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D-1 Demand Prediction

Final Report

Aviation Consultants

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Report

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Executive Summary

European network operational stakeholders increasingly aim to optimize their day of operations (D-0) within available capacity. Early demand predictions are a method to identify periods of possible bottlenecks, which is endorsed by the Dutch aviation sector stakeholders Air Traffic Control the Netherlands (LNVL), Amsterdam Airport Schiphol (AAS) and airspace users including KLM.

Data enabling predictions of tomorrows operations (D-1) are driving the predictions, with more stakeholders requiring enhanced accuracy and consistency. Air Traffic Control the Netherlands (LNVL) uses weather forecasts and information from EUROCONTROL to determine whether certain sectors need regulation at D-0, to mitigate for high workload of air traffic controllers and start. Amsterdam Airport Schiphol (RSG) and airspace users including KLM also started balancing demand and available capacity using data to optimize planning for tomorrows operations.

However, each of these sector stakeholders use their own source data as a basis for their prediction, with differences in outcome as a consequence. This causes the stakeholders to each have a different demand prediction that may lead to different assessments of potential impact on tomorrows operation and resulting decisions about the use of people and resources . Because of different D-1 demand predictions, these decisions may not be optimally aligned resulting in process inefficiency and undesirable related consequences.

As such, To70 was asked to evaluate which methods and tools the sector stakeholders use for their D-1 planning process and how the stakeholders make their choices based on this planning. In order to coordinate demand forecasts between RSG stakeholders, it is important to gain insight into:

- Applied methods and sources of demand predictions;
- The resulting differences in outcome;
- Interpretations of traffic volume and capacity;
- Circumstances, assumptions and restrictions that the results may affect.

The purpose of this report is to present the results of an analysis which was conducted to find the differences in the stakeholders' D-1 process and source data, as well as differences in the resulting outcome of each of the different stakeholders' prediction. This report aims to recommend a possible solution for an aligned D-1 process based on common data. Aim of alignment is to enable all stakeholders to obtain a shared view on D-1 demand predictions to base their resource decisions on.

The following conclusions are drawn:

1. Differences in daily LVNL Pre-Tact unit and RSG APOC D-1 activities contribute to inconsistency of stakeholder and resource decision making. Alignment measures are proposed to have LVNL and airlines involved during APOC meetings, and to align the processes such that the LVNL OPS plan can be included.

2. Data Analysis revealed significant differences between LVNL and RSG datasets, both in terms of traffic numbers, as well as predicted timestamps. The differences are mainly contributed to short-haul arriving aircraft. In general, the NM PREDICT data was found to most accurately represent operations at D0.

3. Data analysis findings clearly indicate that NM PREDICT data as used by LVNL enables a more accurate demand prediction than use of only scheduled data. Airlines flight predictions could complement and enhance accuracy even further.

4. RSG and airlines will significantly benefit improving accuracy when using NM PREDICT data. Consequences of the use of NM PREDICT data for the airline should also be considered, as pre-emptive measures may disrupt operations, especially for the longer flights in the IFPS zone. In case of demand reductions are required, the implementation of a local rule would ensure that sacrifices in terms of cancellations are a shared effort amongst airlines.

The following recommendations are determined:

1. The lack of matching between the flights between RSG and LVNL and between D-1 and D0 significantly reduced the ability to detail the differences. If a more assured matching is possible, the study could be much more driven on the differences per flight and the identity of missing flights.

2. As the analysis was conducted in the second year of the global COVID Pandemic, traffic was severely reduced and 2021 should therefore not be considered a suitable year for benchmarking the outcome of analysis. Furthermore significant portions of the data were missing or filtered, leaving room for improvement in further analysis. Based on this, it is recommended to continue D-1 demand prediction data analysis in order to let benchmarking conclusions be complete and representative.

3. When processes and data matching of LVNL and RSG are aligned, it makes sense to validate the demand predictions accuracy against such benchmark, in order to assign credit to the changes and communicate the accuracy improvement to airlines and sector stakeholders. This credit could then trigger further process adjustments by airlines and enhance process and accuracy of input data, and contribute to D+1 post operations analysis as well as D-3 up to D-7 and D-180 predictions, creating a long term demand outlook.

Table of Contents

1 Introduction

European network operational stakeholders increasingly aim to optimize their day of operations (D-0) within available capacity. Early demand predictions are a method to identify periods of possible bottlenecks, which is endorsed by the Dutch aviation sector stakeholders Air Traffic Control the Netherlands (LNVL), Amsterdam Airport Schiphol (AAS) and airspace users including KLM.

Data enabling predictions of tomorrows operations (D-1) are driving the predictions, with more stakeholders requiring enhanced accuracy and consistency. Air Traffic Control the Netherlands (LNVL) uses weather forecasts and information from EUROCONTROL to determine whether certain sectors need regulation at D-0, to mitigate for high workload of air traffic controllers and start. Amsterdam Airport Schiphol (RSG) and airspace users including KLM also started balancing demand and available capacity using data to optimize planning for tomorrows operations.

However, each of these sector stakeholders use their own source data as a basis for their prediction, with differences in outcome as a consequence. This causes the stakeholders to each have a different demand prediction that may lead to different assessments of potential impact on tomorrows operation and resulting decisions about the use of people and resources . Because of different D-1 demand predictions, these decisions may not be optimally aligned resulting in process inefficiency and undesirable related consequences.

As such, To70 was asked to evaluate which methods and tools the sector stakeholders use for their D-1 planning process and how the stakeholders make their choices based on this planning. In order to coordinate demand forecasts between RSG stakeholders, it is important to gain insight into:

- Applied methods and sources of demand predictions;
- The resulting differences in outcome;
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1.1 Purpose

The purpose of this report is to present the results of an analysis which was conducted to find the differences in the stakeholders' D-1 process and source data, as well as differences in the resulting outcome of each of the different stakeholders' prediction. This report aims to recommend a possible solution for an aligned D-1 process based on common data. Aim of alignment is to enable all stakeholders to obtain a shared view on D-1 demand predictions to base their resource decisions on.

1.2 Audience

The audience of this report consists of the KDC Management, as well as the stakeholders who contributed to this report, i.e. Air Traffic Control the Netherlands (LVNL), Royal Schiphol Group (RSG) and KLM.

1.3 Structure

The document is structured as follows. In order to depict how each of the sector stakeholders generates its forecast, their process analysis is described in Chapter 2. Following this description, an analysis is conducted to determine the accuracy of the data and to determine what causes differences in outcome. This process is described in Chapter 3. The outcomes of the study were discussed with stakeholders during a workshop, in order to come up with a concept alignment solution. This concept solution is discussed and presented in Chapter 4. The report ends with conclusions and recommendations in Chapter 5.

1.4 Scope

This study evaluates the input data which is used by each of the stakeholders for their D-1 processes. It also evaluates how accurate this data is in comparison to the actual operations (D-0). The stakeholder internal processes, as well as any data manipulations that may or may not have been made based on the D-1 input data is not evaluated and considered out of scope.

2 Process Descriptions

The generic method by which D-1 predictions are generated are the same for all stakeholders. Certain input data is used, which is subsequently used in a D-1 process in order to come up with a D-1 prediction. This D-1 prediction may or may not correspond to the actual operations (D-0). This process is depicted by Figure 1.

Figure 1: Generic depiction of the D-1 process

However, the input data used differs between LVNL, RSG and airline. As the scope of sector stakeholders' operations differs with LVNL focusing on airspace users and airspace and runway capacity, whilst RSG focuses on passengers, baggage and terminal processes with capacity restrictions on the ground, the nature of their view on aircraft operations differs. Where LVNL steers and regulates arrivals on runway landing times, the airport works more on airline scheduled arrival and departure times for at the stands.

As a consequence of these resource and planning differences the D-1 processes for LVNL, RSG and airlines differ. To gain insight into these different D-1 processes, interviews were organized with each of the individual stakeholders. By obtaining insight into these processes, the received input data sets could be effectively analysed. Some of the important aspects include the timeline or work horizon with which the stakeholders work, source data used and the level of detail/resolution of the forecast.

This chapter describes the processes of each of three stakeholders and assesses the difference between the processes.

2.1 LVNL Process Description

For LVNL, the priority of the forecast lies with the prediction of data for flights from the FIR boundary to EHAM runway for inbounds, and vice versa for outbounds. Accurate modeling of gate arrival times, for example, is not a concern as it falls outside the scope of their jurisdiction.

LVNL uses a standardized method to make an accurate prediction at D-1. The inputs and data used are highlighted in 2.1.1, and the process used to process this data to operational decisions is described in section 2.1.2.

2.1.1 Data Sources

LVNL bases its D-1 process, also referred to as OPS-Plan by LVNL, on the following types of data:

1. Network Manager (NM) PREDICT data;
2. Capacity meeting decisions using different LVNL QRC's;

3. Runway availability
4. KNMI on Meteorological information, in-person call;
5. Schiphol Kansverwachting (SKV).

2.1.1.1 NM PREDICT data

The source data for air traffic demand on which LVNL relies for its OPS plan is composed by EUROCONTROL. The data is referred to as Network Manager (NM) PREDICT data and is made available via their Demand Data Repository (DDR) portal to ANSPs.[1]

The NM PREDICT dataset process uses flight intentions collected in DDR to enrich the historical traffic demand used as reference, and is generated for D-7, i.e. seven days before scheduled date, to D-1. By default, D-7 flight data is used as basis for the D-0 forecast. This means that flight data of one week prior to the day for which the prediction are made, is used as a basis.

The DDR monitors the coverage of the collected flight intentions, through regular comparisons between NM PREDICT counts derived from flight intentions and Enhanced Tactical Flow Management Systems (ETFMS) counts computed from the Filed Tactical Flight Model (FTFM). Unconfirmed flights (historical flights not correlating with an airport slot) are removed from the NM PREDICT flight data only when operating from/to coordinated airports where the coverage of their airports slots is sufficient (above 90% on average). This is the case for RSG.

The default used D-7 data can be swapped with another day in the past (usually D-14). This is done on request of the pre-tactical team when the D-7 operations have been widely affected by major disruptions directly affecting the nominal routes of a large proportion of flights. The data is correlated with airport slots collected from more than 175 coordinated airports in Europe and enriched using machine learning to provide a prediction which is as accurate as possible.

Some of the elements that are taken into account using the NM PREDICT machine learning algorithm include:

- Buffers in flight schedule times are corrected to flight profiles that are actually flown;
- Simulation of the entire flight distance to accurately estimate an aircraft's location over time;
- Taking wind forecast into account which may have a significant effect on travel duration on longer routes and arrival- or departure directions. Only the forecasts of wind speed is currently used to adjust the time dimension of the historical 4D trajectories in NM PREDICT;
- Taking the positions of North Atlantic Tracks (NAT) into account. I.e., the routes of North transatlantic traffic are substituted routes best reflecting the NATs forecasts for the upcoming three days, respectively for West- and Eastbound flows.
- General Aviation/ Business Aviation (GABA) traffic is based on historic data but verified with the airport;
- Runway use based on historical data.

The process is graphically represented by figure Figure 2.

[1] https://www.eurocontrol.int/ddr, last retrieved December 15th, 2021.

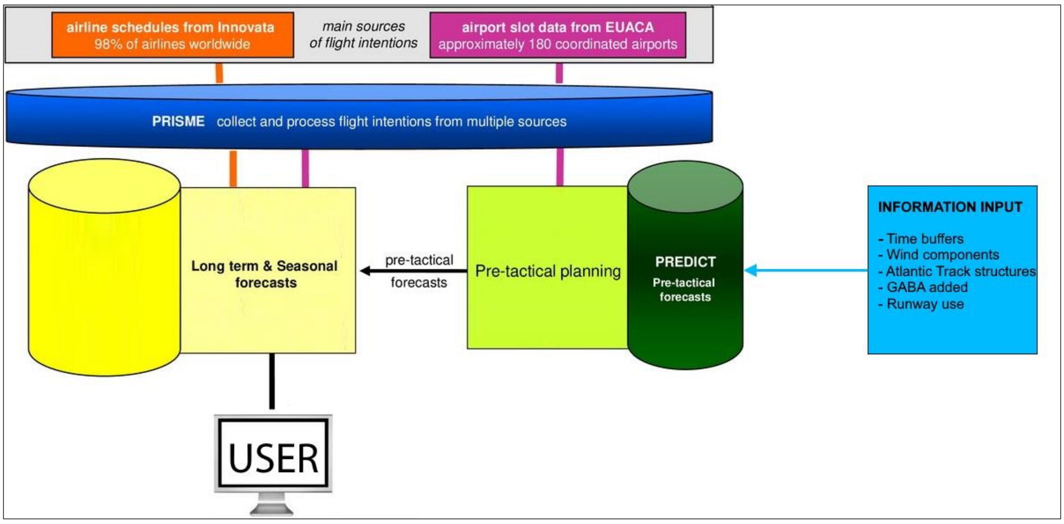

Figure 2: Visual flow diagram of D-1 flight data, as used by LVNL

2.1.1.2 Capacity Meeting Decisions

Internal meeting to discuss announced system changes, strikes, or other events which may affect capacity, and to retrieve available information regarding expected capacity constraints. During this meeting Operational Reference Information (QRC's) is used.

2.1.1.3 KNMI on Meteorological information.

KNMI is consulted in-person at D-1 to obtain the most accurate available weather forecast. The weather data includes the following components:

- Horizontal visibility and cloud base to determine whether so-called "Bijzonder Zicht Omstandigheden", or Special Sight Conditions (BZO)- conditions are in place;
- Wind component, to determine which runways are most likely going to be used, and in order to determine at which capacity the runways can be used;
- Snow or other weather affecting runway capacity.

2.1.1.4 Schiphol Kansverwachting

The "Schiphol Kansverwachting" (SKV) is a weather forecast in terms of probability figures. These figures are automatically loaded into the OPS-plan, where additional text is added when needed based on the KNMI Meteorological information. LVNL decisions to implement regulations for D0 at a pre-tactical level are based on set probability figures in the SKV.

2.1.2 Description

LVNL generates its D-1 plan, or OPS-Plan, on a daily basis. There is an exception to this rule for the weekends, as forecasts for Saturday, Sunday and Monday are generated on Fridays. This effectively causes Sunday and Mondays to be D-2 and D-3 predictions.

Composing the OPS plan is a joint effort and made by the Operational Support & Development (OSD) and Capacity Management & Analytics (CMA) departments. One (rotating) representative of this LVNL

PRETACT unit is responsible for the delivery OPS plan, which means that this person takes care of the briefing and prepares the product for delivery to both internal and external stakeholders.

Daily activities consist of:

- 0930-1030LT: Preparing the joint discussion using the source data;
- 1030-1130LT: Joint internal discussion OSD and CMA;
- 1100LT: Briefing with KNMI;
- 1130LT: Prepare concept OPS plan in .pdf for external users, which is at this moment is only RSG
- 1245-1300LT: Briefing to the unit management (UM), i.e. representatives of the UM ACC and TWR/APP;
- 1330LT: Prepare final OPS plan in .pdf. This OPS plan is automatically distributed using a mailing which ends up in the mailboxes of UM, Area Control Center (ACC) Supervisors, Flow Management Position Controller (FMPC)s and other recipients under the OPS-plan distribution list.
- 1630LT: Forward OPS plan to SUP and FMPC

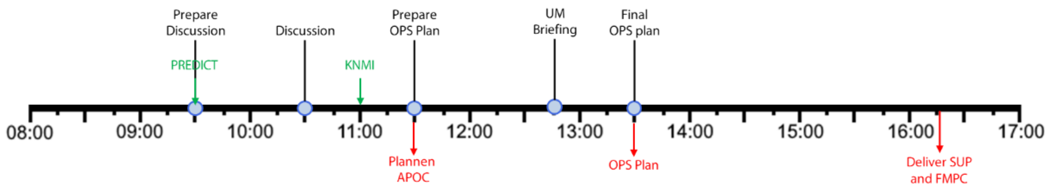

Figure 3: LVNL OPS-Plan timeline

This process is visualised in the timeline in Figure 3. The timeline also shows key timestamps at which information is exchanged with other stakeholders. NM Data is received at 09:30 local time, whereas contact with KNMI takes place around 11:00. Preliminary plans are shared with APOC around 11:30, whereas the final OPS plan is shared around 13:30.

The distributed OPS-Plan has a standard format, and contains the following information:

- The expected traffic numbers:
    - Starts & Landings at RSG;
    - Number of flights ACC;
    - The number of inbounds at EHFIRAM (the most used TFV for traffic regulations by Amsterdam FMP) in the busiest hour, with peak times.
- Graphs with distribution of traffic numbers throughout the day for EHFIRAM;
- Graphs with distribution of starts and landings throughout the day;
- Announcements of special events and announcements from EUROCONTROL's Network Operations Portal (NOP);
- Maintenance Planning, if relevant;
- Operational Helpdesk (OHD) specials, e.g. survey flights or aeronautical events;
- Regulation Scenarios;

- Traffic distribution per stack, and indications when or where bunching will occur;
- Sector configuration throughout the day;
- Traffic distribution per sector;
- Weather forecast;
- Runway use or configuration during in- and outbound peaks, as well as off peak moments.

An example slide of an OPS plan, showing predicted EHFIRAM inbounds, regulation scenarios and other relevant remarks for September 4th, 2021 and based on NM PREDICT data of September 3rd, 2021, is shown in Figure 4.

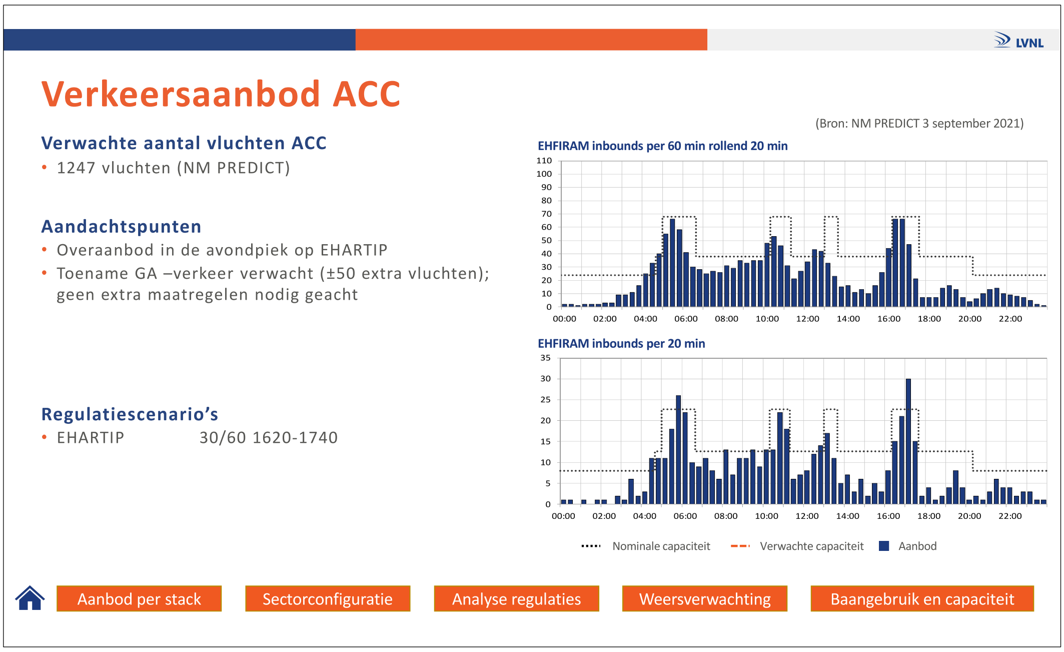

Figure 4: Example slide from a LVNL OPS Plan for Sept. 4th, 2021 showing expected ACC traffic.

2.2 Schiphol Process Description

For RSG, the priority of the forecast lies with the prediction of data for flights at the airport itself. Accurate modeling of departure and arrival times from a stand perspective, for example, allows for efficient gate- and passenger flow planning.

A standardized method is used to make a prediction at D-1. This prediction is captured in their so-called Airport Operation Plan, or AOP. The inputs and data used for the AOP are highlighted in 2.2.1. The process used to build the AOP using this data is subsequently described in section 2.2.2.

2.2.1 Data Sources

RSG bases its D-1 process on the following types of data:

1. Airport Operational Database (CISS);
2. Weekly Flight Schedule (TAF);
3. Weather data, SKV;
4. KERMIT;

5. Incident Change and Development (ICD) Tool, and
6. Eurocontrol D-1 Network Plan.

2.2.1.1 Central Information System Schiphol (CISS)

The Central Information System Schiphol (CISS) is fed with information by handlers/airlines with flight records. In some cases apron controllers manually create flights if data is missing in the flight schedule. The moment at which RSG obtains these flight records differs between various handlers. For the bulk of the KLM data, however, this occurs three days before operations, also referred to as D-3. At that moment, the information only consists of raw flight info i.e. date/time at Schiphol, origin/destination, aircraft type. Passenger numbers and aircraft registrations are not available at that time.

This data is constantly updated towards D-0, by adding timestamps, aircraft registration, passenger count numbers, etcetera. At D-1, only scheduled times are available for traffic at D-0. RSG is in the process to develop an increased level of accuracy, by adding more detailed time stamps earlier in the process. At the moment, however, many of the added timestamps are based on standardized figures. Examples include the ELDT, which is set using a standard buffer. Similarly, EIBT is said to be equal to SIBT as first estimate.

The CISS is leading the various planning systems (RMS, check-in, bus planning, etc.). It should be noted that this planning is not complete as at D-1, as certain flights and timestamps are still missing at that point. Unlike LVNL, RSG therefore works with a continuously updated set of information for their D-1 planning.

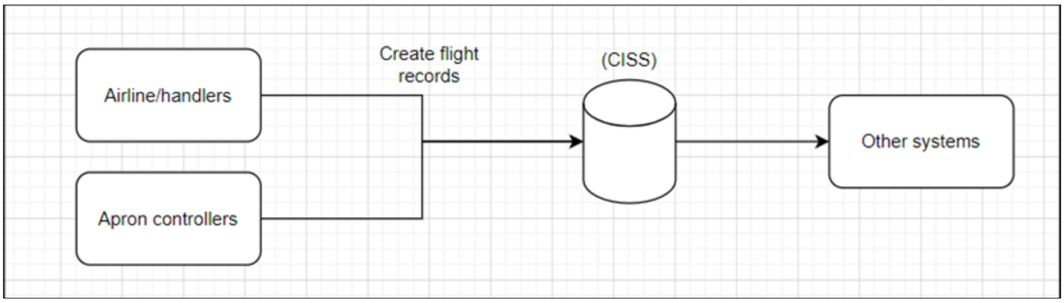

Figure 5: CISS Data Flow Diagram of RSG D-1

2.2.1.2 Weekly Flight Schedule (TAF)

In addition to the CISS data, weekly flight schedules are used which are published by RSG's FACT department. These schedules are also referred to as TAF data by RSG. TAF is based on the SLOT information from the slot coordinator, which is manually adjusted and enriched using expert know-how. An example of such an adjustment includes deleting flight entries for those flights of which is known that the airlines will not use the particular slot. The process is visualized by Figure 6.

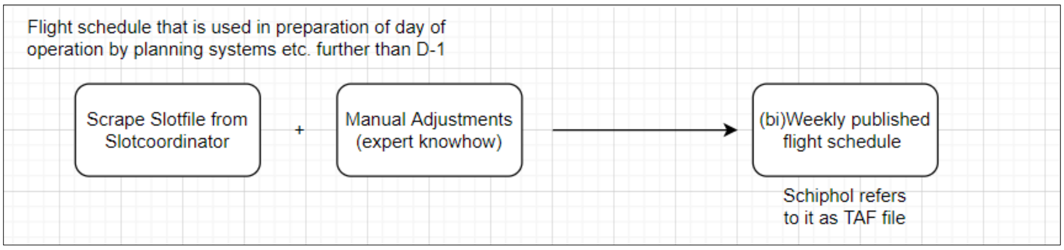

Figure 6: TAF Data Flow Diagram of RSG D-1

The flow diagram of flight data used by RSG for its D-1 prediction is graphically represented by Figure 7.

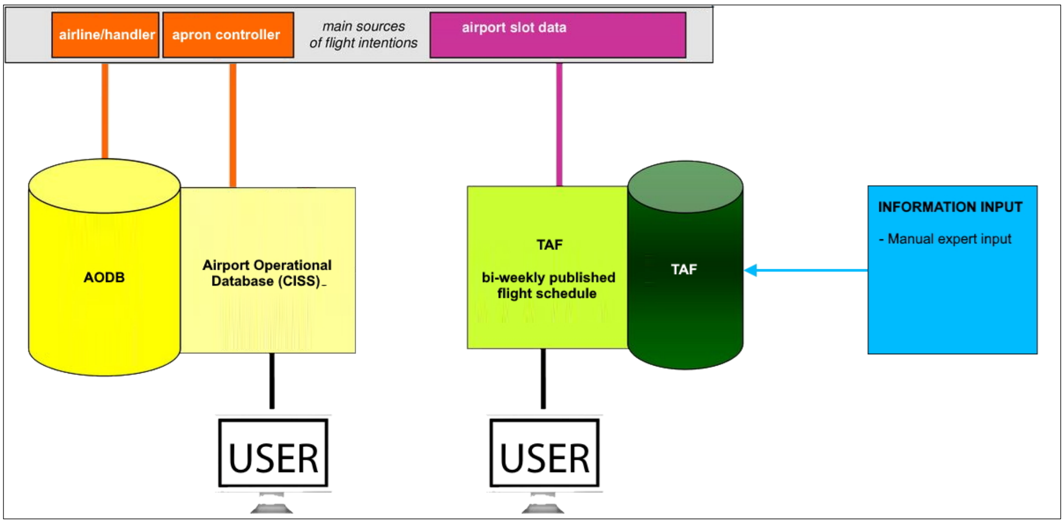

Figure 7: Visual flow diagram of D-1 flight data, as used by RSG

2.2.1.3 Weather Data / SKV

RSG uses weather data from the KNMI in the form of SKV, which is the same source as used by LVNL. RSF also uses KNMI 5-days forecast. Unlike LVNL, there is daily human interaction to discuss any particularities, though a call could be initiated in case of bad weather. External public sources are also utilized. This, amongst others, includes data from Buienradar.

2.2.1.4 KERMIT

A centralized system which keeps track of permits for construction with detailed time information. Operation Coordinators Work (OCW) keep track of these permits and determine if there is any impact on operations.

2.2.1.5 ICD

Incident Change and Development tool, in which all incidents are reported. Service owners can also record new processes and events.

2.2.2 Description

RSG captures its D-1 predictions in the Airport Operations Plan. In 2019 RSG initiated the Airport Operations Centre programme, also known as APOC. The AOP is published and made by the APOC on a daily basis, with a temporary exception for the weekends. This rolling plan has the goal to improve airport performance. The overall purpose of the AOP is twofold:

1. Increase situational awareness from seven days before operation (D-7) towards the day of operation (D-0), and
2. Enable data-analytics on operational information stored in the AOP, so-called actuals, to improve decision-making.

The plan is of importance for all local stakeholders: not only the airport operators and the local ANSPs, but also several airlines, ground handlers, emergency services, MET providers, etc.

KDC initiated a research assignment in 2020 to support RSG in creating a methodology for decision-making in the APOC from three days before operation (D-3) to the day of operations (D-0). The result is an initial decision model for Schiphol's APOC (at D-1), which was developed in close cooperation with relevant stakeholders including LVNL and KLM.

08:00-08:10	The APOC starts off at 08:00 with an informal briefing. Clusterleads Airside, Terminal, Landside and Baggage are present. Any particularities for the day are discussed.
08:10-08:45	Start composing D-1 plan, which has a time scope of 2300LT until 0600LT+2. *<u>Post-operational analysis.</u>* Start with D+1 qualitative information to check if there were any occurrences or exceptions that will impact D-1, e.g. constructions that have begun or which have been finished using KERMIT. Check if there are any impacts on taxi- and runways. *<u>Weather.</u>* Weather is retrieved for a couple of days in advance to determine whether or not excesses will occur and there needs to be regulated in terms of work. *<u>Gate planning</u>* Coordinate with gate planner if there are problems foreseen with regards to gate capacity. *<u>CISS</u>* Determine the traffic demand using information from the CISS. TAFs are also used occasionally.
08:45-09:00	Internal RSG briefing. Prepare for the airport / sector briefing with cluster leads, supervisor, ops representative.
09:00-09:30	Airport briefing. Led by APOC Supervisor as objective person. Cluster leads are not present at this stage as all input coming from RSG OPS representative. Standard participants are: Schiphol Operations, Schiphol Security, Schiphol Asset Management, Customs, KMAR, KLM. Ad-hoc: handlers. Horizon for this discussion is D-3.

09:30-10:00 If there are any particularities that have impact on the operations, scenarios are defined with relevant stakeholders and published in the AOP through a PowerPoint presentation These scenarios propose control measures for a given situation.

10:30-11:00 Operations call to obtain operational expertise and to discuss what the best plan of action is given a certain situation. APOC and DDO (Day to Day Operation) are involved, including Flow Manager Aircraft/Passengers, Team Manager Regie Aircraft/Passengers.

11:00-15:30 Finalize D-1 plan. If there is room available, work on D-2 and D-3.
Between 12:00 and 13:00, the airport desk at EUROCONTROL is contacted to request status for tomorrow (NMOC). Information is also returned from RSG to NMOC. At Thursdays, there is a D-7 call with EUROCONTROL to evaluate potential restrictions in the following week. Also, around 12:00 the D-1 Plan from LVNL is retrieved.

15:30-16:00 Internal APOC debriefing
Discuss with cluster stakeholders if all everything is recorded, or if all scenarios have been accounted for.

16:00-16:30 Four O' clock briefing.
At this moment, DDO transfer. Plan for tomorrow is presented.
From 16:00, DDO is in the lead.

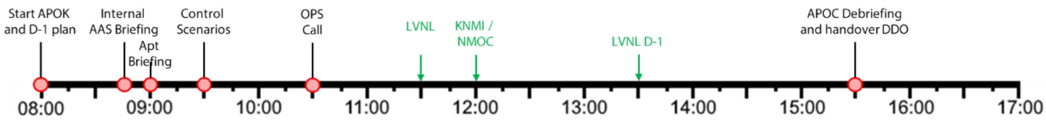

Figure 8: RSG OPS-Plan timeline

This process is visualised in the timeline in Figure 8. The timeline also shows key timestamps at which information is exchanged with other stakeholders. Contact with KNMI and NMOC takes place around 12:00. The preliminary OPS plans of LVNL are shared with APOC around 11:30, whereas the final OPS plan is received by the APOC around 13:30.

2.3 Airline Process Description

For the airline, the priority of the forecast lies specifically with determining whether or not capacity constraints can be foreseen, especially focusing on runway capacity. After all, having prior knowledge with regards to possible restrictions allows for more efficient flight planning.

2.3.1 Data Sources

The airline bases its D-1 process on the following types of data:

1. Meteorological information (KNMI);
2. Airline schedule data;

3. Runway capacity figures.

2.3.1.1 Weather Data

The airline uses weather data as provided by the KNMI, which is the same source as used with LVNL and RSG. This information is interpreted manually and on a qualitative basis.

2.3.1.2 Airline schedule data

To feed the proprietary tool, airline schedule data at RSG is required. The schedule is not limited to the flights of the airline itself but covers all expected flights at D0. These schedules consist of static entries and have not been updated with new information in anticipation of D0.

2.3.1.3 Runway capacity figures

Declared capacity figures of runways will be used, which are obtained during the sector briefings. If no restrictive measures or capacities have been declared for runways, then ATC is not present during sector briefings. However, an estimate can be made based on Quick Reference Cards (QRC) for various wind- and runway combinations.

2.3.2 Description

In general, airlines will not intervene with the scheduled flights in order to counteract possible delays. Only when delays start to build up beyond a certain threshold, or if severe capacity constraints are to be expected, the airline will act.

In the event of serious expected disruptions, a sector meeting take place in which capacities restrictions are issued. It is then deemed that airlines cooperate in order not to exceed capacity. Once a reduced capacity limit is at hand, or if a certain minimum delay threshold is reached, changes are made to the flight planning by means of a proprietary tool. This tool evaluates the input data consisting of meteorological information, airline schedule data, and capacity figures, to calculate and indicate which flights to cancel in a given time window, with the purpose of reducing delays to the set threshold. By cancelling flights, the demand is reduced to match capacity.

It was noted that LVNL already issues regulations for the next day at an early stage, based on predictive NM data and weather models. This sometimes causes some flights, mainly the longer medium haul flights within the Integrated Initial Flight Plan Processing System (IFPS) zone such as those from Israel or the Canary Islands, to incur long delays.

2.4 Assessment

This section describes the differences in terms of stakeholder processes. In the assessment, only LVNL and RSG processes will be evaluated as these stakeholders are seen as a supplier of D-1 predictions. The airline is a consumer of this process.

In general the following conclusions can be drawn:

- From an input perspective, LVNL's D-1 plan is much more data driven. RSG's D-1 plan is more qualitatively driven using stakeholder meetings.

- There is a mismatch in timelines. Ideally, output information (OPS plan) from LVNL is received at an earlier stage for decision making during meetings at RSG. However, it retrieves this information only after these meetings.

The following sections describe main differences in terms of input data for the operations plan (2.4.1), as well as the differences in terms of schedule (2.4.2)

2.4.1 Assessment in terms of input data

Both LVNL and RSG make use of weather data provided for by KNMI, either by using the SKV and/or by means of an in-person briefing. Other types of input data for their D-1 operations plan are more tailored to their specific purpose for the operations plan. For example, the ICD and KERMIT databases provide insight on on-site constructions and reported incidents, to provide additional insight on relevant processes that will influence airport planning at D0. These inputs are less relevant for LVNL, as their main operations focus lies on the flight handling prior to arrival at the stand or after off-block time.

In terms of data on predicted flight demand, there are also notable differences. RSG uses TAF and CISS databases, which mainly contain schedule and slot data. Although the CISS database is continuously updated with up to date information, at D-1 this information is not complete and usually only contains schedule and slot data as originally scheduled. This data is manually manipulated to ensure that for example, slots of flights which are known to not be used, will be removed.

LVNL sources its predicted flight demand from EUROCONTROL. The slot data, as well as airline schedules, are collected by EUROCONTROL. Consecutively, corrections are made to this network data by the NM based on historical behavioural patterns, including the addition of GABA flights, events and weather forecasts, using predictive algorithms. RSG is mainly concerned with the terminal and gate usage. Since GA/BA aircraft are all handled at Schiphol-East, it does not affect their resource planning. LVNL's main concern is demand in the airspace at any given time, irrespective of flight service type. For RSG, the corrected output from the flight databases together with weather and other relevant and known airport processes form the inputs for meetings in which the input data is qualitatively interpreted. Based on this interpretation, the AOP plan is formed.

LVNL bases its OPS plan also on corrected output from NM flight databases. The outputs of this database are used in conjunction with SKV data which expresses potential weather event in terms of chance. Clear decision making rules have been defined in terms of this chance to determine available capacity. It can therefore be concluded that the LVNL process is more data driven, whereas RSG takes a more qualitative approach.

2.4.2 Assessment in terms of schedule

Differences in the D-1 processes scheduling of LVNL and RSG were noted, and can be visually observed in Figure 9. Key observations include:

- The D-1 process is a full day effort for RSG, starting at 08:00 and ending at 16:00;
- The D-1 process is half a day effort for LVNL, starting at 09:30 and ending at 13:30;
- OPS Plans are shared from LVNL to RSG around 11:30 and 13:30;

- Key organisational meetings at RSG take place at 09:00 and 10:30.
- There is a dependency on external information:
    - Availability of NM data, which is received by LVNL around 09:30;
    - Availability of detailed KNMI data, received between 11:00 and 12:00.

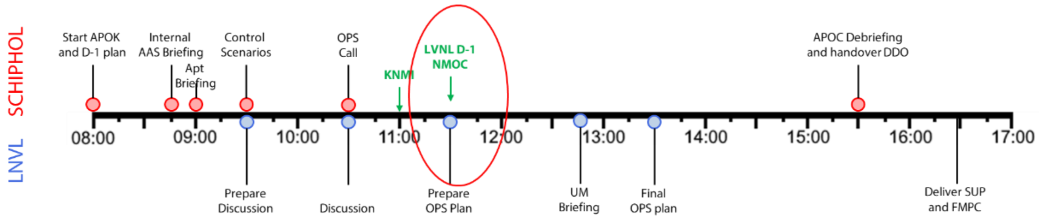

Figure 9: D-1 process scheduling, RSG vs LVNL.

Note that the difference in this timeline of the D-1 process are a consequence of independent development of this process.

3 Data Analysis

This chapter describes the methodology and results of the data analysis which was performed, based on the data provided by the stakeholders. The findings will identify areas of accuracy improvement and enable indications for the alignment of the D-1 process based on the data that is used in the process.

3.1 Methodology

To be able to find differences in the D-1 prediction between LVNL and RSG a four-part method was used as shown in Figure 10**Fout! Verwijzingsbron niet gevonden.** and described below. Focus of the data analysis is put on the arrival and departure times at the stand, as common planning of all stakeholders, despite the focus for LVNL being more on the runway planning.

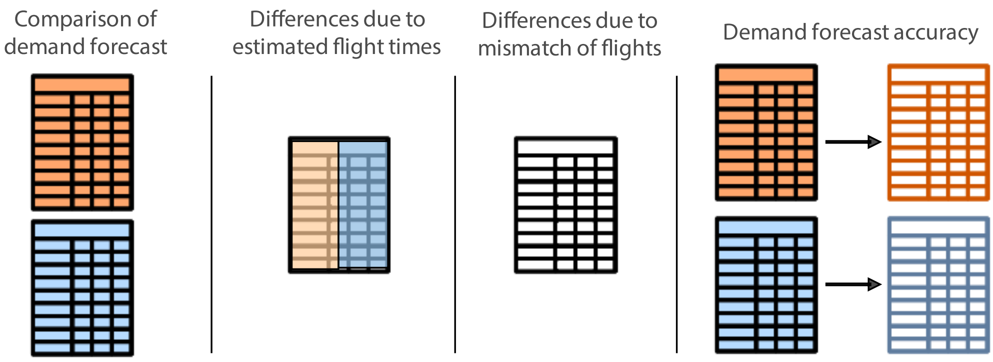

Figure 10: Data Analysis Process

Comparison of demand forecast

In the current operation LVNL and RSG work using their own demand forecast. It is this forecast that could lead to a difference in operational decisions. By comparing the raw forecast, the potential for such different decisions can be identified before identifying underlying causes. Any difference between the two forecasts is due to one of two causes:

1. The flight is not present in one of the datasets
2. There is a difference in the arrival/departure time of a flight

Differences due to estimated flight times

When both forecasts contain the same flights, any difference in demand is due to a difference in predicted times. A comparison of the two forecasts with flights that only exist in both datasets, provides insight in how differences in predicted flight times lead to differences in demand predictions.

Differences due to mismatch of flights

The set of unmatched flights shows what part of the difference in the forecast is due to mismatches in flights.

Demand forecast accuracy

The above analyses provide insight in differences in the prediction at D-1. However, they do not indicate which of the forecasts best matches the actual operation at D-0. By comparing each of the predictions against the actual performance, the accuracy of the individual predictions is determined.

3.2 Presentation of distributions of differences

The main way the results section will describe the difference in forecasts is the difference in number of flights between LVNL and RSG or between D-1 and D0. This difference is reported per day and per hour of the day.

When reported per hour of the day, a diagram will be used to describe the distribution of the difference for that hour over all days as shown in Figure 11. The yellow box contains 90% of days while the outliers total 10% of days.

When comparing the two predictions per hour, the underlying time is the off-block time for departures both for RSG and LVNL. For arrivals the in-block time for RSG and the landing time for LVNL are used as the two datasets do not contain the same milestone. This does generate a bias in which RSG times are later due to the taxi-in time. By comparing at a 1-hour interval, the effect of such a bias is reduced.

When comparing datasets within one organisation, the identical milestones are used. In these cases the bias does not exist.

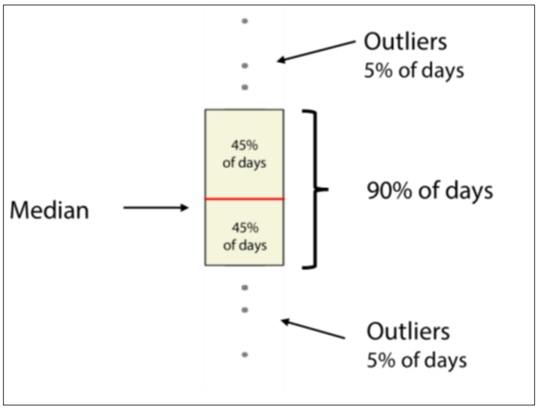

Figure 11: Box used when showing results by the hour by aggregating multiple days

3.3 Description of demand forecast datasets

The analysis evaluates historical data from May 1, 2021 to September 30, 2021 However, because of missing days and outliers in the data 33 days were removed for the demand forecast comparison.

Removed days

Due to unknown causes, 30 days in the LVNL D-1 data was not available for assessment, mostly in the month of August as shown in Figure 12 by the red shaded areas. The three days of 30th August, 31st August and 1st of September (marked by the red outline) were also removed since they were clear outliers where PREDICT seemed to have strongly underestimated the number of fights. It is however unclear if this is due an actual wrong prediction or issues coming from the extraction of the data itself. To avoid skewing the results due this outlier case, the dates were also removed. The remaining analyses contains 121 days.

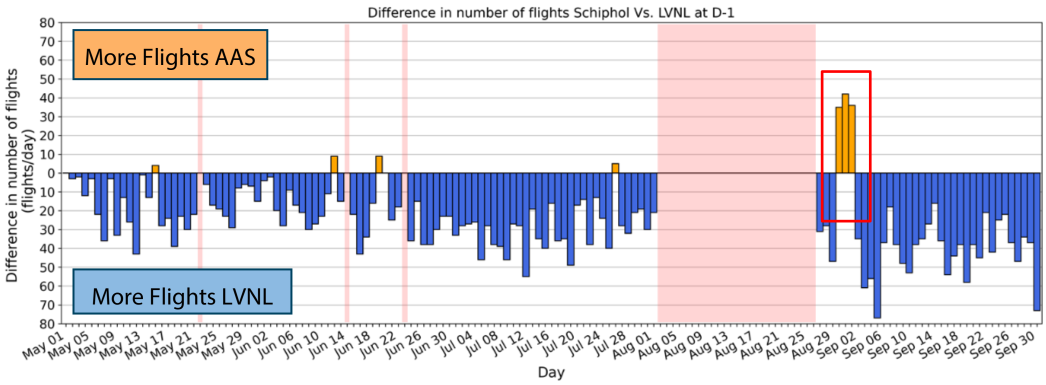

Figure 12: Difference in number of flights each day between 1. May 2021 - 30. September 2021. Including missing days and with GA/BA.

Effect of General and Business aviation

Figure 13 shows the difference in the number of flights for the remaining number of days. In this set LVNL has up to 70 more flights per day in their D-1 data than RSG. On only 4 days does RSG have more flights planned than LVNL predicts. The data from EUROCONTROL includes general aviation (GA) and business aviation (BA). Since RSG's dataset does not contain GA/BA in the stage of D-1, it will be excluded in the following analysis. This resulted in 95,007 flights in the LVNL D-1 dataset while 95,264 for RSG.

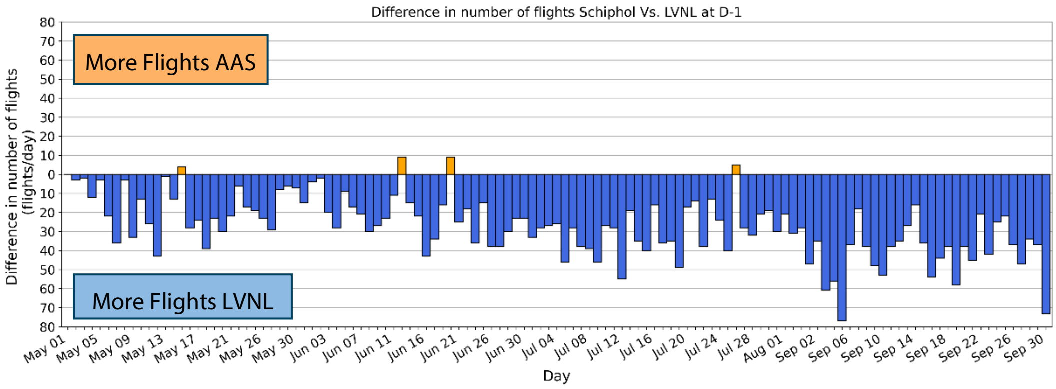

Figure 13: Difference in number of flights each day with dates filtered, but with GA/BA.

3.4 Comparison of demand forecast

The difference in the total forecasts, without the GA/BA flights shows where RSG and LVNL would have different expectations of demand. In this section, this difference will first be explored per day to gain an overall insight and then per hour of the day to get an indication of the potential for different operational decisions.

3.4.1 Differences per day

Figure 14 shows the difference in the number of predicted flights between RSG and LVNL. The graph shows that RSG has on average more flights scheduled in the beginning of the period while LVNL predicts more flights towards the latter half.

The maximum difference on any given day is 30 more flights for either RSG or LVNL. Over the entire period the average difference in the number of flights is 2 flights more in the RSG dataset. A breakdown by arrival and departure can be found in Appendix C

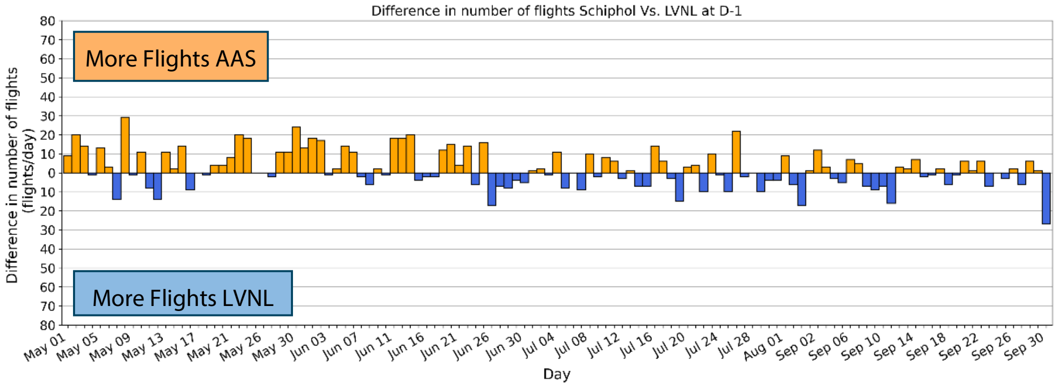

Figure 14: Difference in number of flights each day with dates filtered and removed GA/BA from LVNL dataset.

3.4.2 Differences per hour of the day

To evaluate the effect of the differences by the hour, this section provides the distributions of the differences at a given hour over all days as per Section 3.2. Figure 15 shows the arrivals while Figure 16 shows the departures.

Arriving aircraft cause the largest variation. At both 05:00 and 16:00 UTC which are inbound peaks, LVNL predicts more arriving flights followed by more scheduled flights at RSG in the following two hours.

The departures contribute little to the difference in number of flights different at each hour with the median being zero for almost every hour. Most probably both RSG and EUROCONTROL NM use the scheduled times for departing aircraft hence no difference will exist for departures.

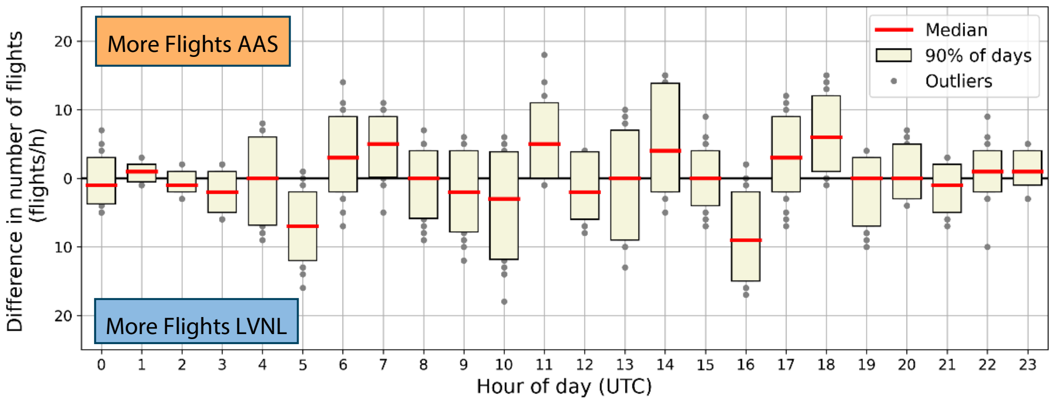

Figure 15: Difference in number of flights LVNL and RSG per hour of day (Arrivals)

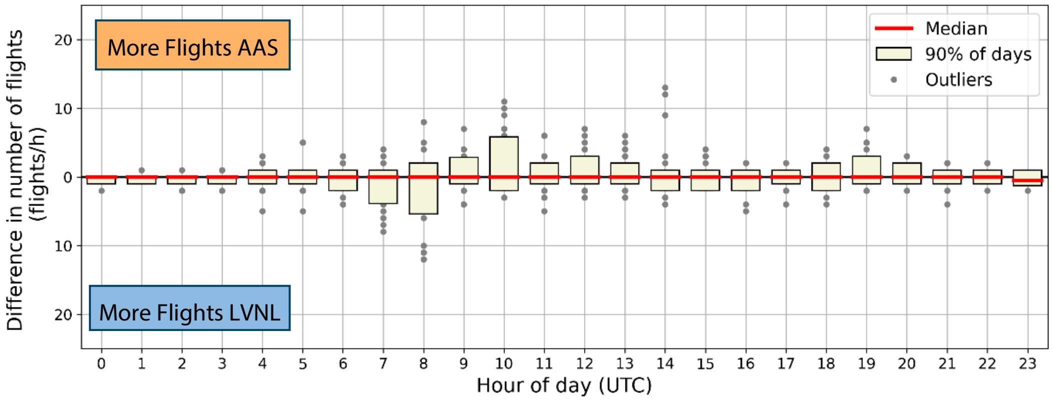

Figure 16: Difference in number of flights LVNL and RSG per hour of day (departures)

3.5 Differences due to estimated flight times

To analyse the effect of differences in estimated times, flights in both datasets need to be correlated. The following section first describes the applied matching process to draw lessons on the compatibility of the data. Subsequently, it analyses the differences for the matched flights to analyse the differences in expected times. Since some differences are found, Section 3.5.3 explores to what degree those differences can be explained by the type of airspace user.

3.5.1 Matching flights

Unfortunately, no single unique identifier exists at this stage in the flight's evolution. Because no common flight identifier exists across the datasets flights were correlated between the LVNL D-1 predictions and RSG schedules using a combination of flight attributes:

- Date/ time
- origin/destination,
- operator/airline
- callsign/flight number,
- aircraft type

Unmatched flights

Within the remaining dataset, and excluding GA/BA, 93% of flights could be matched. The group of unmatched flights can be divided in 3 subgroups:

1. Flights present in the Schiphol D-1 dataset, but not in the LVNL D-1 dataset.
2. Flights present in the LVNL D-1 dataset, but not in the Schiphol D-1 dataset.
3. Flights that exist on both sets, but that could not be matched.

The last group of flights indicates that the mismatch is partially due to inability to correlate data that exists in both sets. The next section looks into the issues in this correlation problem.

Matching issues

The lessons from the matching process in this project may be valuable in developing a possible technique for merging the two datasets as part of a collaborative D-1 process between Schiphol and LVNL. Appendix G provides a further technical outline on a workable process for merging information from the two sources.

As mentioned, no unique flight identifier exists at this stage in the flight's evolution. The key problems in correlating the flights were:

- The Schiphol dataset contains IATA designators for aircraft and airports whereas LVNLs dataset contains the ICAO designators. For both the translation is not unique.
- The (IATA) flight numbers tend to be static and connected to the same flight (time, origin, destination) every day. The (ICAO) callsign is often dynamic not connected to the same flight. The two can therefore not be translated from one into the other.
- The scheduled departure time and date are often a good correlator. However, the Schiphol D-1 dataset only contains the scheduled time at Schiphol. This makes correlating arrival times harder.
- The PREDICT data showed that the system is slow to adopt changes in aircraft type and even airline. The change aircraft type has been seen multiple times per day and can have an effect on the predicted flight speed and therefore time, besides, the difference in type may affect ground handling due to gate sizes for example. The change in ICAO designator of an airline (without a change in the actual flight) has been seen at least 3 times in the dataset but mainly affects matching only.
- On the day of operation, a EUROCONTROL-assigned flight identifier (the IFPLID) is associated to the flight plan which is then provided to all stakeholders, including both LVNL and RSG. However, this identifier is only available once a flight plan is filed which typically happens 3-6 hours before departure. This also means that matching D-1 to D0 is also non-trivial.

3.5.2 Demand comparison of matched flights

As in Section 3.4, the distribution of the differences in the number of flights between RSG and LVNL are plotted by the hour. This section separately discusses arrivals and departures.

Arrivals

Figure 17 below depicts the analysis of arrival flights. During the night the differences are generally centred around zero. However, between 05:00 and 06:00 (UTC) LVNL has more flights predicted than the schedule of RSG. In the following two hours more flights are planned by RSG. This trend is also found during the afternoon, where an excess number of predicted flights from LVNL at 16:00 UTC are followed up by an excess number of flights for RSG in the following hours.

This pattern has a similar shape and magnitude and pattern as seen with the total demand forecast in Figure 15.

Since the flight exist in both the Schiphol and LVNL D-1 datasets, differences demand prediction are only attributed to differences in predicted arrival times. Therefore, the majority of differences for arrivals come from a difference between scheduled times at RSG and predicted times at LVNL.

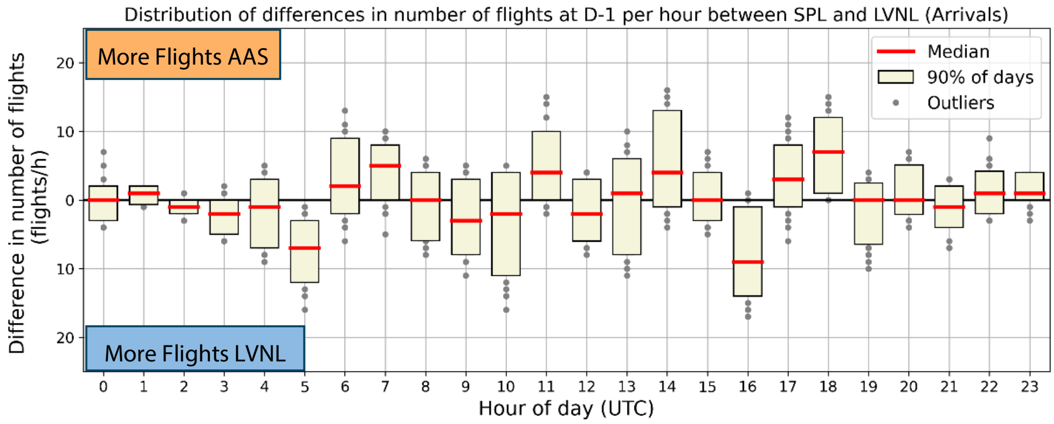

Figure 17: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour for arrival flights

Departures

Figure 18 below shows very little difference in the number of departures at each hour. The lack of difference further supports the suggestion made in Section 3.4.2: Both sources seem to use the scheduled departure time as the expected departure time.

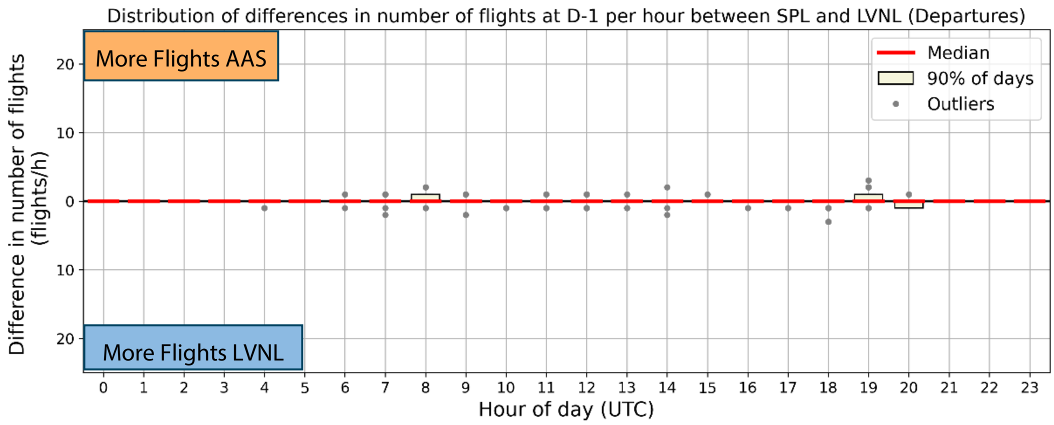

Figure 18: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour for departure flights

3.5.3 Effects of airspace user type on arrivals

To further identify origins of the observed differences in arrival flights, this section further groups the data based on the type of airspace user. The section first looks at service type and then and flight length.

Flight services type

The vast majority of flights (91%) in the dataset are passenger flights. These flights also account for the observed pattern in the differences between the number of planned arrival flights over the hours. Other flight service types (e.g. charter cargo, freight) did not show a significant difference between the planned flights of RSG and LVNL. The results for different flight service types are found in Appendix D

Short-haul versus long-haul

A further distinction was made between short- and long-haul arrivals (1,500 NM threshold), where 79% of the flights were short-haul flights. Figure 19, showing the short-haul arrival flights, clearly shows the previously observed pattern. The differences diminish when focussing on the long-haul arriving flights in Figure 20, where the differences are generally centered around zero throughout the day. The majority in variations for arrivals can therefore be explained by differences in predicted arrival times of the short-haul flights.

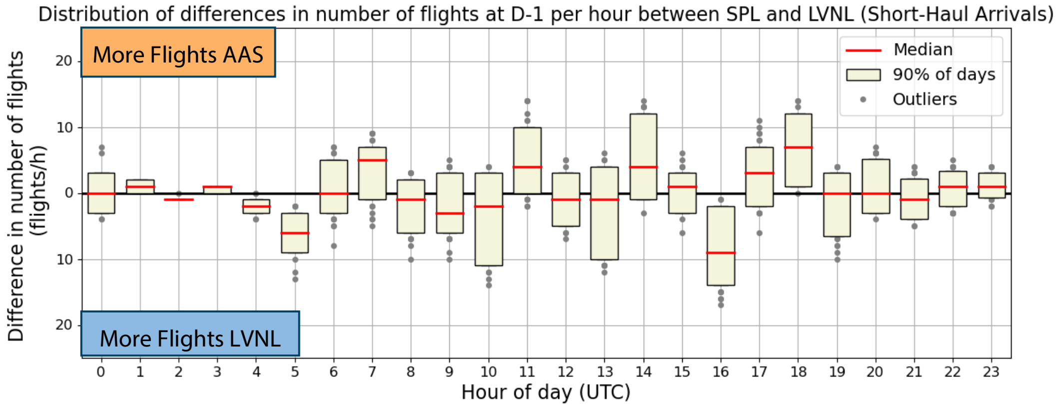

Figure 19: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour for short-haul arrival flights.

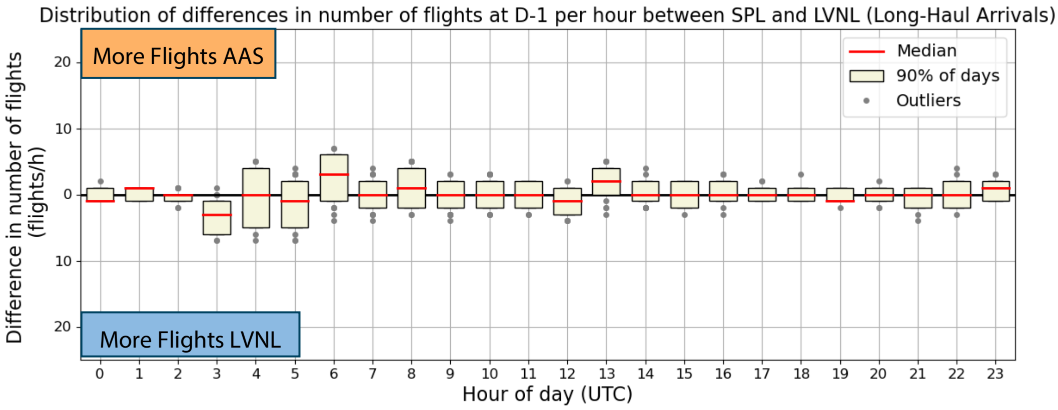

Figure 20: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour for long-haul arrival flights.

3.6 Differences due to mismatch of flights

By evaluating the flights that could not be matched, it is possible to get insight in the potential of causes of differences in decisions. This set consists of around 7% of flights.

Arrivals

In the previous section it was seen that the differences in estimated arrival times between LVNL and RSG was the major reason for a difference in the demand forecast (Figure 17). This also clear from Figure 21, showing the arrivals for the unmatched set of fights. Although difference in forecast is observed, these differences are relatively small compared to the differences seen due to the estimated flight times in Figure 17.

Departures

For departures, the previous section indicated very little difference in expected departure time (Figure 18). That means the difference seen in the demand forecast for departures in Section 3.4 mostly comes from flight that could not be matched.

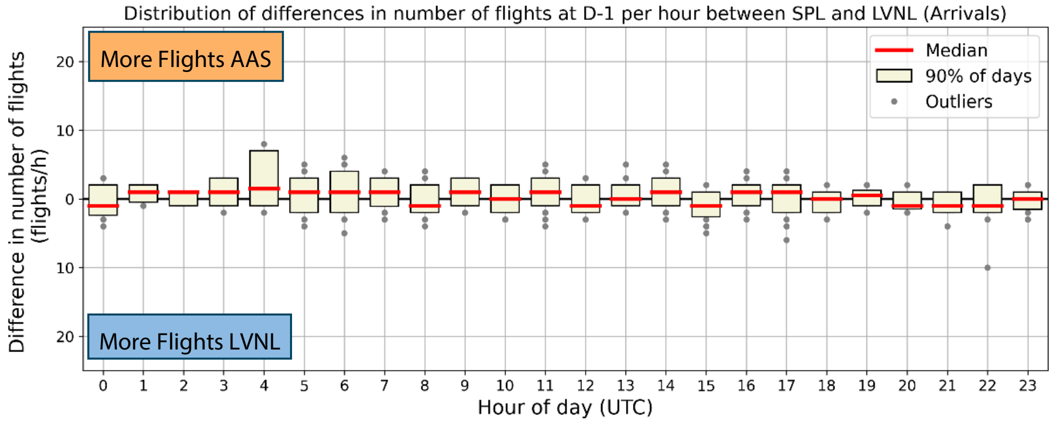

Figure 21: Distribution of differences in number of flights at D-1 between RSG and LVNL for unmatched arrival flights.

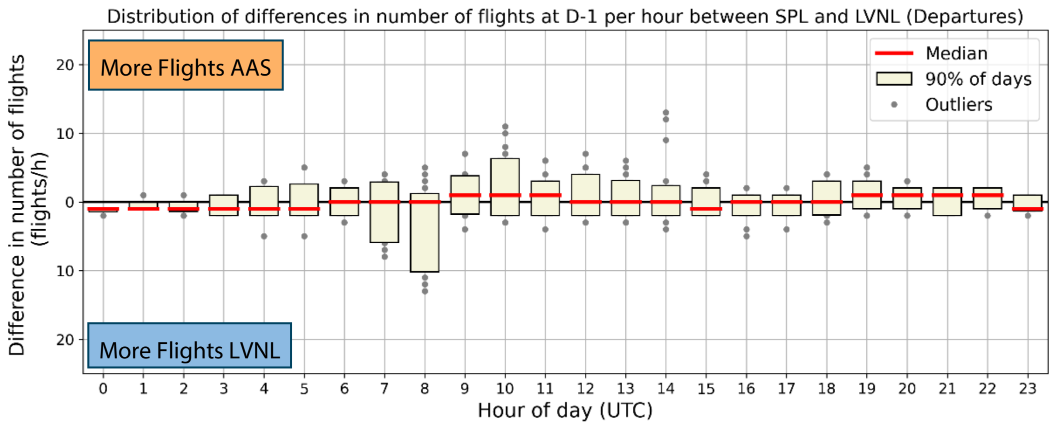

Figure 22: Distribution of differences in number of flights at D-1 between RSG and LVNL for unmatched departure flights.

3.6.1 Effect of flight service type on unmatched departures

Table 1 and Table 2 break down the unmatched departures into flight service type. Table 1 for flights present in the RSG dataset, but not in LVNL while Table 2 show flights in the LVNL dataset, but not in present in the RSG data. When comparing to all departures, the unmatched set has around 23 percentage points more cargo operations than the set of all departure flights. Their overrepresentation in the unmatched set is likely because of the unpredictable nature of operations, causing a difference in the scheduled and predicted times.

Table 1: Flight service type for unmatched departure flights RSG.

Service Type	Number of flights	Percentage unmatched departures	All flights departure
J (Passenger Scheduled)	1,054	63%	90%
F (Cargo Scheduled)	373	22%	6%
H (Cargo Charter)	99	6%	2%
C (Passenger Charter)	87	5%	2%
P (Positioning)	54	3%	<1%

Table 2: Flight service type for unmatched departure flights LVNL.

Service Type	Number of flights	Percentage unmatched departures	All flights departure
Passenger	1,054	69%	92%
Cargo	373	31%	8%
Passenger Charter	99	<1%	2%

3.7 Demand forecast accuracy

In order to identify the accuracy of the planning at D-1, the predictions are compared to the actual operation at the day of operations (D0). In this analysis, the predictions of both LVNL and Schiphol are compared to the operational records of the respective organisations. This provides an insight into the accuracy of both without requiring extensive matching between flights.

3.7.1 Daily demand accuracy RSG

While a total of 123,381 flights are found in the D-1 schedule for RSG throughout the analysed period, 131,637 are observed in the D0 dataset. Since this section analyses RSG data only, the month of August is included since these days were only missing from the LVNL dataset. On average, the D0 dataset includes 55 more daily flights than observed at D-1 (Figure 23). It should be noted, however, that the D0 dataset includes both GA and BA, while the D-1 dataset does not. Unfortunately the provided D0 dataset does not support identification of GA and BA.

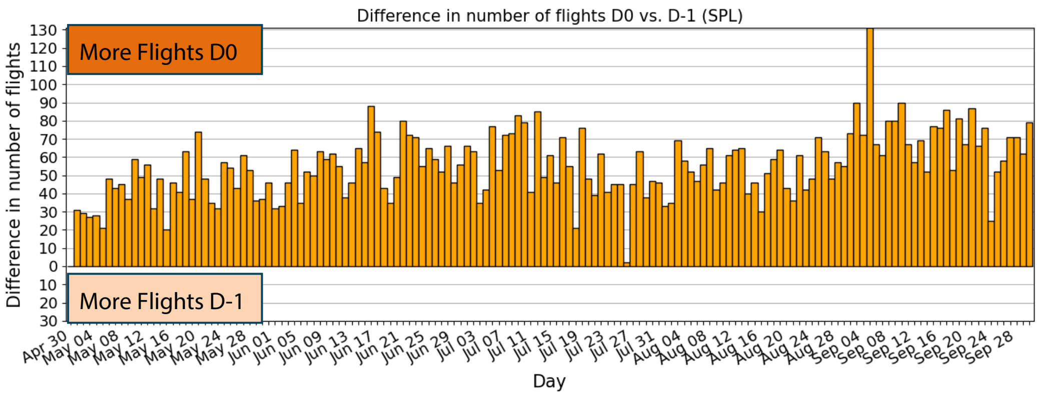

Figure 23: Differences in the number of flights between D0 and D-1 for RSG throughout the analysed period

3.7.2 Hourly demand accuracy RSG

In 3.5.2Section 3.5.2 it was found that LVNL predicts the flights to be arriving earlier than RSG does. This trend was observed in the morning (05:00 – 06:00 UTC) and in the afternoon (16:00 – 17:00 UTC). The comparison of the number of flights by the hour between D-1 and D0 for RSG shows that, during those hours, RSG underestimates the planned number of flights (as observed from Figure 24). More flights were observed in D0 compared to D-1 between 05:00 and 06:00 UTC. In the next two hours, more flights were planned at D-1 than operated at D0.

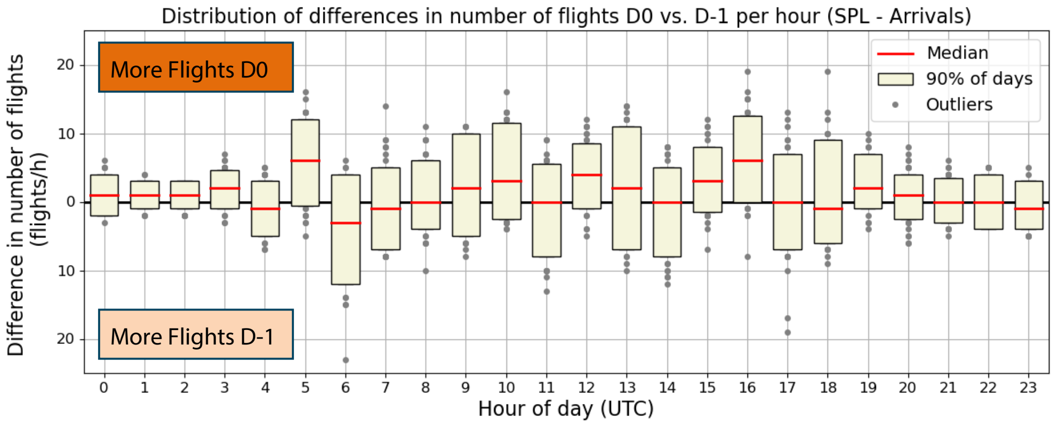

Figure 24: Distribution of the differences in number of flights between D0 and D-1 by the hour for arrivals (RSG)

This means that PREDICT's calculation of the arrival time is a better indicator than the scheduled arrival time in the D-1 forecast at RSG. This effect is obvious in the indicated peaks. Due to the lack of matching data, a structural analysis was not possible.

3.7.3 Daily demand accuracy LVNL

While a total of 98,583 flights are found in the D-1 predictions for LVNL throughout the analysed period, 99,887 are observed in the D0 dataset. This means that on average, the D0 dataset includes 11 more daily flights than D-1 (Figure 25).

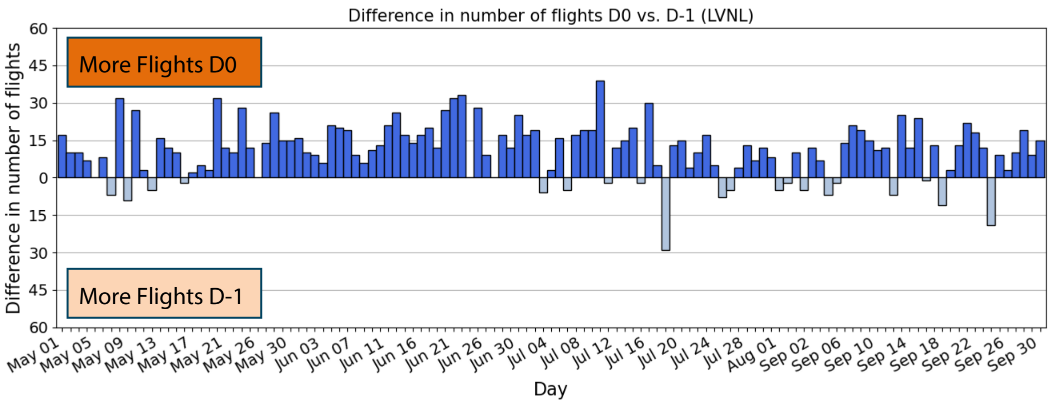

Figure 25: Differences in the number of flights between D0 and D-1 for LVNL throughout the analysed period

3.7.4 Hourly demand accuracy LVNL

Figure 26 depicts the distribution of the differences in the number of arrivals between D0 and D-1 by the hour. In general, the median is centred around zero, with the exception between 03:00 and 04:00 UTC where more flights arrived than expected.

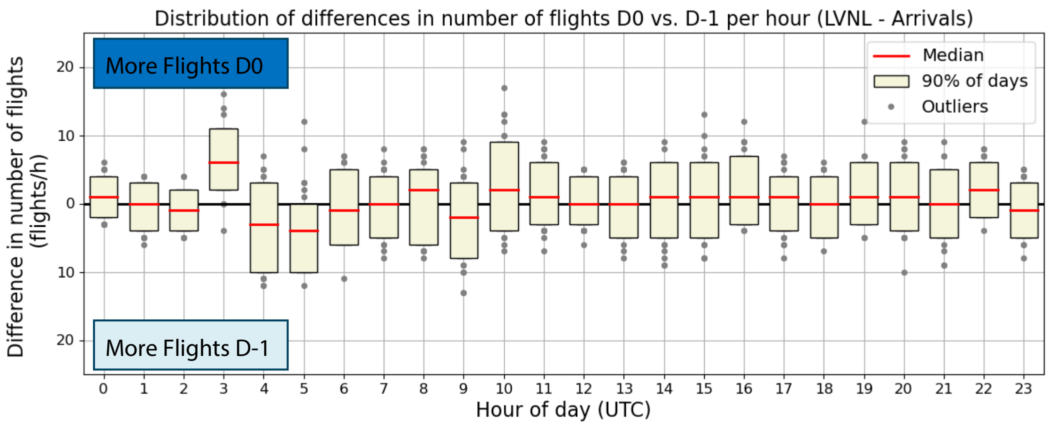

Figure 26: Distribution of the differences in number of flights between D0 and D-1 by the hour for arrivals (LVNL)

3.8 Findings data analysis

The analysis of the D-1 predictions of LVNL and Schiphol shows that:

- The average difference in the number of predicted flights between the D-1 predictions of LVNL and RSG is around 2 per day.
- Even though this not significant by itself the maximum difference on any given day is up to 30 flights/day for either RSG or LVNL. This difference can have operational consequences depending on when and for what flights this difference occurred. In the critical first inbound peak this difference varies up to 10 flights per hour for either RSG or LVNL.
- LVNL and RSG appear to use the same scheduled departure times. Differences in the departure forecast come from flights that could not be correlated between the two datasets and has around 23 percentage points more cargo operations than for the entire dataset.
- LVNL consistently, and correctly, predicts earlier arriving flights during the morning and afternoon peaks. This means aircraft arrive earlier than scheduled which is confirmed when comparing to D0. While RSG use the scheduled arrival times PREDICT simulated the entire flight for its D-1 estimation, causing a difference in expected arrival time at RSG.
- The differences in predicted arrival time mainly stem from the short-haul passenger operations.

Additional findings:

- While PREDICT data includes GA/BA, RSG does not yet include GA/BA in their D-1 demand forecast.
- Correlating flights between the demand forecast of RSG and LVNL is not fully possible because of a lack of a common unique flight identifier. Our analysis managed to match 93% of flights.

4 Potential Alignment Measures

This chapter describes the direction for process and data alignment, based on the discussion with stakeholders in the workshop conducted 9 December 9th 2021. In that workshop assessment results of the process interviews with LVNL, Schiphol and KLM as well as data analysis results were presented. Alignment of process and data sources are considered a first step for stakeholder decision making and operational resource enhancement.

4.1 Data Sources

Based on findings listed in 2.4.1, directions for alignment can be considered.

- LVNL and RSG mainly use weather data from the same source (KNMI), either by using the SKV or by means of in-person briefing. Although the same source is used, the method for using this data differs. LVNL has determined internal decision making rules based on the SKV predictions to determine available capacity.

  > *RSG could consider to adopt a similar process of using clearly defined decision making rules based on SKV. These rules should be aligned with LVNL to allow for a consistent outcome.*

- Various types of input information for the D-1 plan are tailored to their specific needs of the sector party. ICD and KERMIT databases were used by RSG as an example, as these provide insight on on-site constructions and reported incidents which may be of interest as contextual information to LVNL.

  > *No alignment solution proposed.*

Notable differences were observed in terms of data on predicted flight demand.

- RSG uses TAF and CISS databases based on schedule and slot data. The CISS database is continuously updated with up to date information, at D-1 this information is not complete and usually only contains schedule and slot data as originally scheduled. This data is manually adjusted to correct inaccuracies.
- LVNL sources its predicted flight demand from EUROCONTROL's DDR portal. Corrections are made to the network data by the NM based on historical behavioural patterns, events and weather forecasts, using predictive algorithms. Block times from the schedule and slot data are split to account for flight times and taxi times, allowing for more accurate arrival time predictions.

1) *RSG could consider using NM PREDICT data to align its source data with LVNL. Due to the predictive algorithms, the accuracy of this input data for the D-1 processes are more accurate, in particular for arrivals.*
2) *Airlines could consider to share at D-1, next to the scheduled times of their flight operations, the expected flight times with RSG.*
3) *It was observed that NM PREDICT lacks data fields that enable flight matching with RSG data. A proposed approach for matching flights can be found in Appendix G Efforts should be made to have an universal identifier included in all datasets. The future Global Unique Flight Identifier (GUFI) that is proposed to exist during the full lifecycle every unique flight from initial intention at the airline to arrival could provide this solution. The FF-ICE flight plan format foresees use of the GUFI.*

From an airline perspective, several observations have been made as a consequence of putting pre-emptive regulations in place to decrease demand.

4.2 Process alignment

Conclusions in the assessment of D-1 process, conducted in 2.4.2, were also drawn. Based on these conclusions, solutions for alignment can be proposed.

- The D-1 process starts at 08:00 for RSG, and ends at 16:00. LVNL's D-1 process starts at 09:30 and ends at 13:30;
- OPS Plans are shared from LVNL to RSG around 11:30 and 13:30;
- Key organisational meetings at RSG take place at 09:00 and 10:30.
- There is a dependency on external information:
  - Availability of NM data, which is received by LVNL around 09:30;
  - Availability of detailed KNMI data, received between 11:00 and 12:00.

Alignment of the daily schedules could enable synergy and improvement of the accuracy of demand prediction for all stakeholders.

1) *To enable synergy, RSG's key meetings should take place at a later moment of the day be shifted to align:. LVNL could consider to develop a plan at an earlier moment of the day, or RSG a bit later, or both. However,*
2) *As NM predict data is only available from 09:30 onward, an external dependency exists for LVNL. Therefore, LVNL could consider to generate a preliminary OPS plan based on D-2 data which is available at an earlier stage. Because the NM algorithm uses D-7 flight schedules and slot data as a basis for the predictions, it's expected that there are not too many differences in outcome if D-2 NM-data is used rather than D-1 NM-data. This should however be investigated further.*
3) *Consider to involve LVNL during the airport briefings to elucidate on the OPS plan.*

5 Conclusions & Recommendations

An analysis was conducted to determine which methods and tools the sector stakeholders of LVNL, RSG and airline use for their D-1 planning and how the stakeholders make their choices based on this planning. This analysis was threefold. First, inputs for the D-1 process were compared. Thereafter, the schedule and process steps used by each of the stakeholders were compared. Finally, a data analysis was performed to reveal accuracy of the predictions.

This chapter describes the conclusions and recommendations.

5.1 Conclusions

The following conclusions are drawn:

5. Differences in daily LVNL Pre-Tact unit and RSG APOC D-1 activities contribute to inconsistency of stakeholder and resource decision making. Alignment measures are proposed to have LVNL and airlines involved during APOC meetings, and to align the processes such that the LVNL OPS plan can be included.

6. Data Analysis revealed significant differences between LVNL and RSG datasets, both in terms of traffic numbers, as well as predicted timestamps. The differences are mainly contributed to short-haul arriving aircraft. In general, the NM PREDICT data was found to most accurately represent operations at D0.

7. Data analysis findings clearly indicate that NM PREDICT data as used by LVNL enables a more accurate demand prediction than use of only scheduled data. Airlines flight predictions could complement and enhance accuracy even further.

8. RSG and airlines will significantly benefit improving accuracy when using NM PREDICT data. Consequences of the use of NM PREDICT data for the airline should also be considered, as pre-emptive measures may disrupt operations, especially for the longer flights in the IFPS zone. In case of demand reductions are required, the implementation of a local rule would ensure that sacrifices in terms of cancellations are a shared effort amongst airlines.

5.2 Recommendations

The following recommendations are determined:

1. The lack of matching between the flights between RSG and LVNL and between D-1 and D0 significantly reduced the ability to detail the differences. If a more assured matching is possible, the study could be much more driven on the differences per flight and the identity of missing flights.

2. As the analysis was conducted in the second year of the global COVID Pandemic, traffic was severely reduced and 2021 should therefore not be considered a suitable year for benchmarking

the outcome of analysis. Furthermore significant portions of the data were missing or filtered, leaving room for improvement in further analysis. Based on this, it is recommended to continue D-1 demand prediction data analysis in order to let benchmarking conclusions be complete and representative.

3. When processes and data matching of LVNL and RSG are aligned, it makes sense to validate the demand predictions accuracy against such benchmark, in order to assign credit to the changes and communicate the accuracy improvement to airlines and sector stakeholders. This credit could then trigger further process adjustments by airlines and enhance process and accuracy of input data, and contribute to D+1 post operations analysis as well as D-3 up to D-7 and D-180 predictions, creating a long term demand outlook.

A Acronyms

Acronym	Full name	Description
AAS	Amsterdam Airport Schiphol	
ACC	Area Control Center	
ANSP	Air Navigation Service Provider	
APOC	Schiphol Airport Operations Centre	
BZO	Bijzonder Zicht Omstandigheden	
CISS	Central Information System Schiphol	
CMA	Capacity Management and Analytics	concerned with capacity and the environment in both strategically, pre-tactically, tactically and post-operationally
CMA	Capacity Management & Analytics	
DDO	Day to Day Operations	
DDR	Demand data repository	
EHFIRAM		The most used TFV for traffic regulations by Amsterdam FMP
ETFMS	Enhanced Tactical Flow Management Systems	
FACT		
FMA	Flow Manager Aircraft	
FMPC	Flow Management Position Controller	
FTFM	Filed Tactical Flight Model	
GABA	General Aviation/ Business Aviation	
HCC	KLM Hub Control Center	
ICD	Incident Change and Development tool	
IFPS	The Integrated Initial Flight Plan Processing System	
IL&T	Inspectie Leefomgeving & Transport	Human Environment and Transport Inspectorate
KDC	Knowledge & Development Centre	
KLM	Koninklijke Luchtvaartmaatschappij	
KMAR	Koninklijke Marechaussee	
KNMI	Koninklijk Nederlands Metereologisch Instituut	
LVNL	Luchtverkeersleiding Nederland	Air Traffic Control the Netherlands
NAT	North Atlantic Tracks	
NEST	Network Strategic Tool	
NOP	Network Operations Portal	
OCW	Operation Coordinators Work	
OHD	Operationele Helpdesk	
OSD	Operational Support and Development	Supports the Director of Operations, the Unit Management/operational managers, the supervisors, the Operational Experts and the operational staff. The activities of the OSD department are aimed at informing, advising and representing the aforementioned officials
ORC	Operational Reference Information	
RMS	Resource Management System	
RSG	Royal Schiphol Group	
SKV	Schiphol Kansverwachting	
TAF		Weekly Flight Schedule at RSG
TWR/APP	Tower / Approach	
UM	Unit Management	

B Data analysis – sources and extraction

LVNL and RSG have provided To70 with files in various formats in order to conduct this analysis. Some of this data needed to be pre-processed. This section explains what files were received, and what manipulations have been performed to obtain text readable files which could be processed and interpreted.

LVNL

For the analysis at hand, two types of information were used:

PREDICT files	Provided out by LVNL and originally retrieved from the EUROCONTROL DDR portal for each individual date at which D-1 prediction was made. The file contains flight information as predicted by the PREDICT algorithm.
NEST data	Retrieved by To70 from EUROCONTROL's DDR2 portal to use as D0 information. Contains initial, regulated as well as actual flight data (4D routes) of an entire AIRAC cycle, as well as airspace structures and any regulations that may or may not have taken place.

To interpret these data types, EUROCONTROL's Network strategic tool (NEST) stoftware was used [2]. The following sections describe how this tool was used to extract text readable information from the source files.

D-1: PREDICT files

LVNL retrieves its NM PREDICT data on a daily basis from EUROCONTROL's DDR portal. Hereafter, NEST scripting tools are used to convert this data for input in their D-1 planning. This scripting algorithm was replicated by:

- Obtaining a NEST file of the AIRAC cycle covering the NM PREDICT date at hand;
- Stripping the flight- and regulations from this NEST file, so that only airspace definitions of the date at hand remain;
- Import the NM PREDICT file. This essentially yields a historical view of future situation, i.e. D-1.
- The Statistics toolbox in NEST is used to extract relevant information to text readable information, by extracting all flights bound for, or arriving from RSG airport.

D-0: NEST files

NEST files contain historical flight and regulation data of a certain AIRAC cycle. For each individual flight, the file stores the initial flight plan data, as well as regulated- and actual flight data. The initial flight data contains flights as originally scheduled, including flight plan routes and scheduled times. The regulated flight plan data accommodates the flights with regulations at hand, including their tracks and updated time stamps. The actual flight tracks might still differ due to weather and route changes (e.g. vectors or ATC route changes). These changes are captured with in the actual data.

Having the three types of data at hand allows:

- to observe whether flights that were originally scheduled, actually took place;

[2] https://www.eurocontrol.int/model/network-strategic-modelling-tool

- to observe if the flights took place, what kind of regulations were actually applied, which routes were flown and what were the realised time stamps.

This file did not require any manipulation to extract relevant information. Therefore, the Statistics toolbox feature in NEST could directly be used to extract relevant information, by extracting all flights bound for, or arriving from RSG airport from the dataset. This was done for the datasets covering Regulated, as well as Actual flights. These extract were consecutively used as D-0 data.

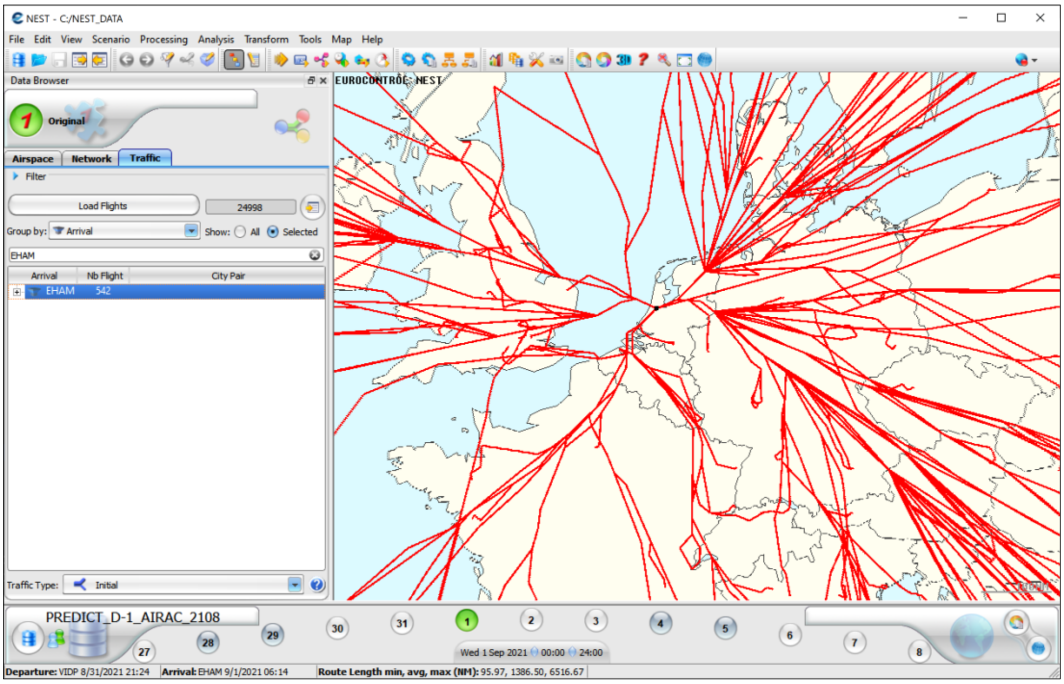

Figure 27: NEST Interface, used to visualise and interact with NM PREDICT data

RSG

Two types of data were obtained from RSG for the analysis at hand:

- Exports from TAF information at D-1, and
- CISS information at D0

This data was delivered in text format and as such, did not need any pre-processing in order to perform the analysis.

C Raw demand by day D-1: Arrival/departure

In Figure 28 and Figure 29 the difference in the number of flights over per day is shown. In the beginning of the period more arrivals at RSG make up a large part of the difference in the number of flights.

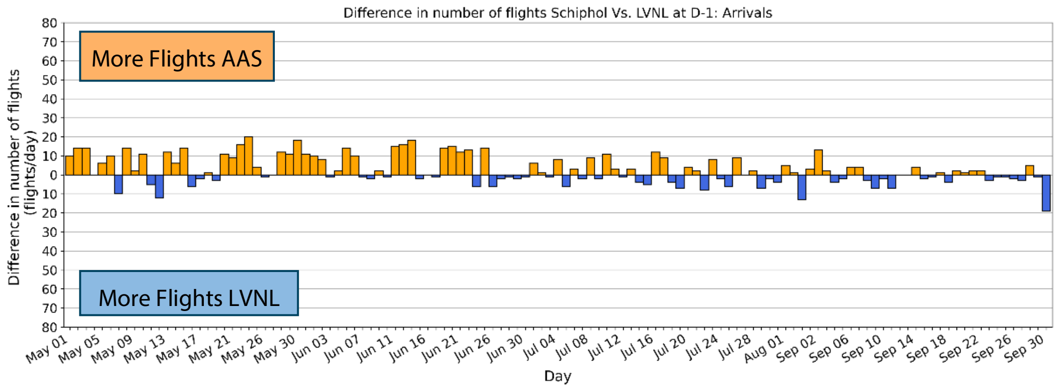

Figure 28: Difference in number of flights for raw D-1 demand arrivals.

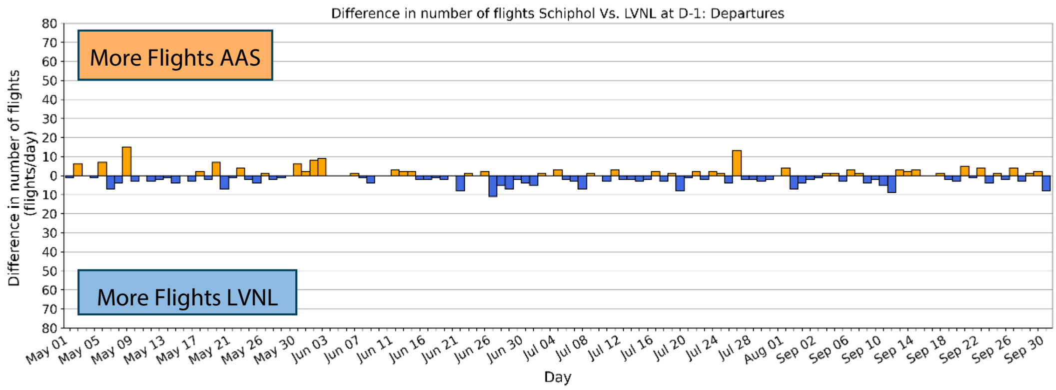

Figure 29: Difference in number of flights for raw D-1 demand departures.

D Analysis of differences in number of flights at D-1

This analysis presents the differences in number of flights at D-1 per hour between RSG and LVNL of matched flights for different flight service types.

As observed from Table 5-1, the vast majority of flights from the matched flights are operated as scheduled passenger flights. Other service types cover cargo charter, cargo scheduled, passenger charter, and positioning flights. The distributions of the differences in number of flights between RSG and LVNL from the matched dataset at D-1 is presented for each individual service type category in Figure 30 up till Figure 34.

Service Type	Number of flights	Percentage of matched flights
J (Passenger Scheduled)	83,404	91%
H (Cargo Charter)	5,217	6%
F (Cargo Scheduled)	1,621	2%
C (Passenger Charter)	1,378	1%
P (Positioning)	299	<1%

Table 5-1: Flight service types in the set of matched flights in D-1

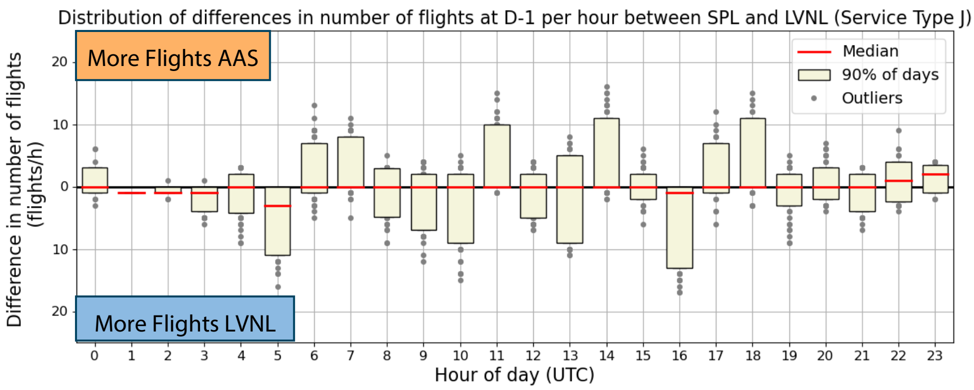

Figure 30: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour (Passenger Scheduled)

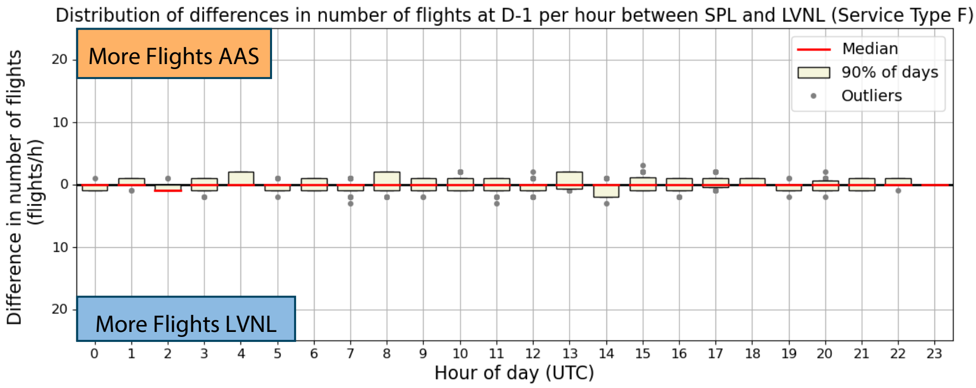

Figure 31: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour (Cargo Scheduled)

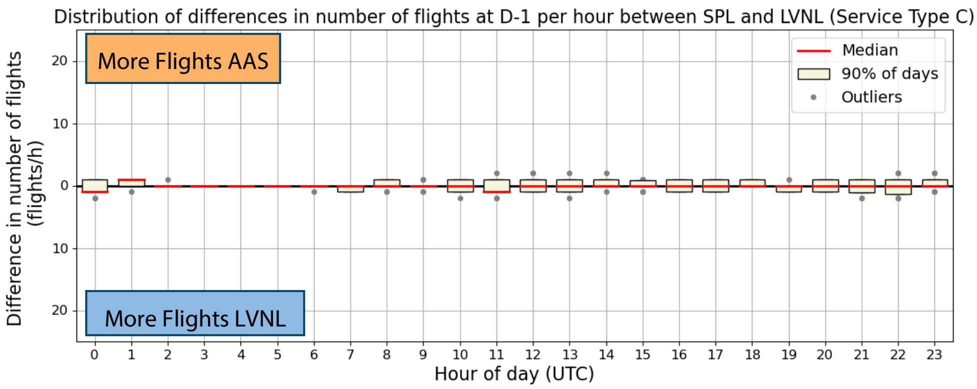

Figure 32: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour (Passenger Charter)

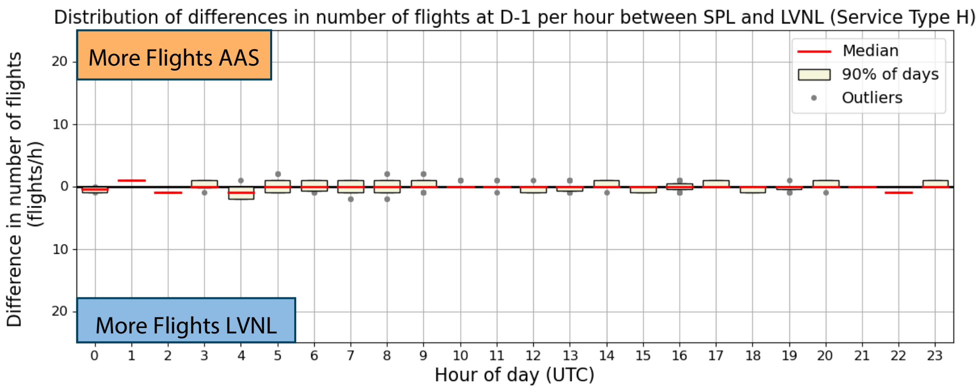

Figure 33: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour (Cargo Charter)

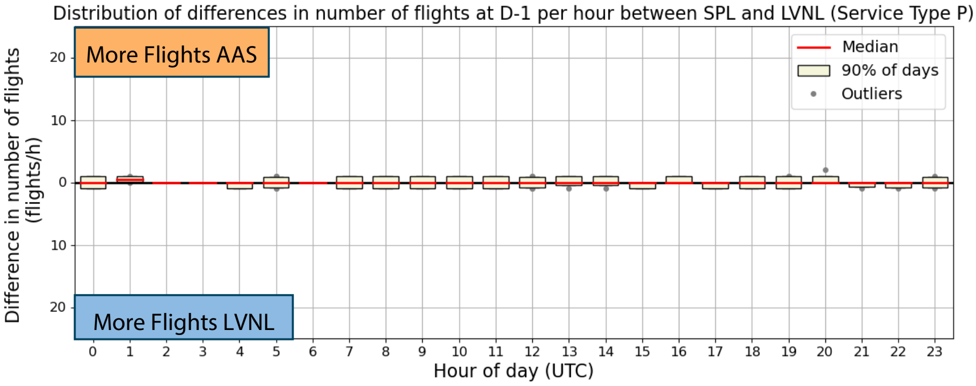

Figure 34: Distribution of differences in number of flights at D-1 between RSG and LVNL by the hour (Positioning)

E Additional analysis of comparison D-1 vs. D0 (Schiphol)

Distribution of differences in number of flights between D0 and D-1 for departures RSG

The results in Figure indicate that the D-1 schedule includes more flights between 07:00 and 08:00 UTC than D0 does. However, the opposite is true for the next hour between 08:00 and 09:00 UTC, where more flights are operated than were planned the day before. Throughout the day, the distributions are skewed to the upper side, which again shows that more flights are found in the D0 dataset for RSG.

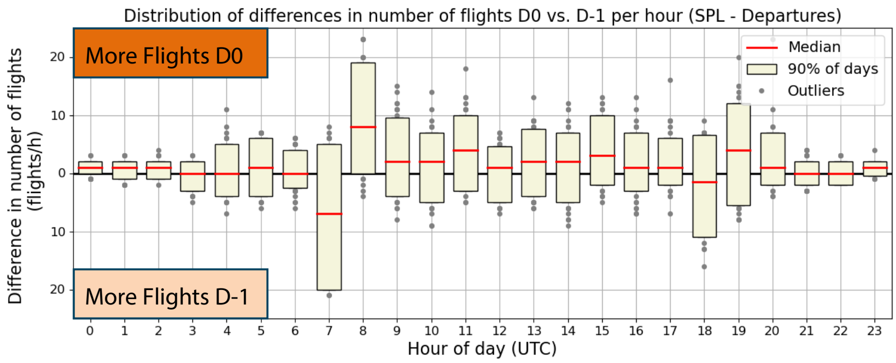

Figure 35: Distribution of the differences in number of flights between D0 and D-1 by the hour for departures (RSG)

Airline distribution D-1 vs. D0 (RSG)

It was observed that a total D0 included 8,256 more flights than D-1 for RSG. This comes down to an average of 55 daily flights. The table below contains five airlines that showed the largest absolute increase in the number of flights included at D0 compared to D-1. The relative contribution of the airline to the total difference is denoted by the final column.

Airline	Number of Flights D-1	Number of Flights D0	Absolute difference	Relative to total difference
ZXP (Police)	0	1,684	1,684 (11 flights/day)	20%
NJE (NetJets)	0	1,000	1,000 (7 flights/day)	12%
NCG (Netherlands Coastguard)	0	583	583 (4 flights/day)	7%
XRO (Exxaero)	0	298	298 (2 flights/day)	4%
PHT (PanJet)	0	235	235 (1 flight/day)	3%

F Additional analysis of comparison D-1 vs. D0 (LVNL)

Distribution of differences in number of flights between D0 and D-1 for departures LVNL

The results in Figure Figure indicate that the D-1 schedule of LVNL includes more flights between 07:00 and 08:00 UTC than D0 does. However, the opposite is true for the next hour between 08:00 and 09:00 UTC, where more flights are operated than were planned the day before. Throughout the remaining of the day, the medians are generally centred around zero.

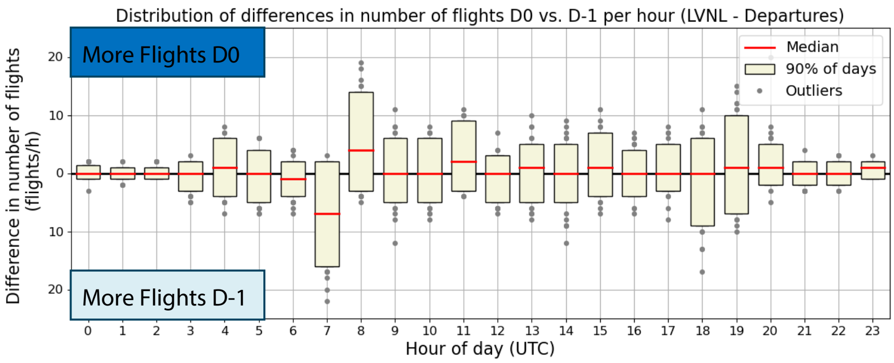

Figure 36: Distribution of the differences in number of flights between D0 and D-1 by the hour for departures (LVNL)

Airline distribution D-1 vs. D0 (LVNL)

It was observed that a total D0 included 1,304 more flights than D-1 for LVNL. This comes down to an average of 11 daily flights. The table below contains five airlines that showed the largest absolute increase in the number of flights included at D0 compared to D-1. The relative contribution of the airline to the total difference is denoted by the final column.

Airline	Number of Flights D-1	Number of Flights D0	Absolute difference	Relative to total difference
NJE (NetJets)	172	803	631 (5 flights/day)	48%
KLM	52,302	52,695	393 (3 flights/day)	30%
SER (AeroCalifornia)	9	101	92 (<1 flight/day)	7%
BLA (BlueAir)	94	162	68 (<1 flight/day)	5%
XRO (Exxaero)	187	242	55 (<1 flight/day)	4%

G Concept for matching of PREDICT data with schedule data at Schiphol

A common source of traffic demand would help in ensuring collaborative decisions. At the same time, the datasets at Schiphol and LVNL both contain information that is not available in the other source. As such the datasets are complimentary.

The analysis showed that PREDICT is better at predicting the arrival time of flights. Schiphol could benefit from this data if it was possible to join both data sources as part of a shared D-1 process. At the same time, the analysis demonstrated that such joining is non-trivial in the absence of a unique common identifier.

The comparison of PREDICT data to the schedule information available at Schiphol provides some insight in how the data could be matched. This appendix describes the outline for a method that is able to gain as much information by matching flights without requiring extensive manual validation.

Currently, a key problem lies in the fact that Schiphol's schedules only provide the scheduled arrival time at Schiphol and not the departure time at the origin airport for inbound flights. Therefore, a separate process for these is recommended.

The recommended process works by applying a sequence of rules in which the next rule is applied to the remaining set of unmatched flights. These rules are based on the matching data available at D-1.

- Departures
    1. Unique matches on departure date, time, airline (ICAO), destination, aircraft type
    2. Unique matches on departure date, time, airline (ICAO), destination – This catches differences due to fleet changes
    3. Unique matches on departure date, time, destination – This catches differences due to airline designator changes
- Arrivals
    1. Unique matches on arrival date, airline (ICAO), origin, aircraft type – This comprises flights that only operate once per day
    2. Unique matches on arrival date, airline (ICAO), origin – Same as above but allowing for change in aircraft
    3. Unique matches on arrival date, airline (ICAO), origin, aircraft type, arrival time - This step should be applied with some margin for the time, which can subsequently be increased stepwise to match the remainders.
    4. Unique matches on arrival date, airline (ICAO), origin, arrival time – Same as above but allowing for change in aircraft

A number of fields exist in both datasets. Depending on the field it is recommended to use the information from either party in case of differences:

- Aircraft type: RSG – the PREDICT data shows some delay in recognising changes
- Operator: RSG – the PREDICT data shows some delay in recognising changes

- Expected landing time: PREDICT – note that taxi time needs to be added for an expected in-blocks time

Based on the experience of the data analysis this would probably allow for matching about 80% of matchable flights. However, development of such an algorithm will require a stepwise approach to limit the number of false matches.