availability management is responsibility of Schiphol
Gate/ramp assignment	Schiphol	Based on agreed business rules (RASAS**). During day of operation changes are aligned with airlines and ground handlers to also support their planning.
Bus transport of passengers	Schiphol	In case a remote aircraft stand is used, Schiphol performs the bus planning. Staff planning is done by our external party, but names are provided up front to Schiphol to enable communication to drivers. Once the new A-pier is completed, busses will also be used to transport transfer passengers from and to A-pier to cover too long distances.
Turn around ground	Ground handlers	There are currently 5 ground handlers, which are hired by the airlines. They perform all the ground turn around activities such as cleaning, tanking, baggage handling, catering, etc.
Arrival/Departure	Airline	Airlines may decide to arrive before schedule. Airlines may also decide to wait for passengers before departing. Actual timing is of course to be agreed with LVNL. Timing estimations are exchanged via A-CDM.
Towing aircraft	Ground handlers/ Schiphol	For example for parking aircraft that would otherwise occupy a gate, or in case of defect or maintenance. Taxi traffic always has priority, so LVNL is to give permission for tow traffic
De-icing	Ground handlers	Alignment with Schiphol on aircraft stand usage
Run way/ground maintenance	Schiphol	Also includes snow operation, bird control, etc

* LVNL: Lucht Verkeersleiding Nederland
** Current RASAS agreements can be found on https://www.schiphol.nl/en/operations/page/aircraft-process/

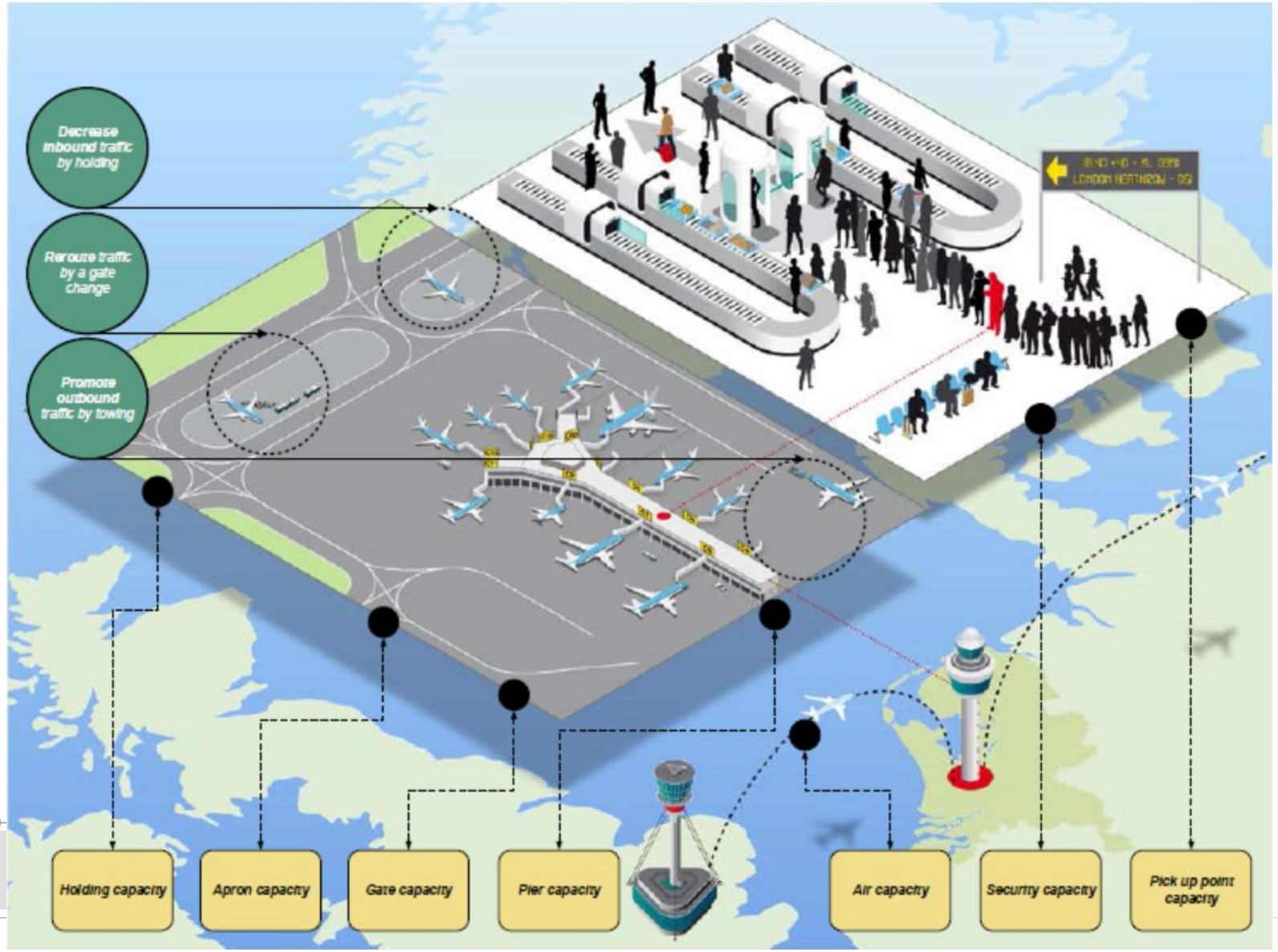
Key capabilities

The key capabilities of the platform are:

1. Planning & optimisation functionality for aircraft handling and bus transport
2. Optimization against constraints and predefined business rules (e.g. airline preferences)
3. Optimization taking related processes into consideration, such as (see next slide for visualisation):
   - Taxiway capacity
   - Ground handler capacity
   - Passenger flow in the terminal
   - Transfer connections
4. Including real-time realisation data during day of operation (e.g. latest arrival / departure time estimates, asset availability/location data)
5. Providing high quality decision support to planners and capacity managers to decide on best possible decisions
6. Calculating scenario's/ what-ifs both during day of operation and longer term (till 5 years ahead)
7. Exchanging (updated) information with other planning processes and partners in multiple ways (online monitoring, alerts and API's)
8. Open to other applications (both input, configuration and output) via API's

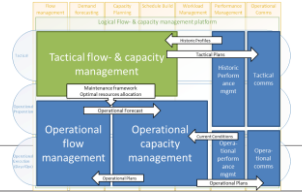
The next slides elaborate more on the functionality that the platform should contain in our view.

High level overview of relations between capacity constraints at the airport



Schiphol
Amsterdam Airport

Functionality for Tactical Forecasting & Capacity management



The Tactical Forecasting and Capacity management module supports the processes for forecasting of aircraft/flight volumes and planning of capacity to handle the flight operation for a period of 5 years to the season ahead. For this period the demand and supply can still be influenced, for example by allowing more planes or adding more piers, gates, taxi ways. Incidentally tactical calculations are done in the current season to check if major flow changes will fit.

Functionality:

1. Define aircraft routing and flow models, including facilitating processes, such as busses, ground handlers, etc.
2. Simulation of airside processes, based on expected volumes and taking relevant business rules, transfer connections and expected behavior variations into account. Covering aircraft traffic but also ground handler/bus drive way capacity
3. Calculate needed capacity for related processes based on this (e.g. busses, remote stands, ground handler capacity, gates, roads)
4. Rapidly simulate, for a complete season, various scenario's, for example various flight schedules, routes, behavior variations, weather impact, based on Business rules.
5. Ability to score performance per segment of the airport process or possible solutions (e.g. changing business rules, adding/upgrading gates, increasing handling capacity).
6. Ability to run simulations in batches for sensitivity analysis purposes.
7. Ability to implement a Plan/Do/Check/Act loop, based on historical performance profiles.
8. Create visualizations for various stakeholders, for example the capacity managers, but also senior management and directors (e.g. movies of flows).

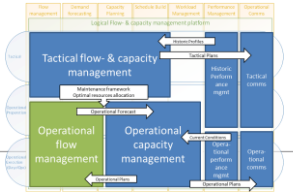
Input:

- Tactical flight forecasts containing flight schedules, load factors/ pax numbers, transfer patterns and passenger categories.
- Historical performance and asset availability profiles. Historical operations based on specific situations.
- Airport design parameters and business rules (gate allocation constraints, airline preferences, transfer connections, handler capacity)
- Process quality performance indicators and norms (on time performance, missed passengers from transfer).

Outputs:

- Achieved capacity in terms of flights that can be handled.
- Planned/predicted performance figures, e.g. predicted waiting times, e.g. on time performance, scores per day, time of day, across season.
- Capacity bottleneck analysis.
- Asset maintenance framework stating the optimal moments to perform maintenance.
- Optimal resource allocation for the working units (i.e.: asset with corresponding personnel).
- Extracts of generated forecasts and related assumptions for quality analysis purposes.

Functionality for Operational Flow Forecasting



Operational flow forecasting module supports forecasting of behavior of external and internal factors, such as predicted landing time, predicted turn around time, taxi time, etc, using A-CDM timestamps as a primary source. This module should support real time operations and data updates (e.g. flight cancellations, real time measurements, updated flight arrival time, etc).
Major difference with tactical forecasting is that in the operational forecasting airport layout and business rules are fixed, but also that real time updates should

Functionality:

1. Simulation of aircraft flow across the airport based on landing/departure times, runway, assigned gates, aircraft routing rules, congestion simulation.
2. Forecasting of relevant process time stamps with a certainty interval, so this can be used by planning
3. Ability to create new forecasts based on real-time data updates: actual flight data, gate-assignment, etc.
4. Simulation of various scenario's, for example, impact of a delay, gate change, etc.
5. Visualization of flows for aircraft, busses, etc.

Input:

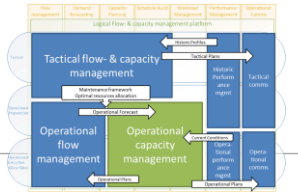
- Operational flight data and gate/ramp planning. (Airlines, handlers & ATC participate with Schiphol in CDM, sharing milestones regarding arrival and departure of aircraft)
- Asset maintenance plans (availability).
- Actual airport layout parameters (runways, taxi ways, routing rules, piers, gates, ramps).
- Real-time measurements: e.g. radar info, sensor data, process times

Outputs:

- Expected process timings
- Expected flows

Schiphol Amsterdam Airport

Functionality for Operational Capacity Management (basic)



Operational capacity management module(s) supports the capacity planning, schedule building and workload management for the season ahead and current season including a detailed day of operations planning. This module also supports the day of operations and therefore should support real time operations.

Functionality:

1. Use the planned flight schedules and asset maintenance/availability planning to create a draft planning for gates/ramps and, busses for coming months/weeks, so that certain planning constraints can already be set in stone to ensure proper availability during day of operation, The exact planning strategy used can be subject to change based on sector agreements and the best way to deal with constraints versus the need for already fixed elements in the planning ahead of time.
2. Use this planning to define required capacity for gates, remote VOPs, towing, busses, de-icing and other resources that need to be made available
3. The above process should iterate towards day of operation to get close estimates of required capacity
4. During day of operation, perform actual gate/ramp planning:
    - Using predefined business rules (RASAS)
    - Using A-CDM as a primary data source for scheduled, target, estimate and actual timing of the most important process steps
    - Taking capacity/planning of related processes into account (taxi-way, busses, ground handling, terminal passenger flow, de-icing, etc)
    - Taking other relevant parameters into account (e.g. safety, de-icing, reducing passenger walking time)
    - Optimizing towards on time performance and airport capacity (being able to support all flights without delay)
    - Reducing last minute changes that have negative passenger impact or operational impact
5. During day of operation, plan bus transport
    - Based on actual aircraft planning where remote VOPs are used
    - Optimally making use of available busses and staff

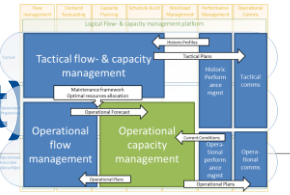
Input:

- Flight schedule, including passenger numbers and transfer information
- Aircraft allocation to flight (needed to plan so-called connecting flights, so that the arriving aircraft is on the gate where its new flight is departing)
- Maintenance planning and asset availability
- Business rules
- Real time data on actual status and planning
- Information on planning and performance of other related processes

Outputs:

- Operational schedule regarding gate/ramp planning and bus planning
- Task assignment for bus drivers.
- Reporting on performance against earlier forecast and planning, also enabling calculation of effectiveness of decisions made during the day

Functionality for Operational Capacity Management (decision support)



Determining the best possible planning for gates and busses requires taking into consideration a large set of (pre-agreed) business rules. The business rules are a combination of hard constraints, end to end optimizations, airline preferences, priority definitions and best practices. These business rules should be modeled in a way that is transparent, open and dynamic. The planning engine can use these business rules to determine the optimal planning
During the day of operation, things tend to turn out differently than planned and often special situation require creativity by the gate/bus planner. The planning system will not always have all relevant information electronically available (e.g. special situation on the ground or rare events). However, the planner should still be supported as much as possible by (enriched) information, evaluations, visualizations, to make the best possible decisions in a fact based manner.

This is why special attention is required to the way man and machine work together to create the best possible planning

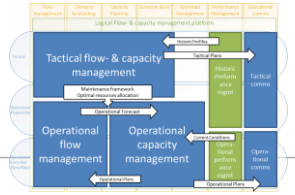
Business rule modeling:

1. Business rules may indicate a necessity, obligation or permission statement (according to OMG – SBVR standard).
2. Business rules should be easy to maintain, preferably by business owners without the need to learn a programming language.
3. Norms in business rules should be parameterized and users may have the option to override norms.
4. Multiple business rules with homogenous conditions should preferably be presented as decision tables
5. The dependencies between multiple rules should be visualized, for example in a decision tree or decision model
6. Business rules should be able to take geography into account, for example to refer to “the nearest gate on the same pier” or “the minimal distance between Gate X and gate Y”.
7. Business rules should be centrally managed and be used across the different processes without the need for re-work or reprogramming.

Decision support:

1. Creating an automated optimal planning proposal and let the gate planner change manually
2. Providing high quality information/support about best possible actions and possible impact of a certain change
3. Intuitive and user friendly GUI, limiting number of mouse clicks to come to the best possible decision
4. Communicating with other planning processes and validate what an optimal end to end solution would be
5. Enabling scenario analysis with calculated impact on the various sub-processes and KPI’s
6. High system performance so multiple scenarios can be evaluated
7. Be able to deal with uncertainty and learn from the past by measuring the uncertainty
8. Advanced optimization and backtracking to reduce the risk of local optima
9. Each planning decision made by the system should be motivated by the relevant business rules and data that contributed to the decisions.

Functionality for tactical & operational performance management



The Tactical / Operational performance management module supports the process of ensuring that that the operation executed within the agreed KPI's and the measurement of these KPI's. Schiphol has already systems in place for these modules, but the platform should provide interfaces to supply the information for this capability and use its (historical) data to improve the forecasting and planning capability.
Tactical and operational data are combined for conciseness.

Functionality:

1. Provide insight in performance Key Performance Indicators (KPI):
   - For historical purposes: this is implemented with a data warehouse reporting solution and is called Integral Process management Operations (IPO)
   - On the day of operations this is implemented in Wilbur. This environment is used to at least look 4 hours ahead. Eventually we also want to extend this towards a real-time interactive map of the airport.
2. Perform integral root cause analysis to explain why performance is not being met for causes that lie beyond the scope of individual capacity planning modules.
   This is also used for operational incident management over different working units, each handling their own capacity management within their own mandate.

Input:

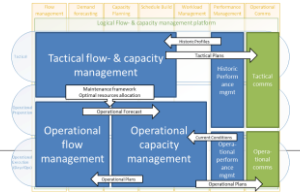
- Tactical / operational forecasts and schedules
- Maintenance schedules
- Realized performance measurements.

Outputs:

- Comparison of forecasted vs actual performance (e.g. Number of tow actions, remote VOP usage)
- Root cause breakdown on causes of lower performance, if applicable
- The level at which certain preferences were really effectuated (e.g. aircrafts with more pax closer to the lounge, aircrafts of a certain airline planned at the same location)
- Review of effect of certain operational decisions in the actual performance

Schiphol Amsterdam Airport

Functionality for tactical & operational communications



The Tactical / Operational communications module supports the communication of the forecasts and plans to other stakeholders. For example via an Airport Operations Plan, conforming the SESAR standards. Currently Schiphol had the CDM subset implemented, but as stated earlier in this document, Schiphol has the ambition to grow to Total Airport Management.

We view the operational communications as the linking pin between the platforms that support the defined process groups. Instead of all modules communicating with each other directly we think a central relay point will make communications more manageable and allows each process group to stay in control within their mandate and scope. So the airside platform would provide the flight forecast to the passenger platform via the operational communications modules.

Schiphol has already systems in place for these modules an the platform should be able to interface with these systems. Tactical and operational are combined for conciseness.

Functionality:

1. Distribute tactical / seasonal outlook and operational plan:

2. Distribute Airport Operations Plan (Season ahead up to day of operations):
   - Currently implemented in the AODB (CISS) for real-time distribution
   - Sharing with Sector is done via the CDM portal. Plans are to evolve the CDM portal to the AOP sector portal with the end goal of Total Airport Management

3. Provide operational briefings so people in the operation know what they can expect

Input:

- Operational plan

Outputs:

- Airport Operations Plan.
- Tactical / Seasonal outlook.
- Operational briefings.

Schiphol Amsterdam Airport

Architecture: platform v.s. complete solution

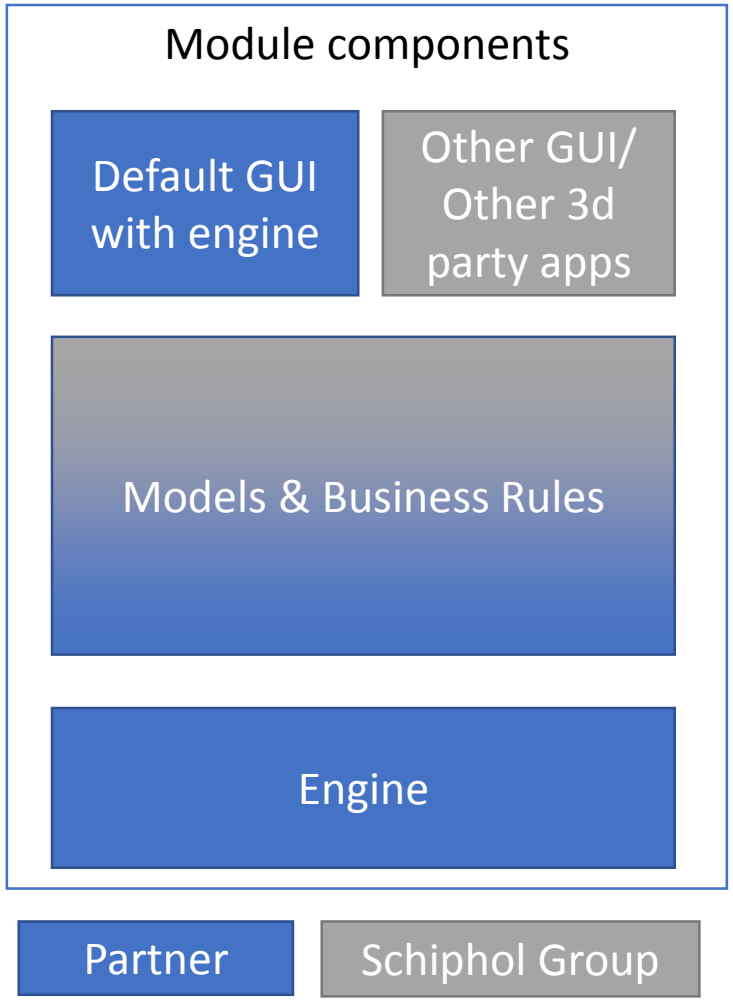
Commercial Off The Shelf products are not modular and flexible and limited in the possibility to adapt the models and business rules to fit the One Terminal concept of Schiphol with complex flows and the high traffic volumes.

A real open platform consists of a coherent toolset. For the flow and capacity capability in the platform we envision that this will be built on top of core engine(s). An engine provides the functionality to implement and continuously improve functionality like passenger volume forecasting on top of a stable platform. This allows us to avoid limitations in predefined products and develop the platform further with the partner.

The figure shows what components a typical platform consist of and where Schiphol must be able to have control:

- Schiphol does not want to develop its own engines for flow & capacity management, for example a forecasting or planning engine. Therefore this part will be supplied by the partner.
- To ensure knowledge retention and ability to continuously improve the solution, Schiphol wants to be able to develop and change models and business rules that are built on top of the engine. Schiphol also wants to leverage the knowledge, expertise and execution power of the partner to accelerate development. So this is a relationship with shared business outcomes.
- Engines typically have a default GUI. Schiphol does not want to recreate these. However for operations we need an integrated GUI with all information needed from different sources.
- Schiphol does want various applications and GUI's to be able to interact with the solution implemented on the engine. This requires a solution that is completely open and accessible.

It is of utmost importance that the platform exposes all functionality as services to other applications to ensure that we are able to create various specific applications based on one platform.



Support for industry standards and best practices

The platform should adhere to commonly accepted industry standards and best practices including but not limited to:

- An open architecture and usage of open standards like W3C, ISO, IETF, IP protocol, XML, RESTFull etc.
- Should fit in a Service Oriented Architecture (SOA) and Event Driven Architecture (EDA)
- All Schiphol employees should be able to have access to the platform via SNBV's standard desktop and mobile devices. This implies web based access or support for (Citrix) thin client applications, using SAML 2.0 or OAuth 2.0 for authentication and SCIM 2.0 for user provisioning.
- For maintenance and support industry best practice are used e.g. ITIL, ASL, BISL or its agile equivalent
- Adhere to ACI and IATA resolutions and best practices
- Non functional requirements (e.g. ISO/IEC 25010:2011) are properly balanced
- Information security policies and best practices are implemented, for example OWASP, or General Data Protection Regulation (GDPR).

Non functional requirements

- The platform should provide excellent user experience and visualizations; The primary factor in adoption of software is if the experience for the user is positive and the user can get the information they need.
- The performance must be excellent and the platform should be highly scalable. An operational reforecast for the entire airside flow should be completed within a few minutes. The system should be able to handle both real-time events and be capable to do batch processing of large volumes of data e.g. for analysis.
- Availability: as an real-time operational system, the system must support high availability e.g. by supporting redundant core components.
- Modifiability: the platform should be highly flexible and modular so at any point in time we can choose which functionality we use from the platform or for which functionality we use other solutions, for example: bus planning could at some point become more insourced, or certain ground handling activities could be arranged differently to limit dependencies.
- Requirements & the IT landscape change continuously, therefore continuous integration & deployment should be supported
- Maintainability: the platform should support versioning of models and business rules; Terminal layout and business rules change over time. It should be possible to have various versions of models and business rules in the system and have user friendly management of these versions. The Terminal layout must be easily retrieved from the Schiphol Geo Information System.
- Publish or read data to/from other systems, like our data warehouse; we want to be able to store “Snapshots of the operation” from all viewpoints so we can perform root cause analysis and advanced analytics on our operations.
- Use the Schiphol Data Hub as input and or output; Big data platform exposing data services based on machine learning, AI and advanced analytics. We expect that the platform is able to incorporate these data service, for example advanced algorithms to determine real-time show-up patterns or determine the amount of trays used at security based on weather conditions.
- Integrate with the Airport Service Bus using standardized messaging; This Enterprise Service Bus of Schiphol that provides real time reliable messaging and exposes various systems like our AODB, Data Hub, Data Warehouse and planning systems real time. We expect the platform can both subscribe to information and publish information on the ASB and support interface technology like Message Queuing and Restfull API’s.