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TECHNICAL NOTE

# AIRPORT CAPACITY IMBALANCE

STUDY

PERFORMANCE REVIEW COMMISSION

19-08-2020

## Edition History

The following table records the complete history of the successive editions of the present document.

| Edition No. | Edition Validity Date | Reason |
|---|---|---|
| 0.1 | 30-07-2020 | Initial draft published for consultation |
| 0.2 | 19-08-2020 | Correction of time period used for the study. Clarification of methodology followed for identification of the runway configurations and their share. |

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## 1. PURPOSE OF THE STUDY

Available runways at a given airport, together with their relative disposition, length, navigational aids, environmental constraints and local meteorological conditions (wind rouse, visibility,…) can result in very different operating conditions, with a direct impact on the capacity of the airport and the operational performance.

This study intends to evaluate the potential capacity and performance imbalance between these operating conditions, through the identification of runway configurations and the analysis of **the difference in capacity and performance depending on the runway configuration, associated with the probability of each configuration.**

There are therefore 3 main elements to investigate:

- Capacity per runway configuration.
- Operational performance associated to the runway configuration.
- Runway configuration probability.

## 2. BACKGROUND

The airport capacity declaration and associated scheduling process entails high complexity as it is influenced by many different factors.

Airport Airside Capacity refers to the ability of the airport runway/taxiway/apron system to handle a given demand of flights within a specified time period, incurring an acceptable level of delay (to be determined by the airport stakeholders). It is defined by the International Civil Aviation Organisation (ICAO) as the *'number of movements per unit of time that can be accepted during different meteorological conditions'* [1], whilst Airport Council International defines it in terms *of 'maximum aircraft movements per hour assuming average delay of no more than four minutes, or such other number of delay minutes as the airport may set*' [3].

Airport capacity is a combination of the available infrastructures, the existing ATM systems and the capabilities of human actors. Investments in the runway system infrastructure are usually the most expensive, so the capacity at the apron, taxiway system and terminal should always be adapted to get the most out of the runway system, being this the determining factor for overall capacity. Additionally, new technologies and optimization in aircraft spacing and sequencing could result in an airport capacity growth when accounting for the operational side.

Among all factors affecting the runway system capacity, the runway layout and configuration is considered as the most relevant. While some airport layouts allow for very similar operation conditions in one runway configuration or another, resulting in equal or similar capacities for all possible runway configurations, other layouts do not offer that "symmetric capacity" as the different configurations might have very different operating conditions, dependencies and limitations.

## 2.1. THE INTERDEPENDENCY TRIANGLE

Airport capacity, demand and delay are three elements that influence each other (see Figure 1). Capacity refers to the theoretical traffic density the airport can serves while the demand corresponds to the airline scheduled operations in correspondence to the theoretical capacity. Both elements are linked by the delay which results from the demand/capacity imbalance. If one of them changes, the other 2 elements might be affected. The operational problem to be addressed by planners and operational decision makers is how to strike a balance between these elements, e.g. how much delay is acceptable to accommodate more demand.

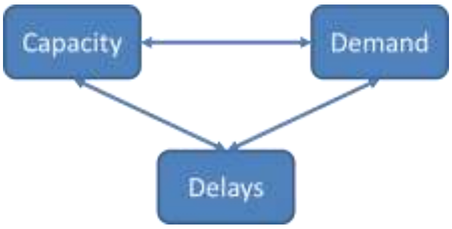


*Figure 1: The interdependency triangle*

In case of a change in the runway configuration that reduces the capacity, different scenarios are possible:

- If the change is unforeseen, the demand is unlikely to be adapted immediately due to this reduction in capacity. In this case demand (temporarily) exceeds the new (reduced) capacity and there will be an impact on the airport performance and related delays.
- If the change is unforeseen but the demand remains below the new (reduced) capacity, the airport system should cope without an impact on performance.
- If the change is foreseen (e.g. night runway configurations due to noise abatement), demand should be adapted to account for the available runway system capacity. In this scenario demand will be managed to the available capacity (e.g. limited number of slots). The chance for demand/capacity imbalance is kept to a minimum but still can exist.

Hence, assuming no change in demand, a change in runway configuration might have an impact on the airport performance.

## 2.2. CAPACITY ANALYSIS

One of the main difficulties found while developing the present study deals with the calculation of the airport capacity, as there is no universal method for this calculation. Although all methods might take into account similar factors, there are different approaches. Among the elements used in such studies are: structural layout (runway, taxiway, apron, gates, terminals, local airspace); environmental impact and economic factors.

The analysis and methodologies will also depend on the time horizon for which the capacity calculation is being made, serving different purposes in the airport capacity plans, as shown in Figure 2

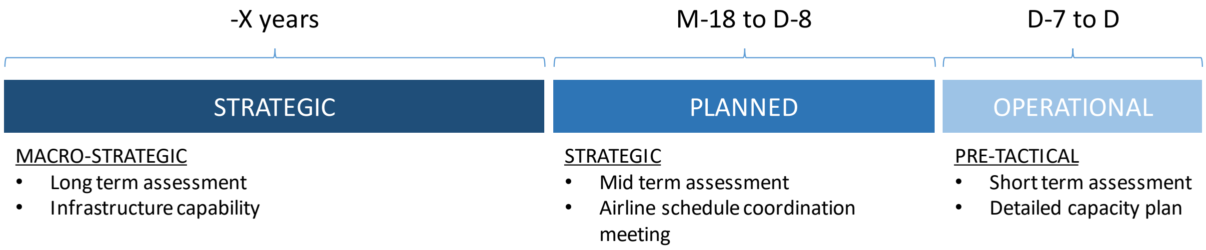


*Figure 2: Airport capacity planning phases.*

An example of capacity calculation methodology would follow these steps:

1. Historical throughput data (track performance & areas to prioritize)
2. Tables & analytical models (high level starting point)
3. Simulation models (fast time and real time)
4. Pareto frontiers (optimum solution)

Nevertheless, as previously mentioned, not all airports do regular capacity studies or follow the same steps. At the moment the only common information repository including airport capacity is Eurocontrol's Airport Corner[1] [4] where airports can report their capacities on a voluntary basis. Ideally, this information is provided per runway configuration. However, many airports do not provide any information in this regard. Even when the information is available, the differences between methodologies and recurrence in the capacity studies for airports across Europe makes very difficult to have a consistent capacities database.

## Peak Service Rate

When demand is above the capacity, the delivered throughput will be an indication of the capacity itself. This is the principle behind the ***peak service rate***: defined as the percentile 99 of the throughput, it is a proxy for the **peak airport operational capacity**, that is, the highest sustainable throughput the airport can achieve under optimum conditions, assuming there is sufficient demand, i.e. during periods of congestion.

The percentile 99 is based on the cumulative distribution of the movements per hour over a sample time period.

Note that at airports which are never or rarely congested, the **peak service rate** might be significantly lower than the **peak airport operational capacity**. This proxy will be valid only when the period considered includes enough hours where the demand was in fact above the capacity. If an airport is underutilised, the peak service rate will simply detect the peak demand, but not the capacity.

[1] Airport Corner is an airport-focused data repository developed by Eurocontrol with operational information provided by the airports (as a result of local coordination between Airport Operator and ATC)

At airports that are rarely congested, the observed maximum throughput can provide a better indication of the operational capacity.

The advantage of this proxy is that it allows for a consistent analysis of airport capacity based on historical data.

## 2.3. AIRPORT OPERATIONAL PERFORMANCE

As result of airport demand/capacity balancing, the traffic demand will be 'pushed' through the capacity bottlenecks (constraints) at the various planning stages and flight phases. Depending on the phase at which the capacity constraint is known, the balancing will be done in different ways. The runway configuration defines one of these capacity constraints.

- **Until the day before operations**: Some runway configurations are already known (or preselected for certain times of the day) long enough in advance for the schedule to be adapted to them and therefore it should result in no impact on performance.
- **On the day of operations:** If there is the need to change to a less favourable runway configuration than the one initially planned, the demand on the runways is managed differently for arrivals and departures**:**
  - For arrivals: A combination of arrival regulations (leading to arrival ATFM delay) together with queuing in the Arrival Sequencing and Metering Area (leading to ASMA additional time). As regulations will only hold the flights before their take-off, they are not able to arrange the arrival flow with inmediate effect. Therefore when there is a unexpected change of configuration, the adjustment of the arrival flow is done through holdings and vectoring in the approach.
  - For departures: A combination of pre-departure delays (flights held at the gate/stand, with or without departure regulations and leading to ATC pre-departure delay), and queuing at the runway (leading to additional taxi-out time). The balance between these two measures will also depend on other factors like the need to free parking stands.

The impact on performance of the change in runway configuration can consequently be studied by observing the following indicators:
- Additional taxi-out time
- Additional ASMA time
- ATC pre-departure delay
- Arrival ATFM delay

## 2.4. RUNWAY SYSTEM CONFIGURATION

The preferable runway direction is related to **the wind conditions (direction and speed)** but the decision on runway configuration (OPS) in use also depends highly on other factors:
- **Operational Safety.** Aircraft lift is by design influenced and benefitted from aircraft departing and landing into the wind.

- **Demand**. Arrival and departure demand play a key role in configurations selection, especially in high demand situation when high capacity configurations are preferred to serve incoming traffic.
- **Meteorology (ceiling & visibility + wind gusts)**. Besides wind speed and direction, other meteorological conditions are of great importance for runway system configuration, such as visibility and cloud ceiling and wind gusts that can cause serious harm to aircraft on its vicinity.
- **Noise abatement procedures**. Noise abatement procedures are used at most major airports in order to reduce noise impact on neighbour communities and are normally active at night and early morning period.
- **Inertia (controllers' preference)**. Air traffic controllers tend to prefer certain runway system configurations or to remain in a same configuration in order to avoid changes, so it has an important factor on configuration selection. These habits or Subtle Navigation Factors (SNF) have been identified in SESAR projects using Machine Learning Techniques.
- **Time of the day (curfews)**. The time of the day influences the staff availability and the range of possible configurations that can be selected.
- **Coordination (TMA/airport)**. Flows in and out the airport need to be coordinated, especially in multi airport Terminal Maneuver Areas.
- **Other factors:** Unavailability of runways (works in progress, maintenance, snow removal…)

Regulatory authorities may further restrict the use of the runway system to so-called preferential runway system (PRS). Typically, PRS refers to a subset of the total set of runway system configurations defined by specific conditions.

Research studies are mainly focused on configuration selection process prediction. These investigations are based on two types of models: prescriptive & descriptive:

- Prescriptive models: Look for an optimal solution (accounting different factors)
- Descriptive models: Conduct historical data analysis

Examples on configuration prediction models include a data-driven model using discrete choice modelling framework which computes configuration prediction in every next 15 min interval, extended to 3h probabilistic forecast. Case studies performed in LGA and SFO airports in USA reveal an accuracy of ≈80% [5] Another example is a decision-tree based model to predict airport acceptance rate used as a decision support tool in Ground Delay Programs (GDPs) [6].

# 3. APPROACH

Given the lack of consistent capacity and runway configuration information, the analysis will use a data driven descriptive model that focuses on the available data in the Airport Operator Data Flow (APDF) managed by the PRU. Furthermore, this data source is currently used for the computation of the required indicators for the performance monitoring, so using the same source for all areas of the study ensures the aligment between them.

## 3.1. AVAILABLE DATA

The Airport Operator Data Flow is established for 90 airports (status as April 2020) and it includes, amongst other extensive data for every flight, the runway time (that is, take off time for departures and landing time for arrivals) for every movement, the type of movement (arrival or departure) and the runway used.
The data is provided monthly by the airport operators and integrated in a common database after data quality checks.
This data allows for an approach that addresses the key elements of this study:

- Identification of runway configuration: based on the type of movement, time at the runway and runway used.
- Runway configuration probability: understood as the percentage of time each configuration is in use at each airport during the period being analysed.
- Capacity per runway configuration: understood as the peak service rate of each configuration and calculated as the 99$^{th}$ percentile of the throughput in 1 hour intervals with such runway configuration.
- Performance indicators for each movement and associated with the corresponding runway configuration. The analysis of the impact on arrival ATFM delay will be dealt with in the next version of this study. Due to data quality issues in the provision of pre-departure delay information, the analysis of ATC pre-departure delay across most of the 90 airports is not possible at the moment. Therefore the performance indicators analysed per runway configuration will be Additional ASMA time and Additional taxi-out time.

These 90 airports present a wide variety of airport layouts typologies (Annex I: Results summary includes the results with layouts of each of the 90 airports analysed for further information):

- 1 runway
- 2 runways intersecting
- 2 runways not parallel
- 2 runways parallel and closely spaced
- 2 runways parallel and independent
- 3 or more runways

The study is conducted for the calendar year 2019, covering the time window between 7h and 22h local time for each day.

## 3.2. ANALYSIS

The APDF data allows for a post-ops data driven analysis including the runway use. The objective is to identify the runway system configurations in use based on the historic data, taking into account that in theory each airport with *N* runways has $6^N$ possible configurations (assuming each runway can be operated for arrivals, departures or both and in either direction) (i.e. an airport with 2 landing strips could be operated in 36 different ways).

In parallel, as a proxy for capacity, the peak service rate (that is, the percentile 99 of the hourly throughput) will be calculated for each of these runway system configurations.

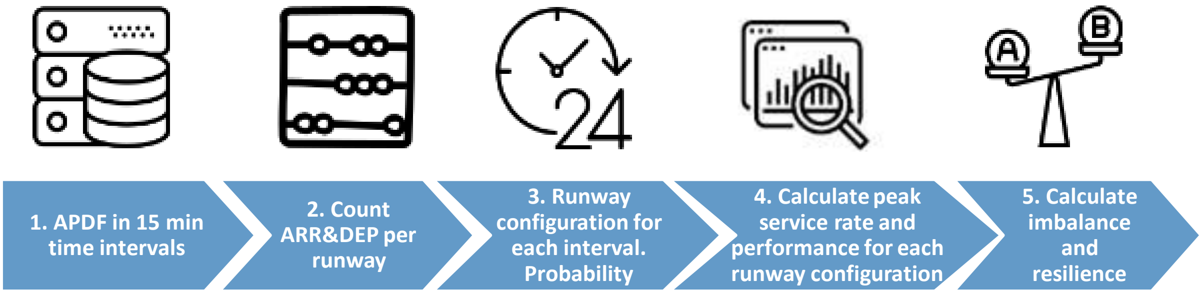


*Figure 3: Steps of the analysis.*

For each airport the analysis involves the following steps:

1. Establish 15 min time intervals that will be used for identification of the runway system configuration (c.f. Table 1)
2. Identification, in each time interval, of active runways and type of movement (ARR/DEP) at each runway (c.f. Table 1), resulting in a detected runway configuration for that 15 min. time interval.

   When for a time interval only a type of movement (i.e. arrivals) has been observed, that configuration will be completed with a runway for the other type of movement (departures in this case). That runway will be assigned by analysing the adjacent intervals, or if necessary, assuming the runway is used in mixed mode. This is generally observed at small airports with very low demand.

3. Identification of sustained runway configurations for each 15 min. rolling hour, by checking, for each 15 min time interval (i), configurations in the following 45 min [(ii), (iii), (iv)]. If the configuration observed in (i) is also observed in at least 2 of the next 3 intervals [(ii), (iii), (iv)], the configuration is considered sustained and valid (condition TRUE in Table 2) and associated to the rolling hour starting with time interval (i).

| AIRPORT | CALLSIGN | TIME UTC | LOCAL HOUR | PERIOD | ARR or DEP | RUNWAY |
|---|---|---|---|---|---|---|
| LEBL | AFL2512 | 29-06-2018 20:46 | 22 | 4 | ARR | 25R |
| LEBL | VLG20GK | 29-06-2018 20:47 | 22 | 4 | ARR | 25R |
| LEBL | VLG91QL | 29-06-2018 20:49 | 22 | 4 | ARR | 25R |
| LEBL | VLG18JC | 29-06-2018 20:50 | 22 | 4 | ARR | 25R |
| LEBL | VLG66YE | 29-06-2018 20:52 | 22 | 4 | ARR | 25R |
| LEBL | ABG8326 | 29-06-2018 20:53 | 22 | 4 | DEP | 25L |
| LEBL | KLM81J | 29-06-2018 20:53 | 22 | 4 | ARR | 25R |
| LEBL | WZZ1075 | 29-06-2018 20:55 | 22 | 4 | DEP | 25L |
| LEBL | RYR6369 | 29-06-2018 20:55 | 22 | 4 | ARR | 25R |
| LEBL | RYR15HD | 29-06-2018 20:56 | 22 | 4 | DEP | 25L |
| LEBL | RYR74BH | 29-06-2018 20:56 | 22 | 4 | ARR | 25R |
| LEBL | VLG18MC | 29-06-2018 20:58 | 22 | 4 | ARR | 25R |
| LEBL | ORO901 | 29-06-2018 21:03 | 23 | 1 | DEP | 07R |
| LEBL | BCS8049 | 29-06-2018 21:05 | 23 | 1 | DEP | 07R |
| LEBL | IBK59V | 29-06-2018 21:07 | 23 | 1 | ARR | 02 |
| LEBL | VLG39LM | 29-06-2018 21:09 | 23 | 1 | ARR | 02 |
| LEBL | QTR142 | 29-06-2018 21:09 | 23 | 1 | DEP | 07R |
| LEBL | WZZ152 | 29-06-2018 21:11 | 23 | 1 | ARR | 02 |
| LEBL | IBK7VY | 29-06-2018 21:12 | 23 | 1 | ARR | 02 |
| LEBL | UAE188 | 29-06-2018 21:13 | 23 | 1 | DEP | 07R |
| LEBL | AFR144X | 29-06-2018 21:14 | 23 | 1 | ARR | 02 |
| LEBL | IBK3ZR | 29-06-2018 21:16 | 23 | 1 | ARR | 02 |

TIME INTERVAL n

ARR:25R-DEP:25L

TIME INTERVAL n+1

ARR:02-DEP:07R

*Table 1: Identification of runway system configuration.*

The reason to allow 1 in 4 time intervals to correspond to another configuration is to be able to accommodate some unexpected movement that does not exactly fit with the runway configuration (in the example in Table 2, the use of runway 25R for a departure of a Heavy aircraft, although that was not the standard runway for departures in that hour).

The calculation of the time share for each configuration is done on the basis of these rolling hours with condition TRUE. To identify typical configurations, a minimum share of 3% of the analysed time has been considered (that is, if a configuration is not active more than 3% of the period of the study, it is not considered representative). The time window considered is 7 to 22h local time to discard night operations where the demand is normally too low to consider the peak service rate as a proxy for capacity and the configurations that are mainly related to environmental constrains.

| AIRPORT | TIME_SLICE | CONFIGURATION | FOUR_SLICE | ARR_HOUR | DEP_HOUR | TOTAL_HOUR |
|---|---|---|---|---|---|---|
| LEBL | 29-06-2018 20:30 | ARR:25R - DEP:25L | TRUE | 34 | 31 | 65 |
| LEBL | 29-06-2018 20:45 | ARR:25R - DEP:25L | TRUE | 36 | 31 | 67 |
| LEBL | 29-06-2018 21:00 | ARR:25R - DEP:25L | TRUE | 34 | 29 | 63 |
| LEBL | 29-06-2018 21:15 | ARR:25R - DEP:25L - DEP:25R | FALSE | 28 | 32 | 60 |
| LEBL | 29-06-2018 21:30 | ARR:25R - DEP:25L | TRUE | 28 | 29 | 57 |
| LEBL | 29-06-2018 21:45 | ARR:25R - DEP:25L | TRUE | 28 | 29 | 57 |
| LEBL | 29-06-2018 22:00 | ARR:25R - DEP:25L | TRUE | 30 | 27 | 57 |
| LEBL | 29-06-2018 22:15 | ARR:25R - DEP:25L | TRUE | 27 | 22 | 49 |
| LEBL | 29-06-2018 22:30 | ARR:25R - DEP:25L | FALSE | 21 | 18 | 39 |
| LEBL | 29-06-2018 22:45 | ARR:25R - DEP:25L | FALSE | 13 | 16 | 29 |
| LEBL | 30-06-2018 06:00 | DEP:07R | FALSE | 8 | 19 | 27 |
| LEBL | 30-06-2018 06:15 | ARR:02 - DEP:07R | TRUE | 11 | 26 | 37 |
| LEBL | 30-06-2018 06:30 | ARR:02 - DEP:07R | FALSE | 9 | 34 | 43 |
| LEBL | 30-06-2018 06:45 | ARR:02 - DEP:07R | FALSE | 13 | 37 | 50 |
| LEBL | 30-06-2018 07:00 | ARR:25R - DEP:25L | TRUE | 13 | 38 | 51 |
| LEBL | 30-06-2018 07:15 | ARR:25R - DEP:25L | TRUE | 17 | 35 | 52 |

*Table 2: Calculation of peak throughput.*

4. The analysis of the peak service rate requires first the calculation of the throughput for all rolling hours. Taking then only the hours with valid configurations (that is, rolling hours where a configuration is sustained in 3 of 4 consecutive time intervals), we calculate the percentile 99 (peak service rate) for each configuration with a representative time share (>3%) (see 3.2 Step 3). The throughput analysis can be split in arrivals departures or total (c.f. Table 3).

| AIRPORT | CONFIGURATION | PERC99_ARR | PERC99_DEP | PERC99_TOTAL |
|---|---|---|---|---|
| LEBL | ARR:25R - DEP:25L | 37 | 39 | 70 |
| LEBL | ARR:07L - DEP:07R | 38 | 38 | 70 |
| LEBL | ARR:02 - DEP:07R | 29 | 31 | 56 |
| LEBL | ARR:25L - DEP:25L | 26 | 28 | 49 |

*Table 3: Representative runway system configurations and peak service rates.*

5. Once a runway configuration has been assigned to certain interval, each flight in that interval can be associated with a configuration. As the performance indicators are calculated per flight, this association will be used for the analysis of performance per runway configuration, resulting in different additional ASMA and taxi-out times per runway configuration.

Now that all the components of the study have been analysed, the following indicators can be calculated:

### 3.2.1. Airport Capacity Resilience

When the probability of a certain runway configuration and the corresponding peak service rate have been established, the capacity resilience for a given configuration, *conf i*, will be calculated as:

$$\text{Configuration Capacity Resilience}_{\text{conf i}}\ (\%) = 1 - (\text{Probability}_{\text{conf i}} * \text{Capacity Reduction}_{\text{conf i}})$$

Where:

$$\text{Probability}_{\text{conf i}} = \text{share of time intervals with runway system configuration Conf i}$$

$$\text{Capacity Reduction}_{\text{conf i}} = \frac{\text{Reference Capacity} - \text{P99 Total}_{\text{Conf i}}}{\text{Reference Capacity}}$$

$$\text{Reference Capacity} = \max_{i}(\text{P99 Total}_{\text{Conf i}})$$

$$\text{Conf i}: \text{ all those configurations with a probability} > 3\%$$

Finally, the airport capacity resilience:

$$\text{Airport Capacity Resilience} = \min_{\text{i}}(\text{Configuration Capacity Resilience}_{\text{conf i}})$$

Understanding that the airport resilience will be the lowest of the resilience for the different configurations.

### 3.2.2. Impact on the peak service rate

Taking the previously calculated diference between the reference capacity and the peak service rate of conf i: $(\text{Reference Capacity} - \text{ P99 Total}_{\text{Conf i}})$, calculated for each of the *n* representative configurations, and the probability of such reduction (given by the probability of the configuration i), the impact on the peak service rate, expressed in absolute number of movements, can be calculated as the weighted average:

$$\text{Impact on Peak Service Rate} = \sum_{i=1}^{n}(\text{Probability}_{\text{conf i}} * (\text{Reference Capacity} - \text{ P99 Total}_{\text{Conf i}}))$$

This indicator informs in absolute terms of how many movements per hour are lost (assuming enough demand) when taking all runway configurations into account, with respect to an hypothetical 100% share of the most favourable runway configuration in terms of peak service rate.

### 3.2.3. Impact on the performance indicators (Additional ASMA and taxi-out times)

In terms of additional ASMA and taxi-out times, the *best* performance corresponds to the lowest additional times (that is, less queuing). Therefore in this case the reference performance is the minimum, as follows:

$$\text{Reference Add. ASMA time} = \min_{\text{i}}(\text{Add. ASMA time}_{\text{Conf i}})$$

And in a similar way to the impact on the peak service rate, the total impact on the additional ASMA time will be the weighted average of the impact for each configuration :

$$\text{Impact on Add. ASMA time} = \sum_{i=1}^{n}(\text{Probability}_{\text{conf i}} * (\text{Add. ASMA time}_{\text{Conf i}} - \text{ Reference Add. ASMA time}))$$

The same calculation applies for the additional taxi-out time.

# 4. RESULTS

This section provides an overview of the results after applying the described methodology to the 90 airports under study Annex I: **RESULTS SUMMARY** provides details for each individual airport After applying the described methodology to the 90 airports under study, there are several aspects to be evaluated. This section provides an overview of the results, see Annex I: Results summary for further information on each airport.

## 4.1. Identification of runway configuration and probability

The approach shows good coverage in terms of identifying a valid runway configuration for each time interval. The minimum share of 3% of the analysed time proves to be a reasonable threshold to discard non-representative configurations, covering more than 95% of the operations in 2019 for 73 out of 90 airports. Only four aiports had less than 90 % of the operation covered by these representative runway configurations: Hannover (EDDV; 89% coverage), Helsinki (EFHK; 83%), Rome Fiumicino (LIRF; 86%) and Amsterdam (EHAM; 73%).

In cases like Amsterdam (EHAM) where more available runways result in numerous configuration possibilities, the 15 minutes intervals might be too short to detect all runways in use, or the 3% threshold too restrictive (as many runway configurations also mean reduced shares for each one of them).

When comparing the identified runway configurations for each airport with the information registered in the Airport Corner, the methodology proves to find not only the main runway configurations , but also other operating modes that are not recognised in the Airport Corner but are actually in use at these airports.

## 4.2. Capacity per runway configuration

*Annex I: Results summary* presents the detailed results for each airport including the identified runway configurations and corresponding peak service rates for each airport, together with the calculated resilience and impact. As mentioned in previous sections, the main limitation for the identification of the capacity for each configuration is the absence of enough demand, which might be the case for many of the smaller airports and even some of the bigger ones.
Figure 4 illustrates the results for the top 30 airports in Europe (from which data is available for 27) in terms of peak service rate and probability for each runway configuration. Each bubble represents a runway configuration with the corresponding peak service rate (vertical axis) and share of utilization (size of the bubble).

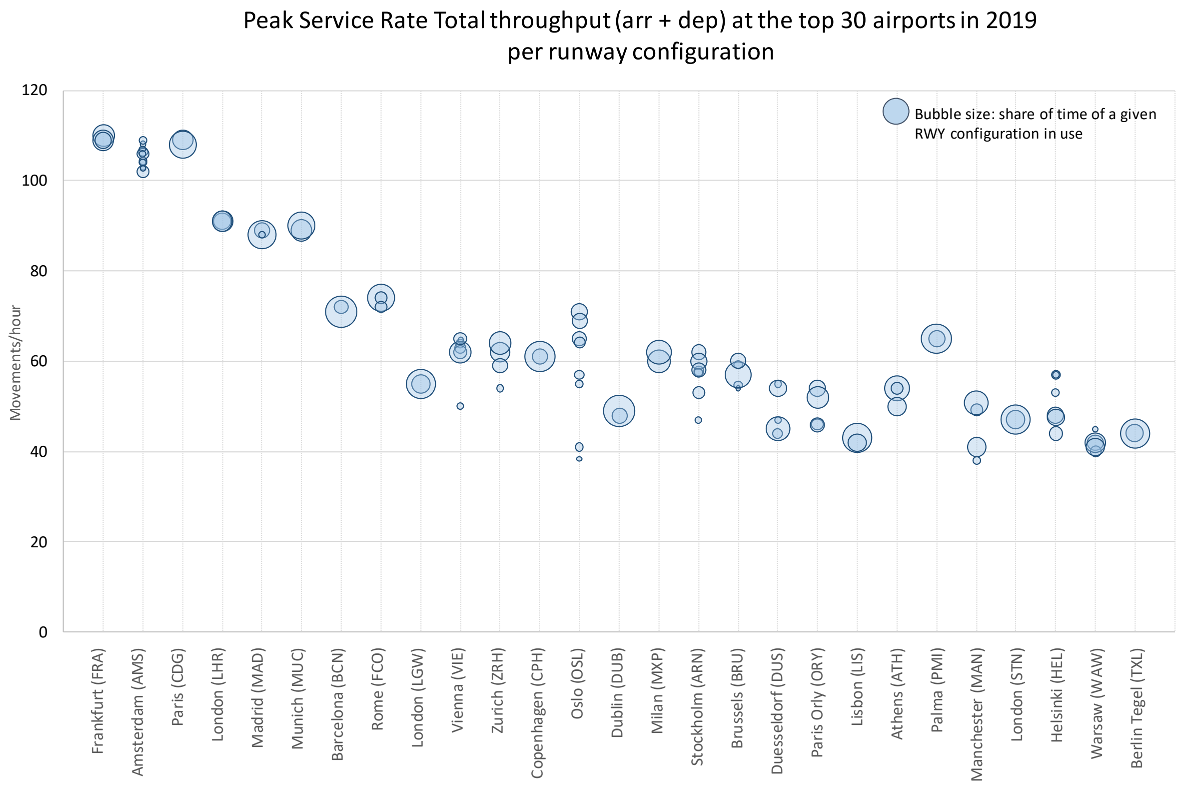


*Figure 4: Difference in peak service rate and share for representative runway configurations*

Within these 27 busier airports, 15 have no significant deviations in this peak service rate for the main configurations, that is, the peak throughput does not seem that affected by the runway configurations (the difference is 2 movements or less). On the other hand, there are some cases like Oslo (ENGM), Helsinki (EFHK), Stockholm (ESSA) and Amsterdam (EHAM) where the dispersion is much higher, and cases like Manchester, where not only there is a significant deviation, but also an even distribution of the share amongst the configurations.

The proposed indicators (resilience and impact on peak service rate) will integrate these different aspects (deviations and share) to be able to assess the imbalance of the operation as a whole.

The comparison of the observed peak service rate and the maximum total throughput with the capacities declared in the Airport Corner, for those airports where information is available, yields mixed results.

At airports like Heathrow (EGLL), Gatwick (EGKK), Frankfurt (EDDF), Munich (EDDM), Dusseldorf (EDDL), Dublin (EIDW), Warsaw (EPWA), Lisbon(LPPT), Zurich (LSZH) or Athens (LGAV), the calculated peak service rate during 2019 is very close to the declared total capacity for each runway configuration.

On the other hand, at other airports like Stockholm (ESSA), Helsinki (EFHK), Copenhagen (EKCH) Rome (LIRF), Charles de Gaulle (LFPG) or Orly (LFPO), the peak service rate, or

percentile 99 is too low compared to the declared capacities. In these cases, the maximum delivered throughput comes closer and might be a better guess for the capacity.
Nevertheless, as mentioned in the section 2.2 CAPACITY ANALYSIS, differences between methodologies and recurrence in the airport capacity studies in Europe also make difficult a consistent comparison.

## 4.3. Airport capacity resilience

Figure 5 represents the Airport Capacity Resilience results obtained for the analysed airports following the described methodology. As highlighted in the chart, only 1 airport, Bratislava (LZIB) has a resilience below 80%, and only other three airports, Gran Canaria (GCLP), Málaga (LEMG) and Nice (LFMN) show a resilience value below 90%.

Although this study does not allow to decipher if the imbalance in the peak service rate is due to lack of capacity or lack of demand, especially for the less busy airports like these four, the analysis at airport level (See Annex I: Results summary for further information) allows to better understand the imbalance at each particular airport, unvealing for example cases in which the most common configuration is a single runway use (even when multiple runways are available) that has lower peak service rate with an associated detrimental impact on performance.

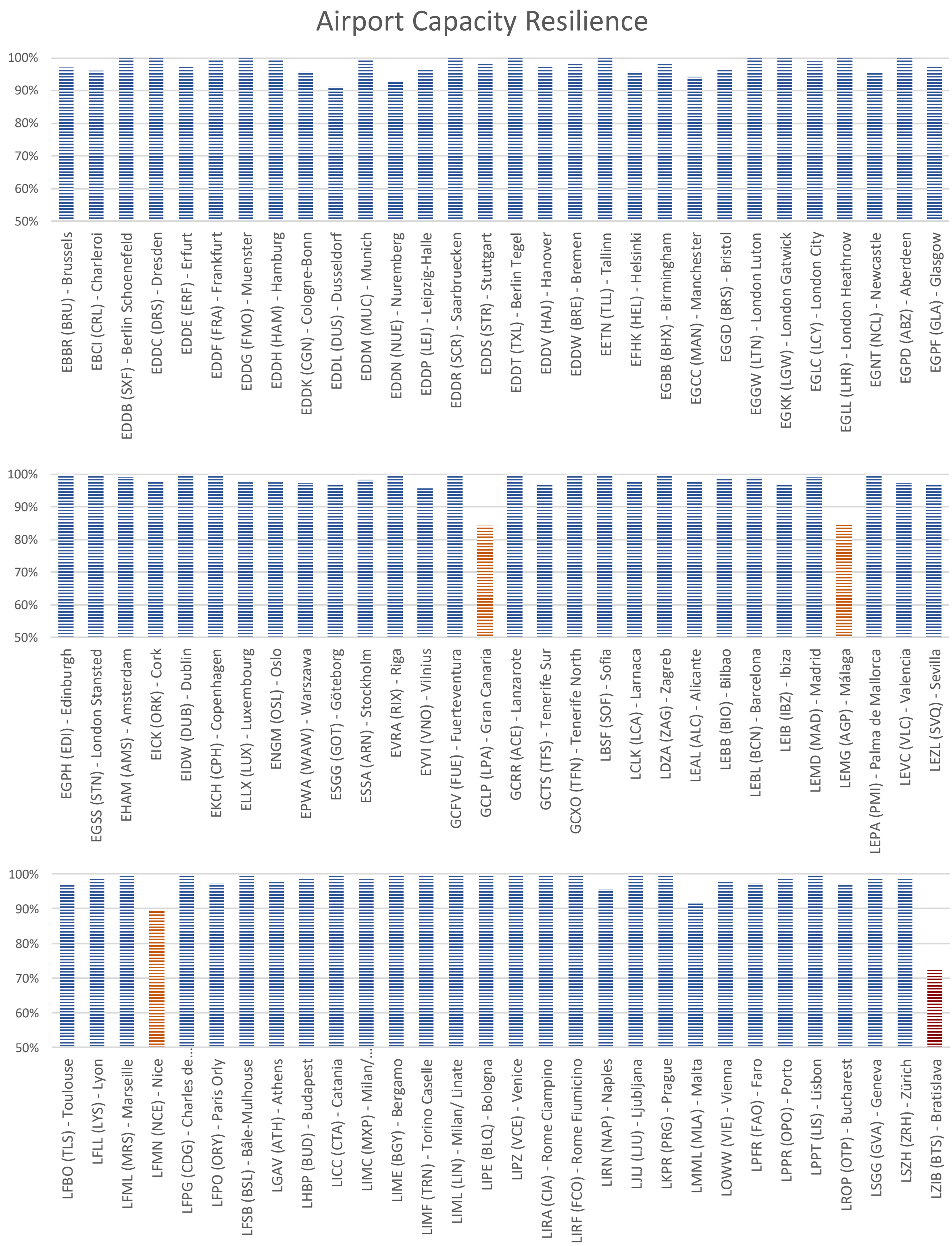


*Figure 5: Airport Capacity Resilience for the 90 airports analysed in this study*

The airport capacity resilience is a relative indicator, that is, the magnitude of the problem is measured with respect to the reference capacity at the airport. Therefore, an imbalance of 4 movements at Amsterdam (EHAM; reference capacity=109) will have a lower reduction of resilience than the same imbalance at Bratislava (LZIB; reference capacity=18). The following indicators (impact on peak service rate and performance) provide an indication of the issue in absolute terms.

## 4.4. Impact on peak service rate and performance

The results of the calculated impact on both peak service rate and performance indicators derived from the use of different runway configurations are presented in Figure 6 and Figure 7.

Regarding the impact on the peak service rate, 29 of the analised airports show total capacity symmetry (impact on peak service rate is zero); at 36 airports the impact is less than 1 movement per hour, and 10 more airports have an impact between 1 and 2 movements.
From the remaining 15 airports, the highest impacts are observed at Málaga (LEMG), followed by Nice (LFMN), Oslo (ENGM), Gran Canaria (GCLP), Helsinki (EFHK), Dusseldorf (EDDL) and Bratislava(LZIB).
Most of these airports that show the biggest impact on peak service rate in absolute terms, also had the lowest resilience results. Additionally, when observing the impact on performance for these airports, it is noticeable that three of them, Oslo (ENGM), Málaga (LEMG) and Helsinki (EFHK), also suffer important combined impacts on the performance indicators of above 1 minute per flight.

As explained before, an unexpected change of configuration can worsen performance in the form of higher delays and holdings. In this study two performance indicators related to the management of the arrival and departure flows are analysed separately for the identified runway configurations. Nevertheless, the runway configuration also has a great influence in the taxi-out and approach routes, where it might perfectly be that one configuration is more prone to suffer bottlenecks on the taxiway system or conflicting approaches. In that case, even with equal or similar peak service rates, the performance of two runway configurations might be very different. This is the case for airports like Saarbruecken (EDDR), Porto (LPPR), Budapest (LHBP), Leipzig (EDDP), Vienna (LOWW), Zurich (LSZH) and even Frankfurt (EDDF), all of them with an impact on delays above 1 minute per flight (additional ASMA and taxi-out combined).

The detailed analysis airport by airport (see Annex I: Results summary) shows as well the peak service rates for arrival and departures for each runway configuration, together with the maximum hourly throughput observed in 2019. The results for arrivals and departures also evidence that some configurations are preferential for departure peaks and others for arrival peaks (i.e. Amsterdam)

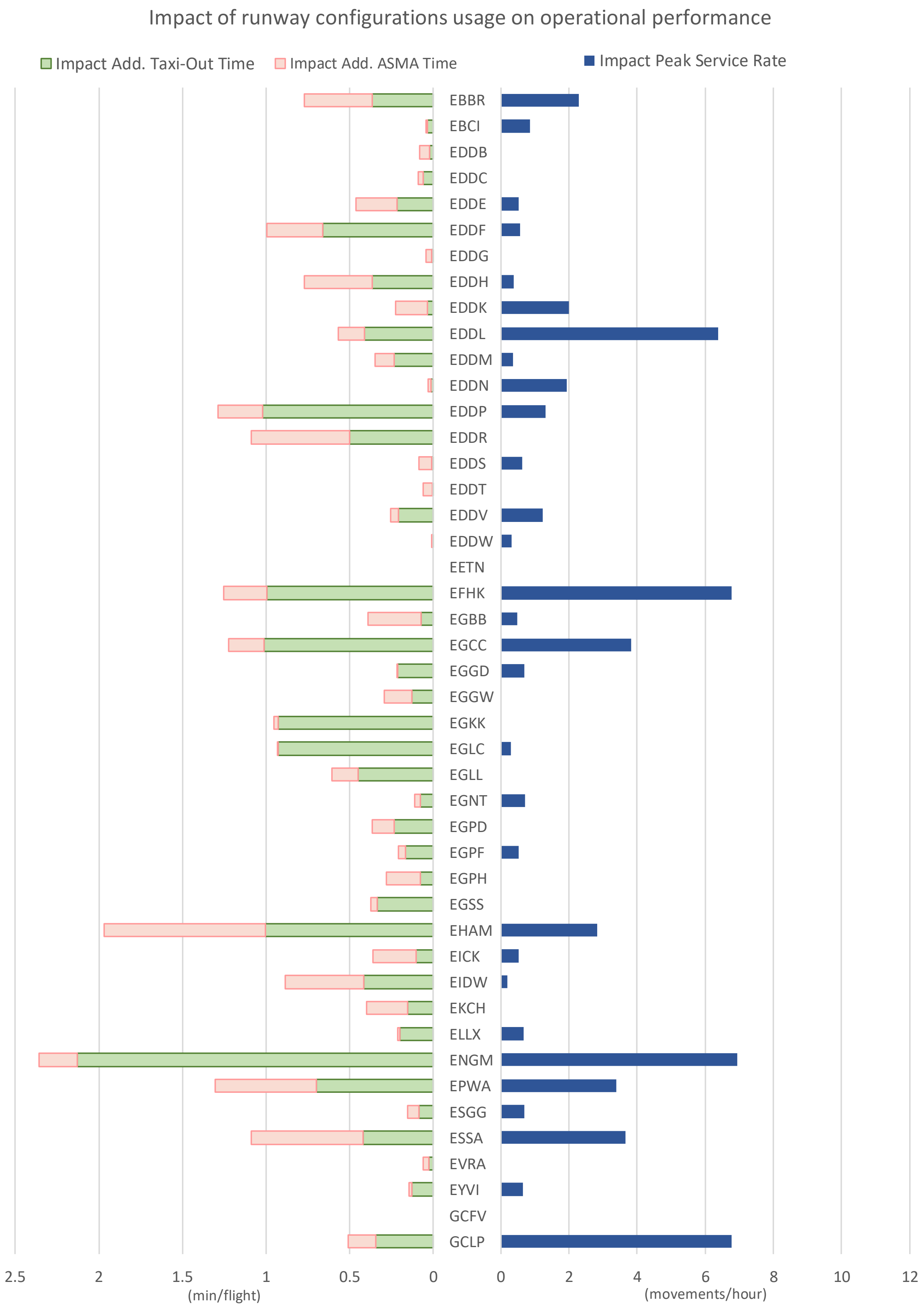


*Figure 6: Runway configurations' impact on peak service rate and performance*

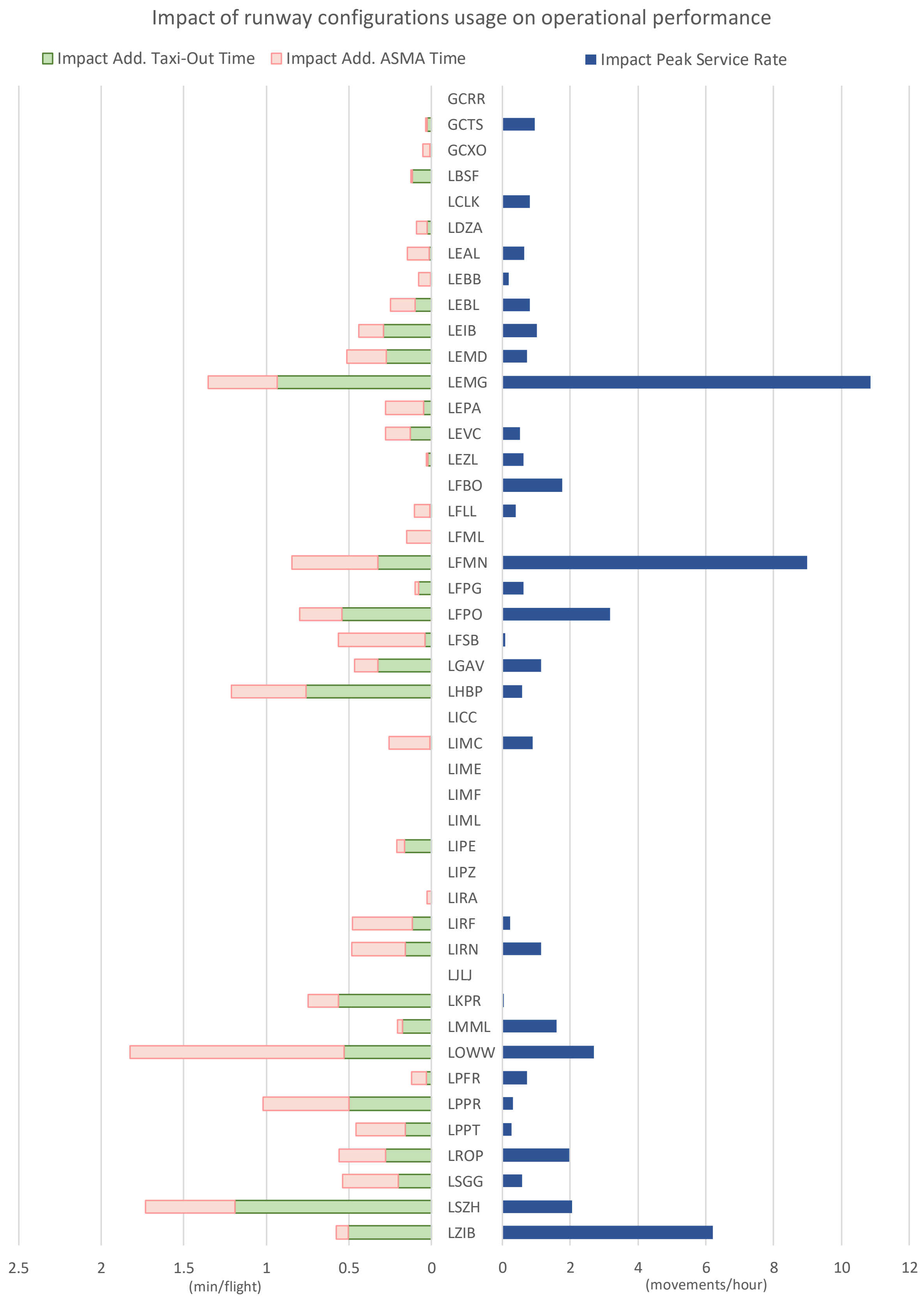


*Figure 7: Runway configurations' impact on peak service rate and performance*

## 5. CONCLUSIONS

This study presents a data-driven analysis of the airport capacity resilience from a conceptual definition to its implementation. It analyses the configurations of 90 European airports, based on one year of data (2019) covering airport movements between 7h and 22h local time, and the risk of capacity reduction associated to the change from one configuration to another, together with the impact in throughput and performance. The main conclusions are summarised as follows:

- The followed data-driven approach provides a common framework for airport configuration determination which ensures that the real airport operation is taken into account rather than the declared one. This allows an easy-to-maintain methodology for the identification of the runway system configuration in use at each airport at each time.
- The comparison of runway configurations obtained via the data-driven methodology described against the one published in the Airport Corner coincides or is very similar for the majority of the airports. That means that the data-driven detected configurations with a minimum 3% probability are in the majority of cases the same as the ones declared by the airports.
- Regarding the identification of the capacity for each runway configuration, the peak service rate is in some cases significantly lower than the declared capacities in the Airport Corner That may be an indication that these airports still have some buffer for traffic increase, while the others, where the peak service rate is close to the declared capacity, may be already operating at their maximum capacity.
- Resilience values are calculated based on the reference capacity (maximum peak service rate of all available configurations at the airport), accounting for real operation aspects of the year of data analysed (2019). This implies that the resilience obtained corresponds to the time period analysed; whenever operation in the airport changes, resilience values will also change to adapt to the new situation. Hence, the airport resilience is a dynamic indicator and its evolution can be monitored.
- The daily time-window covered in the analysed goes between 7h to 22h local time, which ensures curfews (like for noise abatement procedures) are not taken into account in the analysis since they are normally active in the in-between period. However, in some cases specific noise abatement configurations might be activated outside of this time window, with its consequent impact on the resilience calculation, as night configuration imply less staff and normally also less demand in the airport.
- Resilience results are relative to the peak service rate at the airport and suggest there is no drastic decrease in capacity (in relative terms) related to a configuration change at most airports and, whenever there is such a decrease, it happens for a configuration with a very low probability therefore limiting the impact on the resilience value of the airport.
- Most of the 90 airports analysed show very small changes in capacity for the most common runway configurations, as derived from the Impact on peak service rate. There are some of them, though, that show significantly less throughput and higher delays.

- The impact on the additional taxi-out and ASMA times yields very interesting results and evidences at some airports an important imbalance in terms of performance for different runway configurations, highlighting configurations that, beyond a potential capacity issue, have intrinsic bottlenecks in both approach and taxi-out procedures.
- The environmental constrains, the runway closures due to works in progress and many other factors like implementation of new procedures have a clear impact in the identified runway configurations and performance. The high level results are to be completed by the analysis per airport and when important imbalances are detected, further breakdown per month and/or hours of the day can bring additional insight.

In summary, this data driven analysis allows to study the imbalance of the operation associated to the runway configurations use and its impact on performance, helping in the identification of operational constraints at airports. This can significantly contribute to the fine tuning of the process of assessing capacity limits specially delivered by slot coordinators at the congested airports.

# 6. REFERENCES

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## 7. Annex I: Results summary

This annex compiles the results obtained for each of the 90 airports analysed, including the following indicators:

| Annual traffic 2019 | Number of configurations | **Impact Add. Taxi-Out Time (min/dep)** | **Impact Add. ASMA Time (min/arr)** | **Impact PSR[2] (mov/hour)** | **Airport Resilience** |
|---|---|---|---|---|---|

A graph displaying these results <u>for each configuration</u>:

| | |
|---|---|
| Configuration identification with active runways for arrivals (ARR) and departures (DEP) | **ARR:25L - DEP:25R** |
| Probability | 58% |
| Peak Service Rate (P99) Total movements | 57 |
| Maximum Throughput Total movements | 65 |
| Peak Service Rate (P99) Arrivals | 24 |
| Maximum Throughput Arrivals | 31 |
| Peak Service Rate (P99) Departures | 42 |
| Maximum Throughput Departures | 46 |
| Average Additional ASMA time per arrival | |
| Average Additional Taxi-out time per departure | |

The airport layouts are also included for a better understanding of the configurations and identification of potential interdependencies in the use of runways.

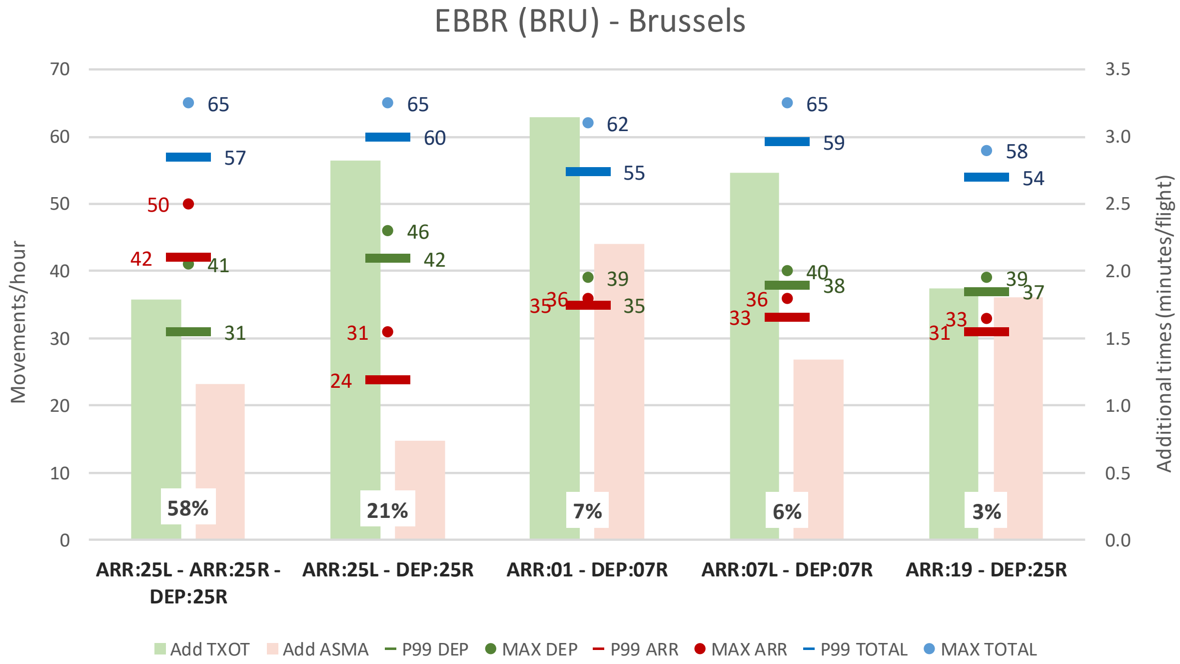
This comprehensive overview allows to evaluate the main operating modes and differences in the resulting performance.

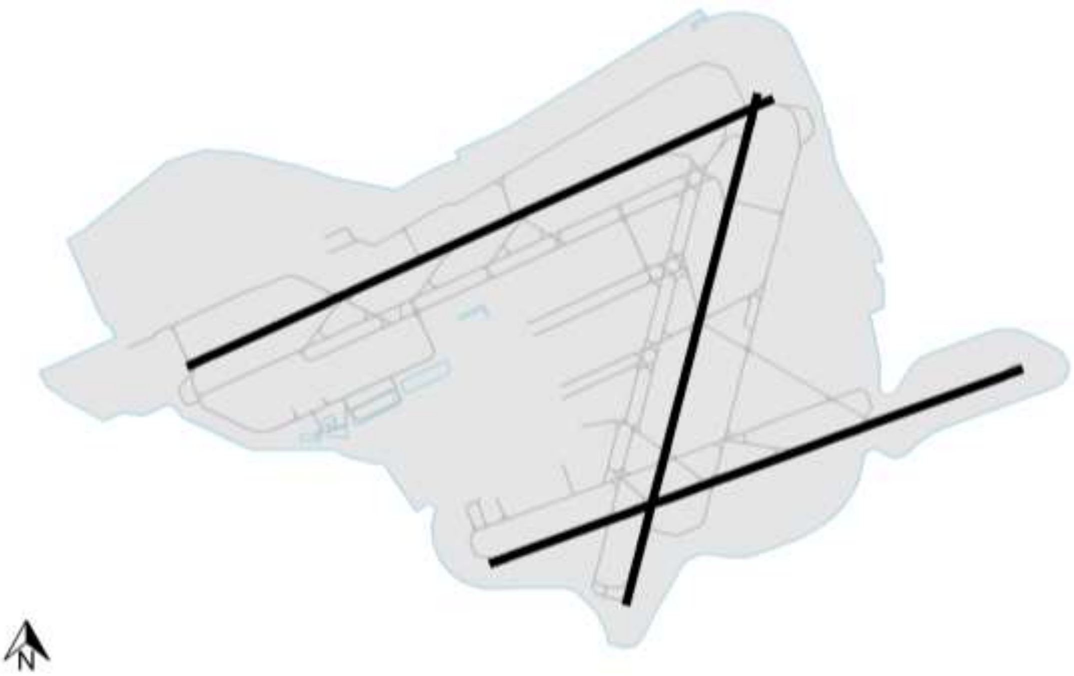
[2] PSR: Peak service rate

## 1. EBBR (BRU) – Brussels

The analysis of the operation during 2019 at Brussels shows 5 representative configurations, 4 of them in segregated mode. The most common configuration does not show the highest peak service rate but it does show the best arrival rate and low additional times compared to the rest. Configuration ARR:01-DEP:07R (7%) causes the highest delays in both ASMA and taxi-out, with a lower peak service rate.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact PSR (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EBBR | Brussels | 229281 | 5 | 0.37 | 0.40 | 2.30 | 97.12% |

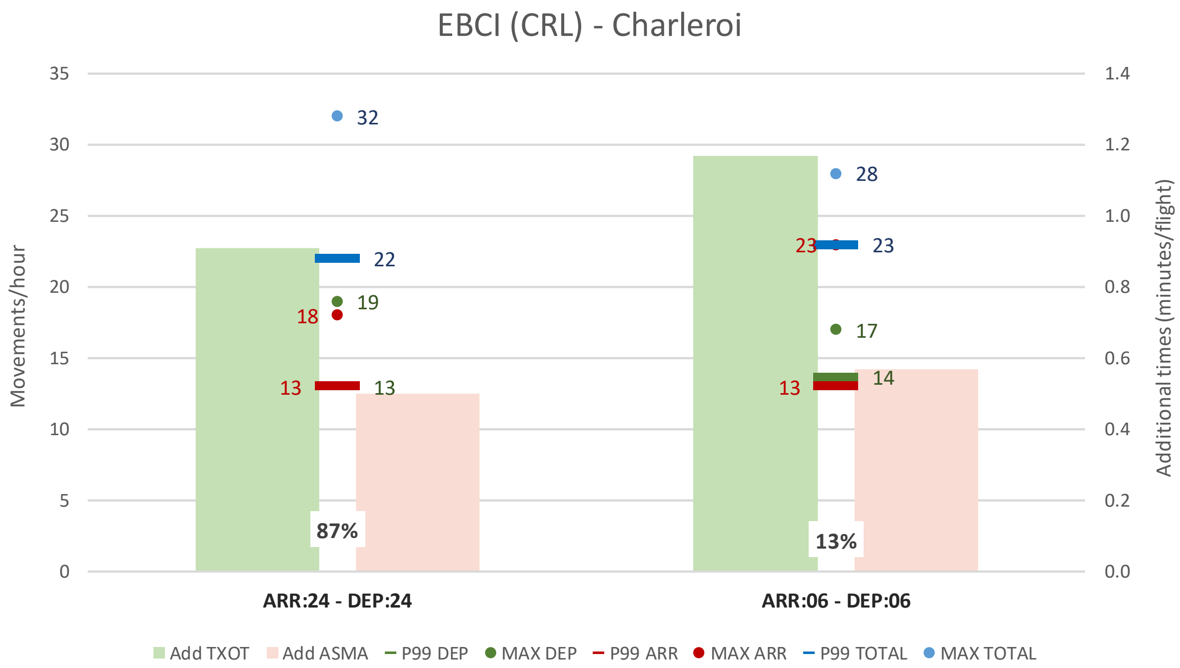


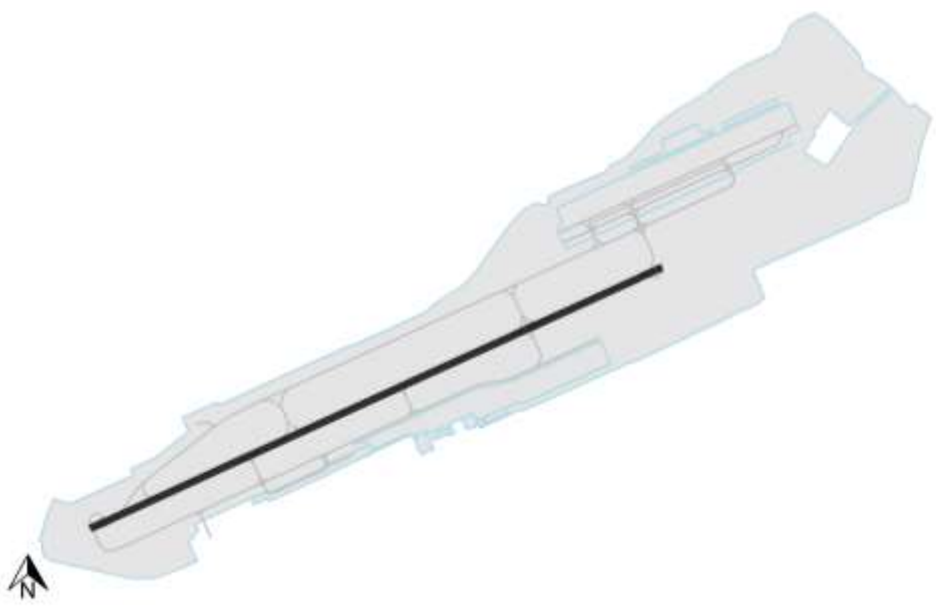



## 2. EBCI (CRL) - Charleroi

Charleroi is a single runway airport with only two possible operating modes and a clear runway direction preference. In general terms the performance in both runway configurations is very similar, and only additional taxi-out when using RWY06 shows an increase compared to when using the preferential runway direction (RWY24).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EBCI | Charleroi | 54763 | 2 | 0.03 | 0.01 | 0.87 | 96.23% |

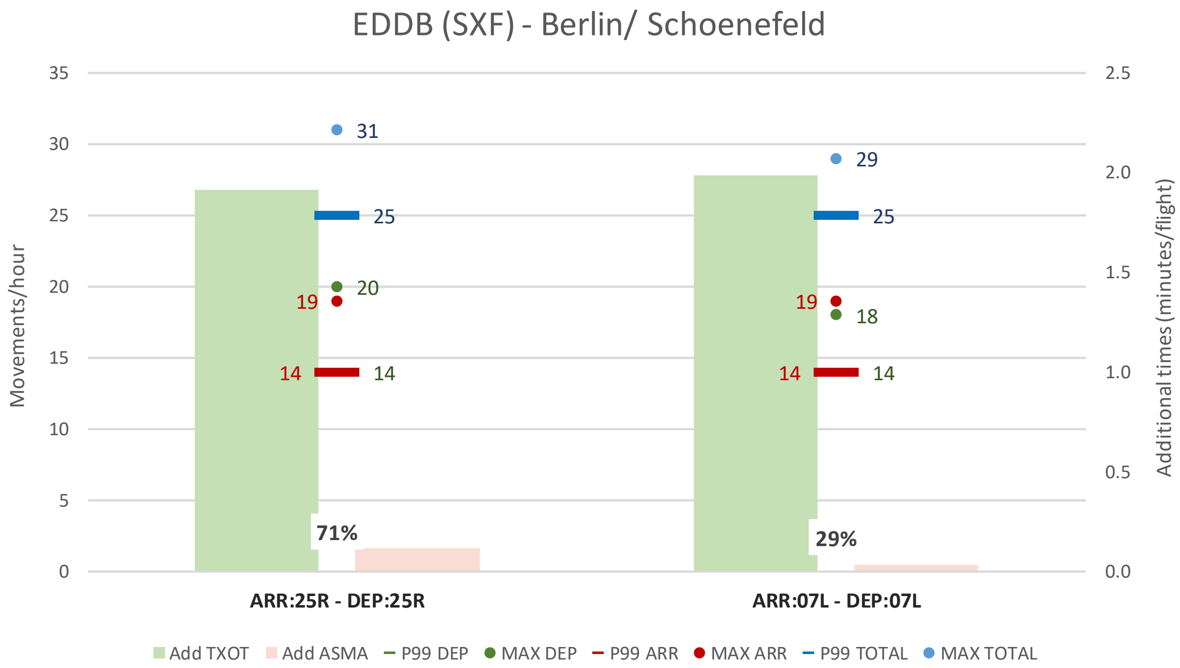


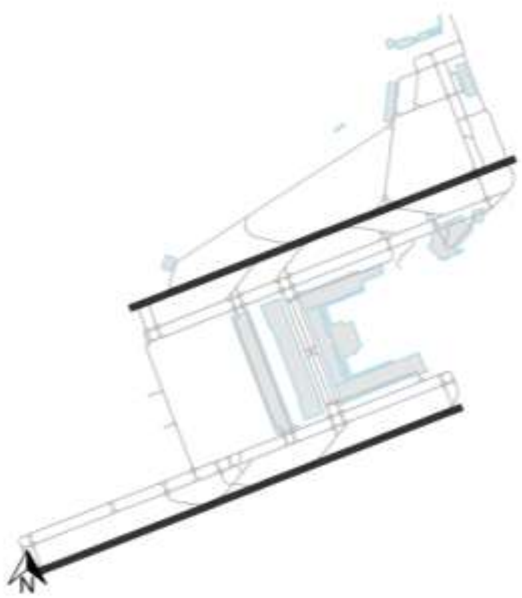



## 3. EDDB (SXF) - Berlin/ Schoenefeld

Berlin Schoenefeld operates only one runway (07L/25R) in both directions mixed mode, with almost identical result in performance.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDB | Berlin/ Schoenefeld | 90231 | 2 | 0.02 | 0.06 | 0.00 | 100.00% |

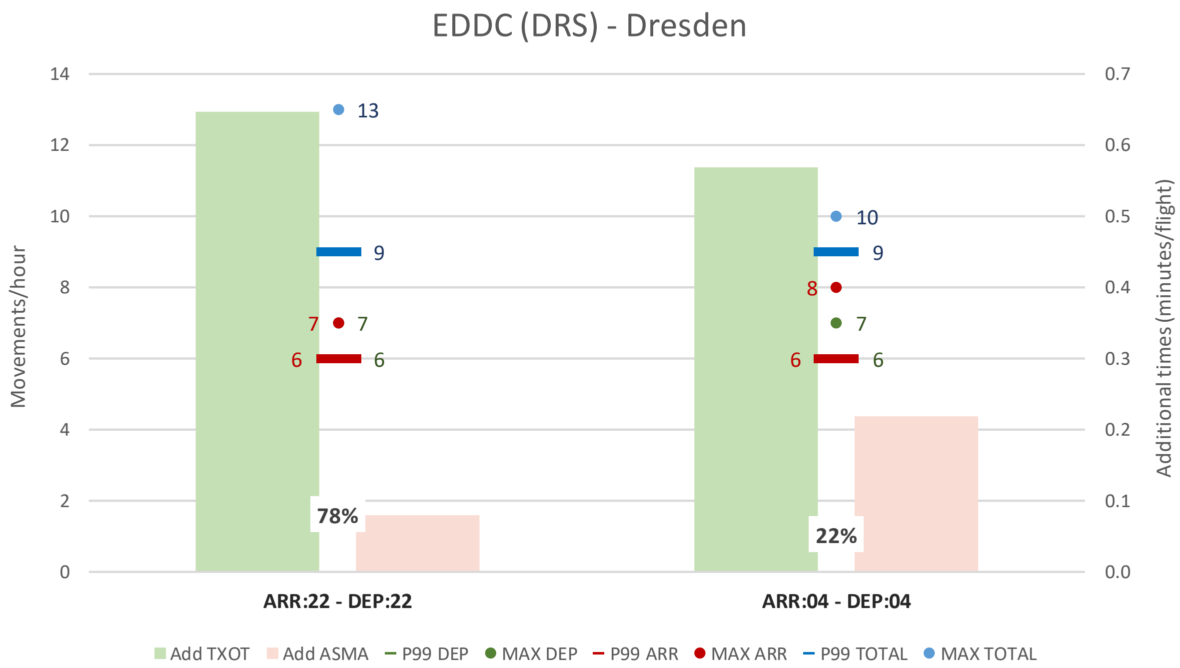


## 4. EDDC (DRS) – Dresden

Dresden is a single runway airport, operated in mixed mode in both directions, being RWY22 the preferential. Performance in terms of peak service rate is identical, and while RWY04 results in longer additional ASMA times, RWY 22 shows higher additional taxi-out times .

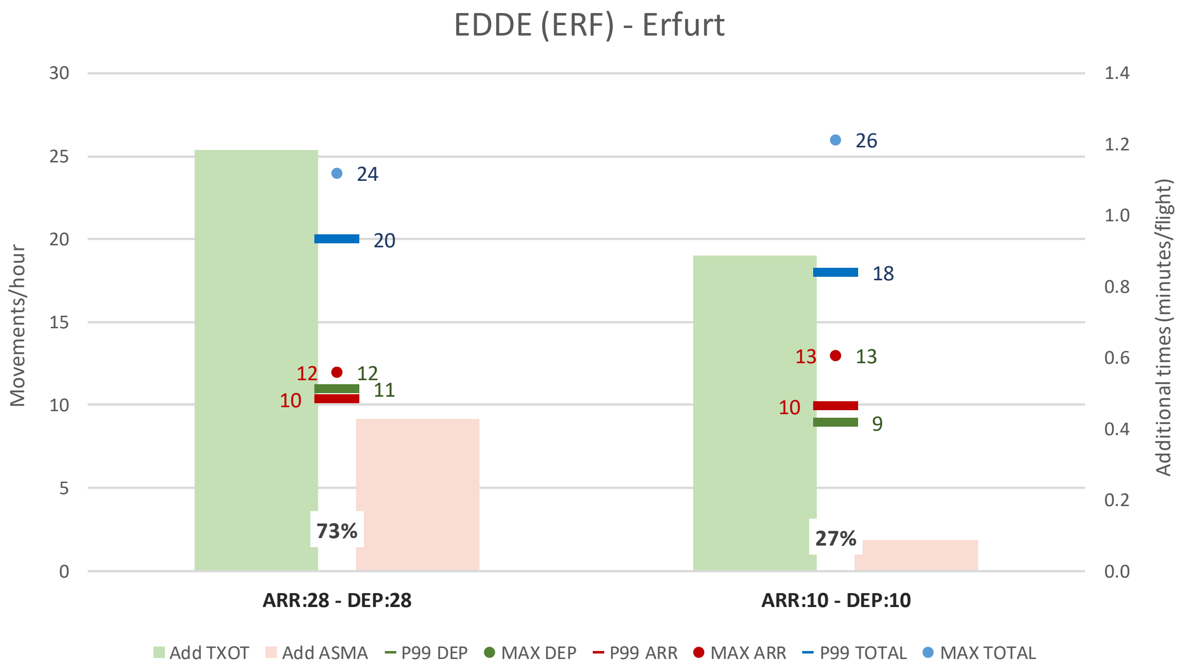
| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDC | Dresden | 20524 | 2 | 0.06 | 0.03 | 0.00 | 100.00% |




## 5. EDDE (ERF) – Erfurt

Erfurt operates one runway in mixed mode in both directions, being RWY28 the preferential. The peak service rate for RWY28 is 2 movements higher than for RWY10, but the maximum throughput is actually higher for RWY10, which leads to think the imbalance in peak service rate is driven by demand and not capacity. In terms of performance, it is interesting to observe how the preferential runway use results in higher additional times.

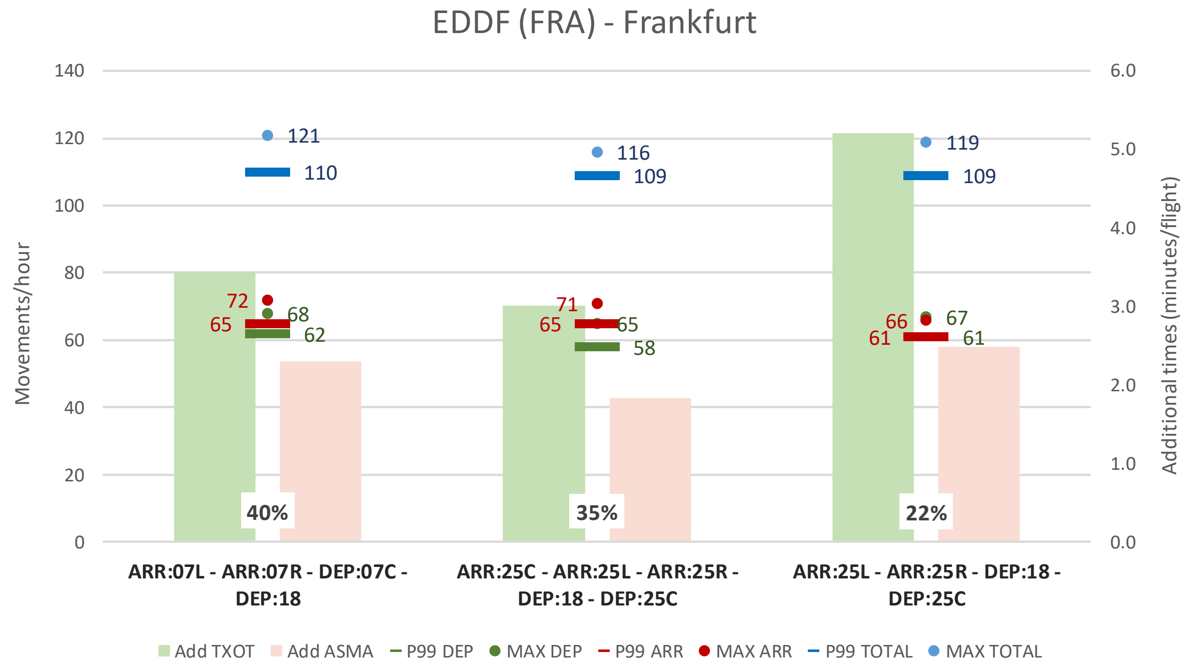
| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDE | Erfurt | 4607 | 2 | 0.22 | 0.25 | 0.53 | 97.33% |

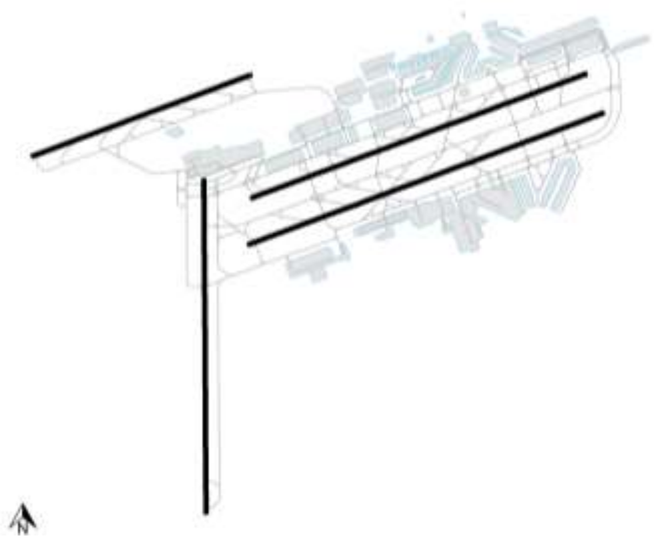



## 6. EDDF (FRA) - Frankfurt

Frankfurt, the busiest airport in Europe, operates 4 runways, 3 of them in both directions and 1 (18/36) only as RWY18. This results is many different configuration possibilities, from which the study identified only 3 as representative, covering 97% of the operation. Out of these 3 configurations, 2 are identical to those declared in the Airport Corner in 2019, and one is very similar. Peak service rate for the three configurations is almost the same, resulting in very high resilience and low impact on the PSR. Regarding performance, configuration ARR:25L;ARR:25R-DEP18;DEP25C, used 22% of the time, shows the considerably worse additional times, especially in the taxi-out phase, with more than 5 min/dep.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDF | Frankfurt | 513866 | 3 | 0.66 | 0.33 | 0.58 | 99.68% |

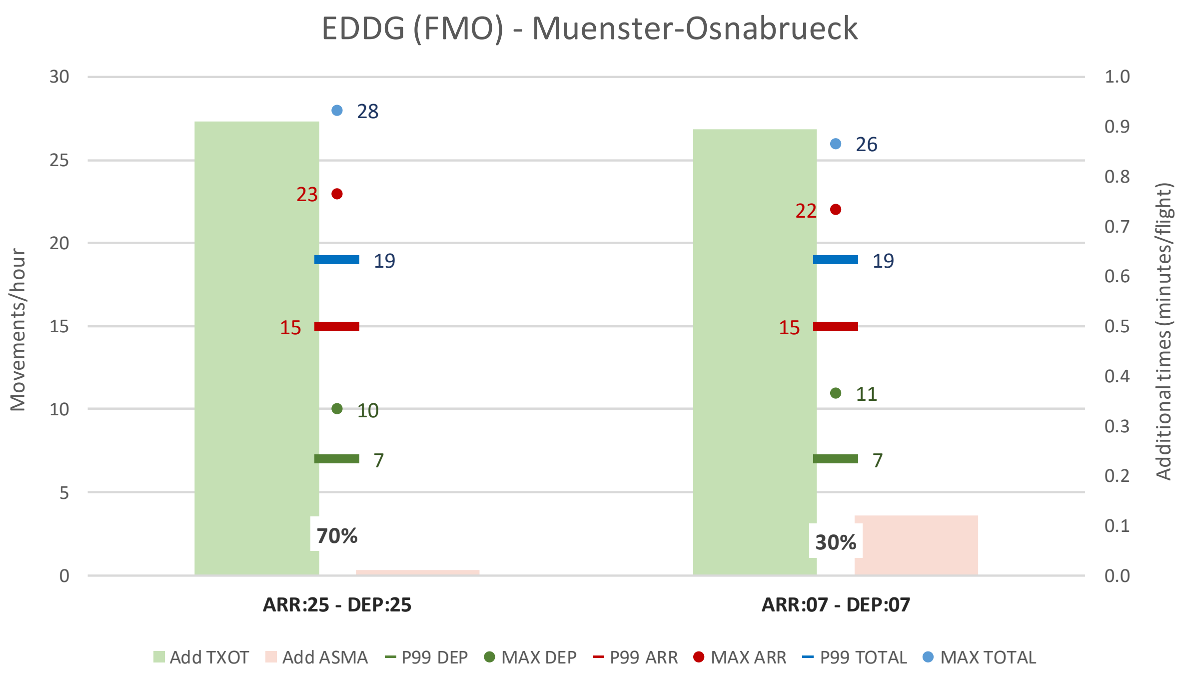


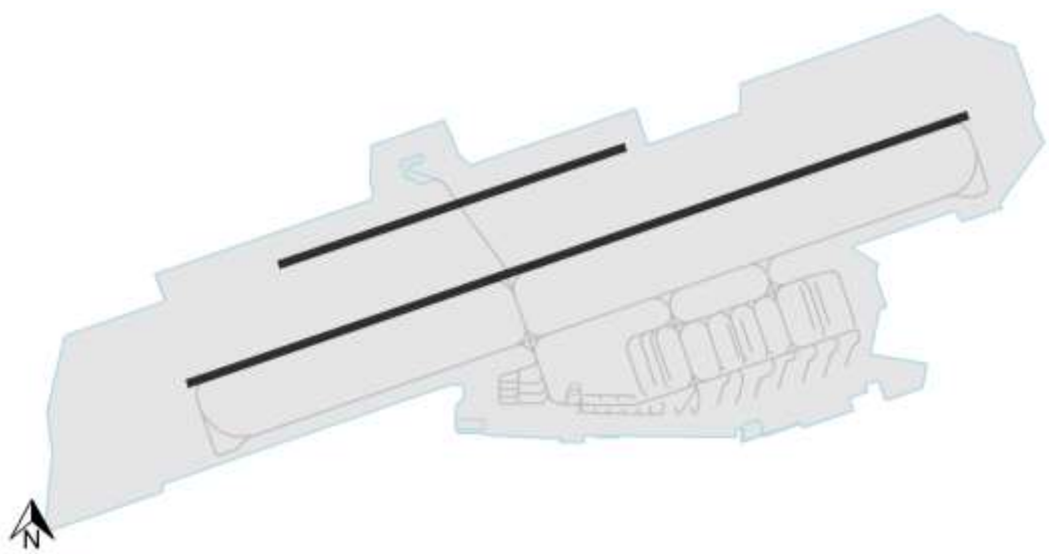



## 7. EDDG (FMO) - Muenster-Osnabrueck

Muenster has one runway (07/25) that can only be operated in mixed mode in both directions. PSR is identical for both configurations and performance is very similar, with a small impact on the additional ASMA time when using RWY07 (30% share). The big dispersion between the maximum observed throughput and the PSR signals the airport might be under utlilised and therefore the PSR would not be a good proxy for capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDG | Muenster-Osnabrueck | 18604 | 2 | 0.01 | 0.03 | 0.00 | 100.00% |

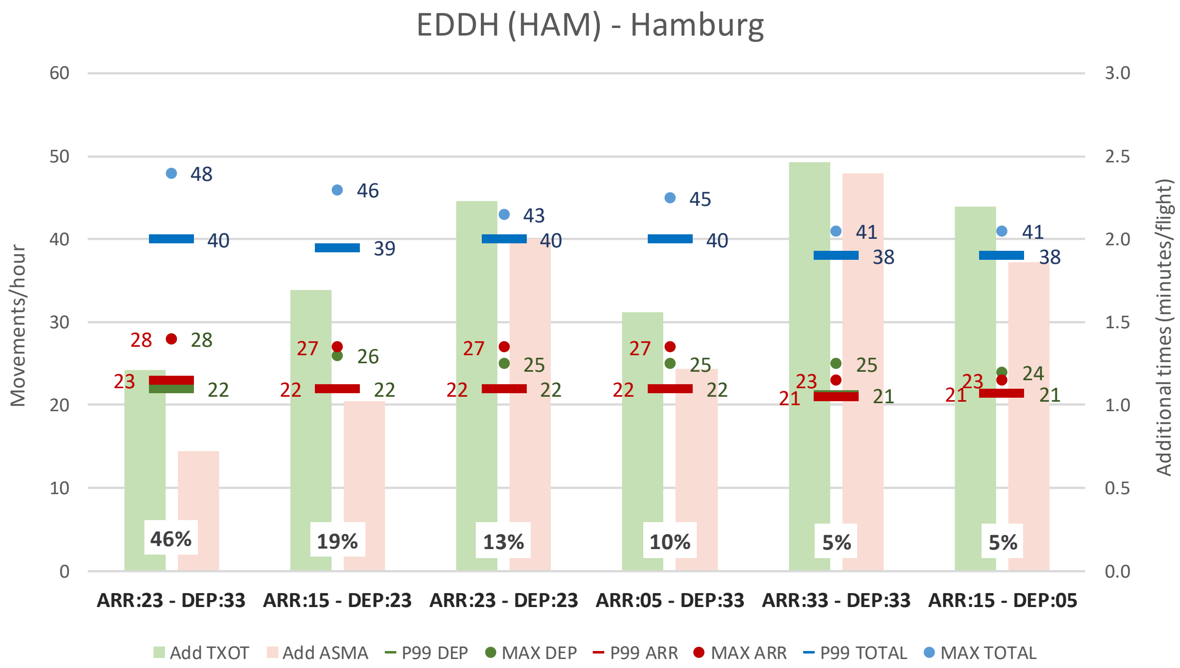


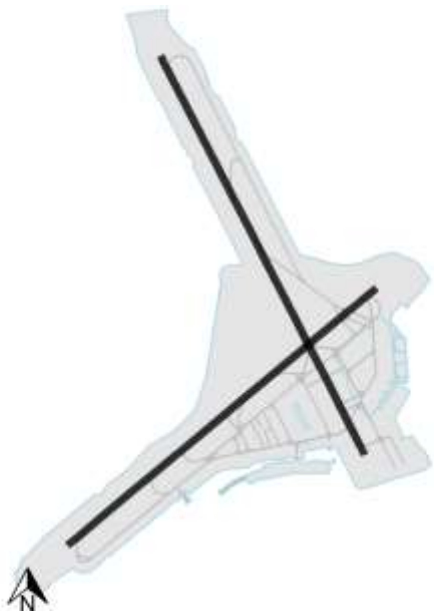



## 8. EDDH (HAM) - Hamburg

Hamburg has 2 crossing runways, resulting in 6 identified runway configurations. The PSR is similar for all configurations (1 or 2 movements difference, so high resilience results), even when using only one of the runways in mixed mode (ARR:23-DEP:23 or ARR ARR:33-DEP:33). However, when single runway configurations show a clear impact on performance, with much higher additional times. The most commonly used configuration offers the best results in performance and throughput.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDH | Hamburg | 149221 | 6 | 0.36 | 0.41 | 0.39 | 99.52% |

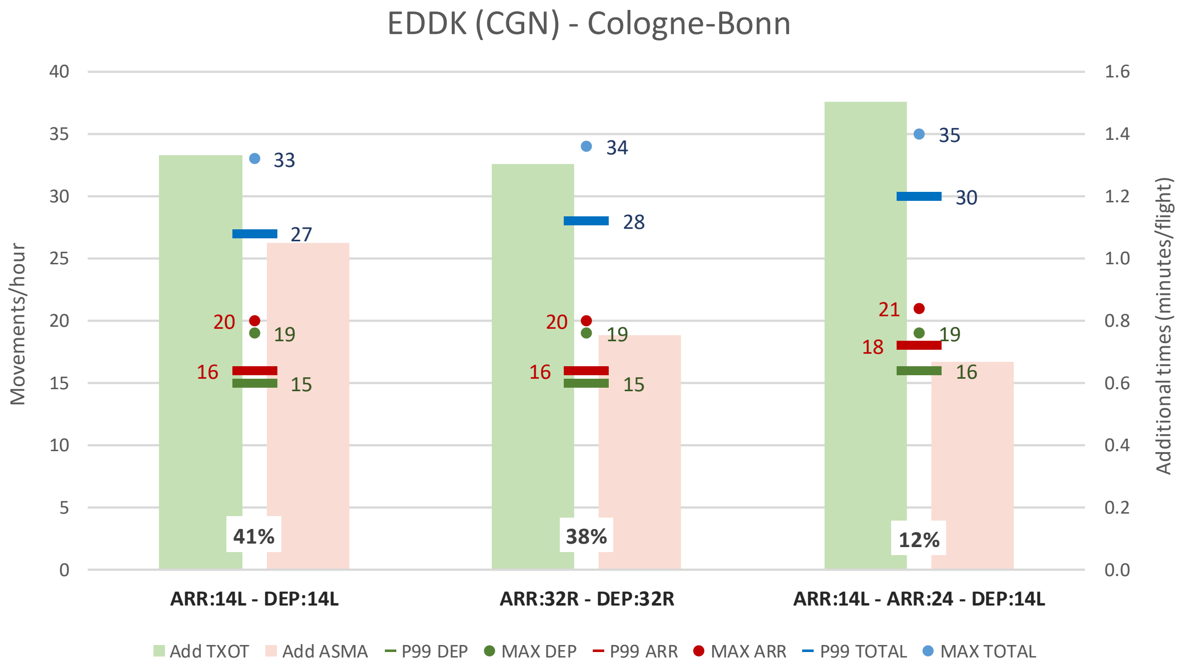


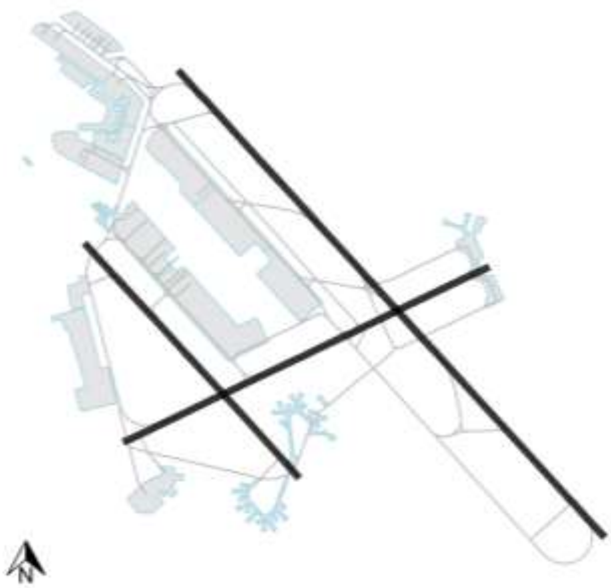



## 9. EDDK (CGN) - Cologne-Bonn

Köln has 3 runways, but for almost 80% of the time, the airport operates only one (14L/32R) in single runway mixed mode, as the other 2 runways are much shorter and might not offer the same navigational aids. The maximum throughput and PSR is reached though, when using also RWY 24 for arrivals in addition to 14L in mixed mode. In terms of performance, there is an imbalance in the additional times between configurations, and different impact depending on the indicator.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDK | Cologne-Bonn | 140929 | 3 | 0.03 | 0.19 | 2.00 | 95.90% |

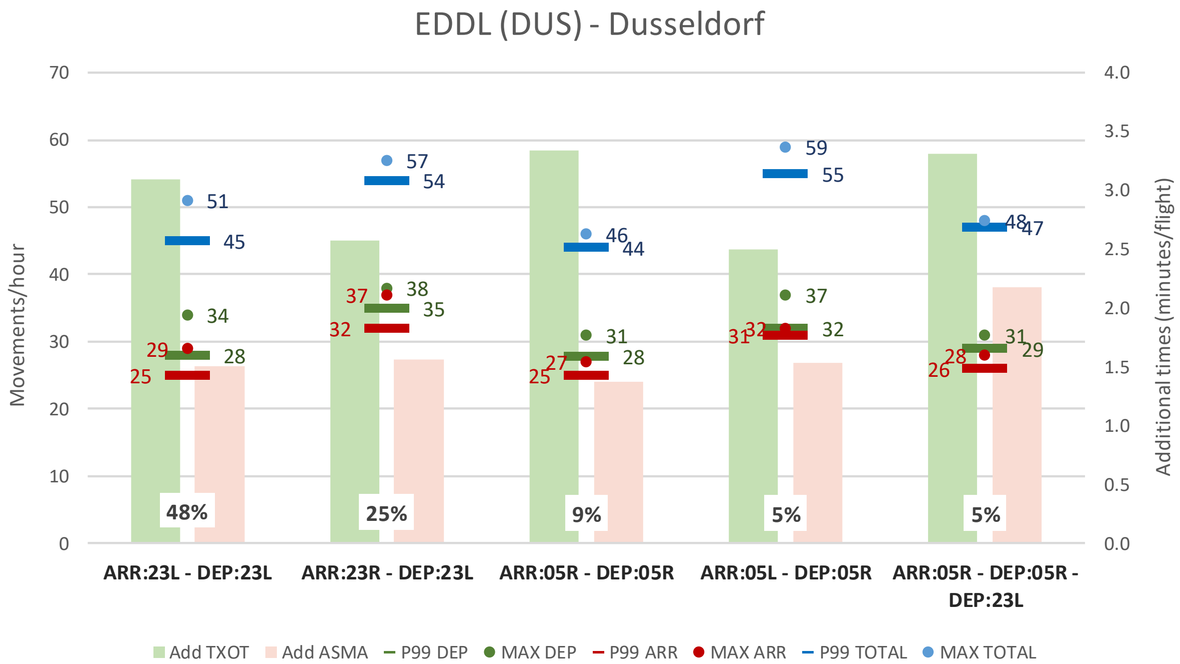


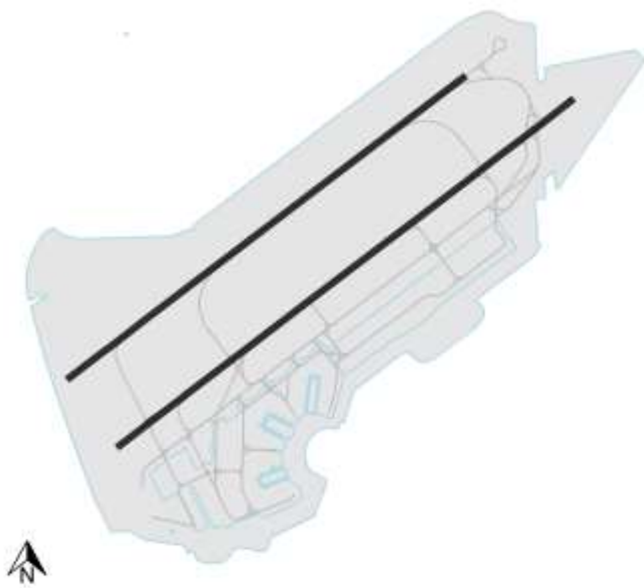



## 10.EDDL (DUS) - Dusseldorf

Dusseldorf has two parallel runways that are sometimes used in segregated mode around 30 % of the time. However 57% of the operation is handled in a single runway mixed mode, that results in much lower PSR and maximum throughput, and also less efficient taxi-out times. Operation of both RWY simultaneously is restricted to 56 hours per week due to court judgment, which results in a resilience that is consequently lower that at other airports, and also a higher impact on the additional taxi-out times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDL | Dusseldorf | 225541 | 5 | 0.41 | 0.15 | 6.37 | 91.30% |

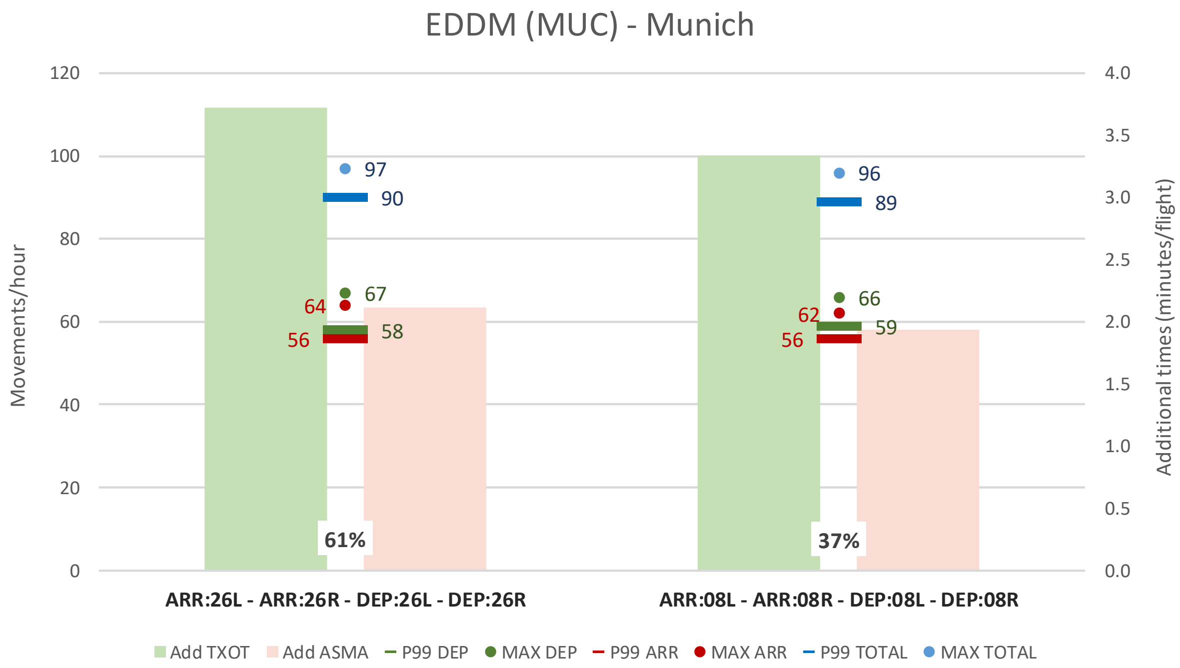


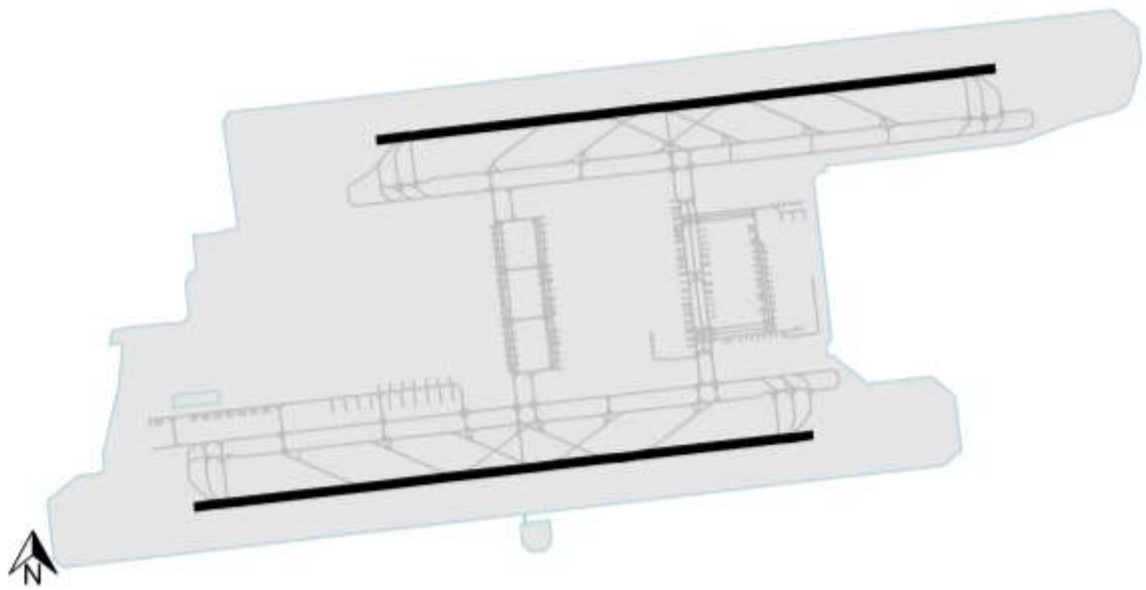



## 11.EDDM (MUC) - Munich

Munich offers a perfect symmetrical layout with 2 parallel independent runways, both of them used in mixed mode, with RWYs 26L/R used 61% of the time. The symmetry also applies to the results in terms of PSR and maximum throughputs leading to high resilience. The observed performance, although similar, is slightly better when using RWYs 08L/R

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDM | Munich | 414222 | 2 | 0.23 | 0.11 | 0.37 | 99.59% |

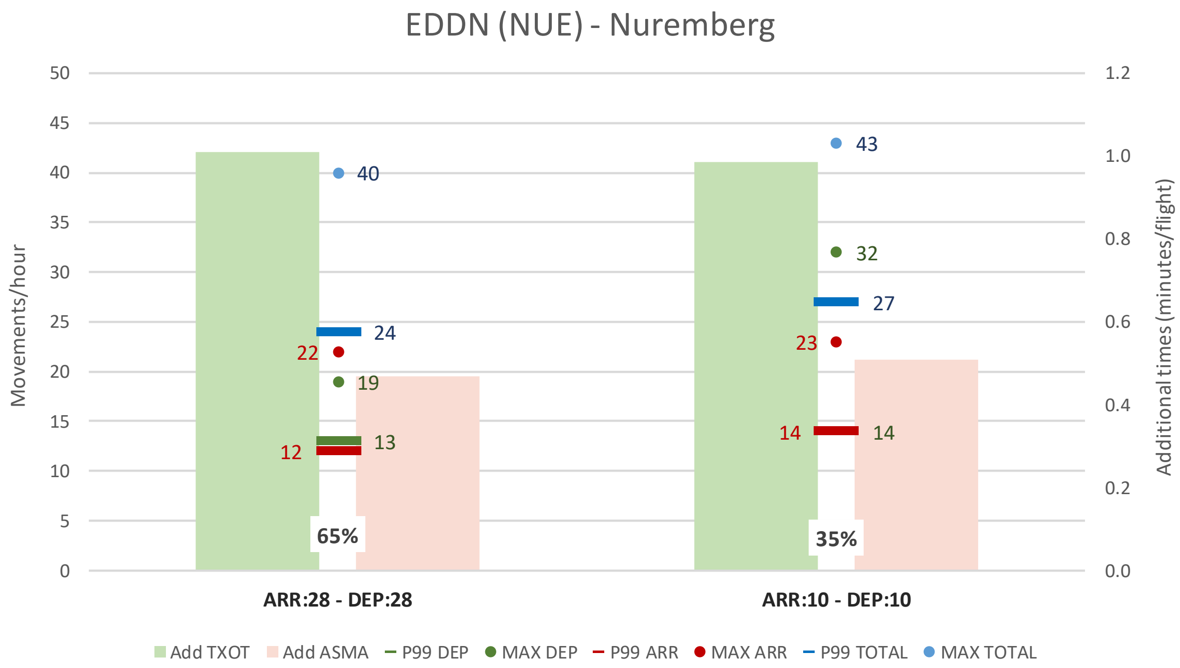


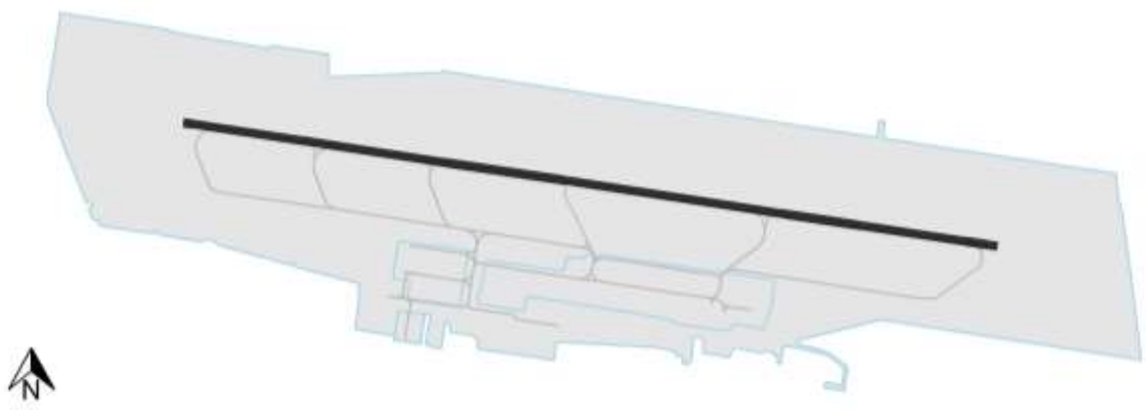



## 12. EDDN (NUE) - Nuremberg

Nuremberg is a single runway airport, used in mixed mode on both directions and with a big dispersion between the maximum observed throughput and the PSR, which signals the airport might be under utlilised and therefore the PSR not be a good indication for capacity. In terms of performance, there are almost no differences between runway configurations.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDN | Nuremberg | 49207 | 2 | 0.02 | 0.01 | 1.94 | 92.80% |

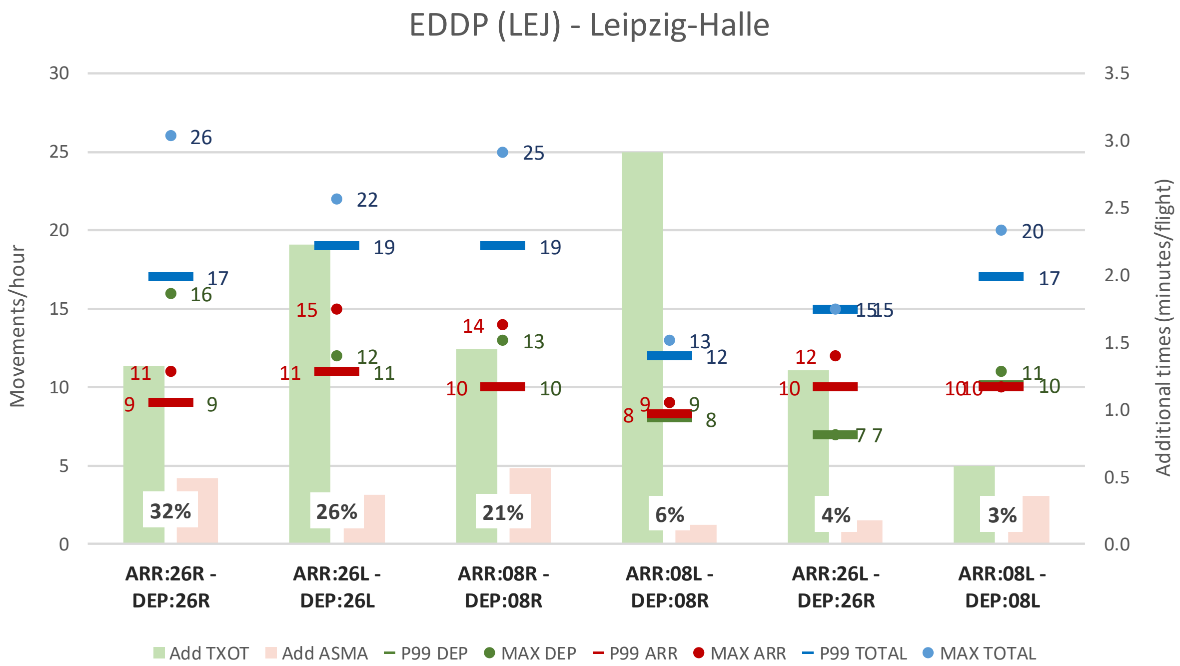


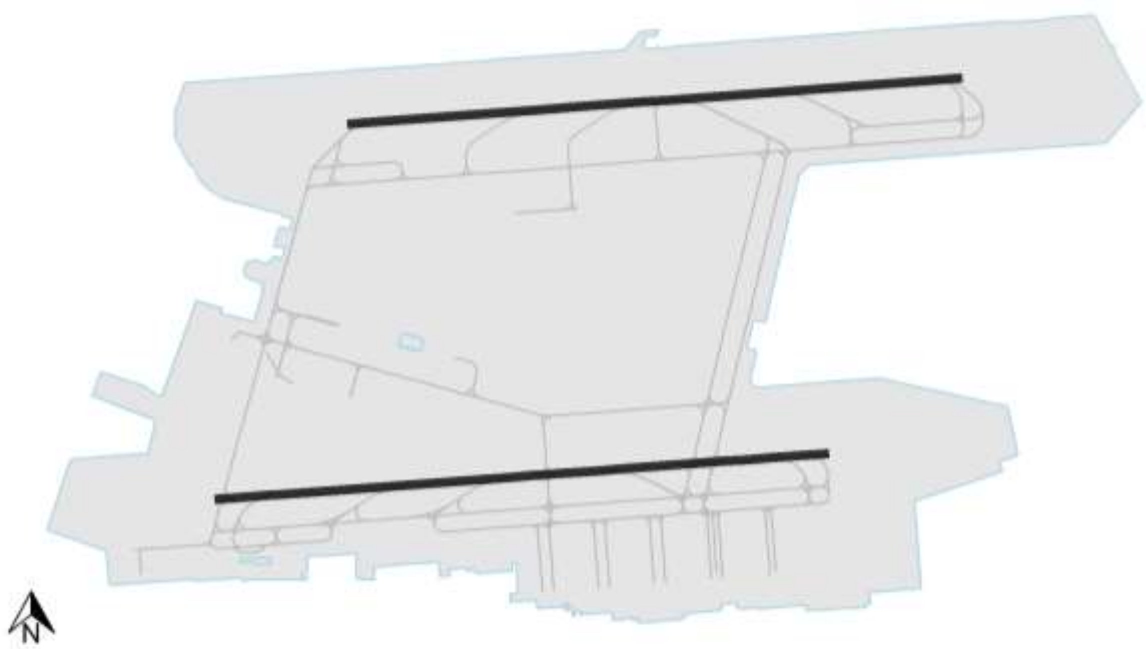



## 13.EDDP (LEJ) - Leipzig-Halle

Leipzig is has 2 parallel runways and not that many movements for that infrastructure. The analysis indicates that for 82% of the time, the airport is operated in a single runway mixed mode, and only 10% in segregated mode. In fact, significant lower throughput is observed for the segregated modes and also significant worse additional taxi-out times for conf. ARR:08L-DEP:08R.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDP | Leipzig-Halle | 75413 | 6 | 1.02 | 0.27 | 1.31 | 96.68% |

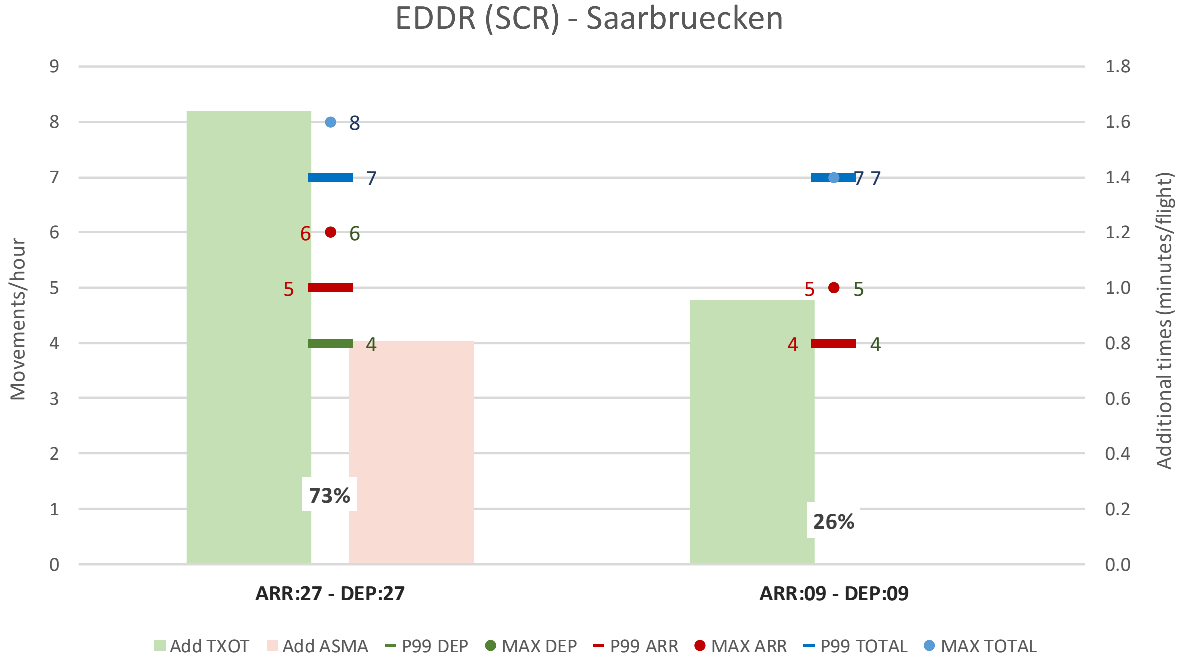


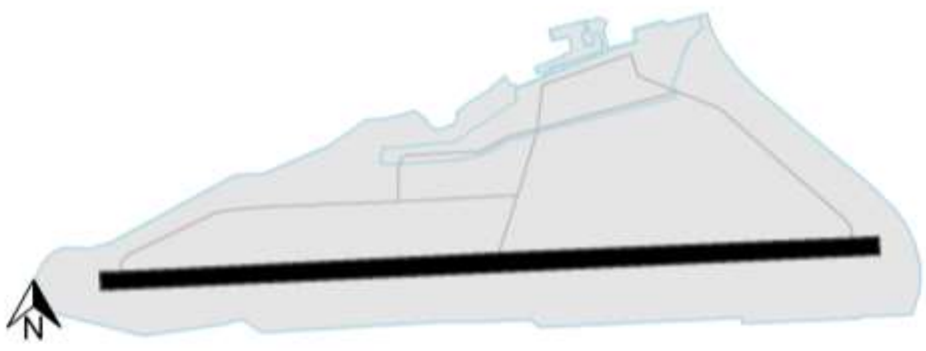



## 14.EDDR (SCR) - Saarbruecken

Saarbruecken is a single runway airport, operated in mixed mode in both directions, being RWY27 the preferential. Performance in terms of peak service rate is identical, but the performance for the preferential runways in terms of additional times is considerably worse, resulting in a high impact on both additional taxi-out and ASMA times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDR | Saarbruecken | 7978 | 2 | 0.50 | 0.59 | 0.00 | 100.00% |

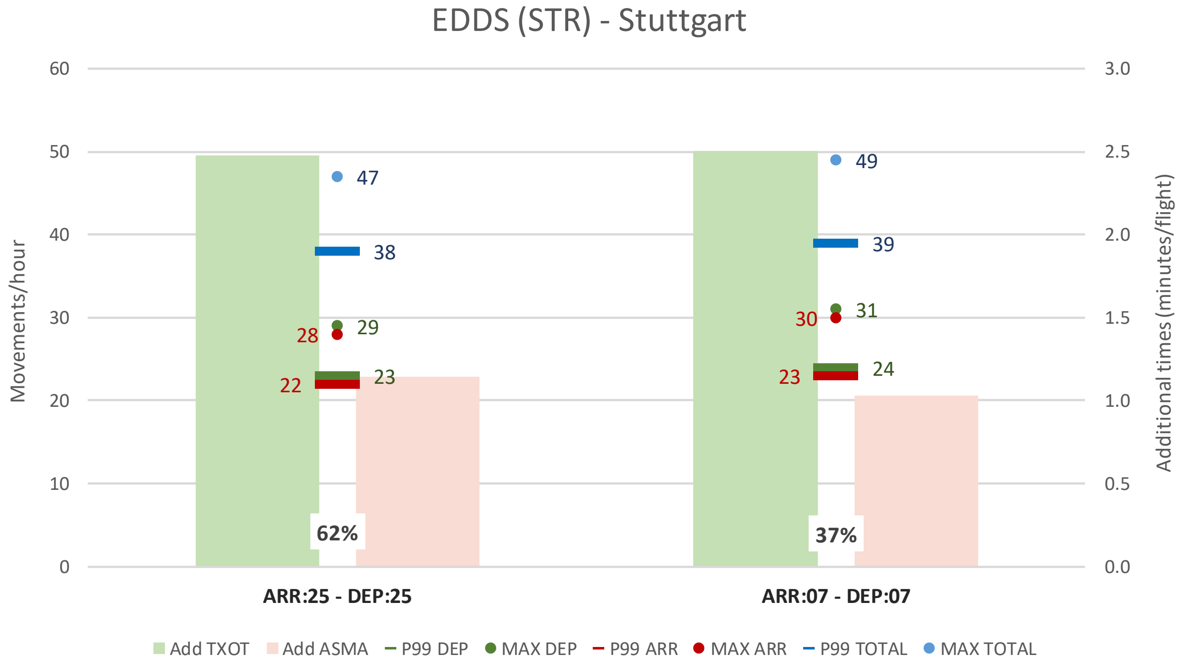


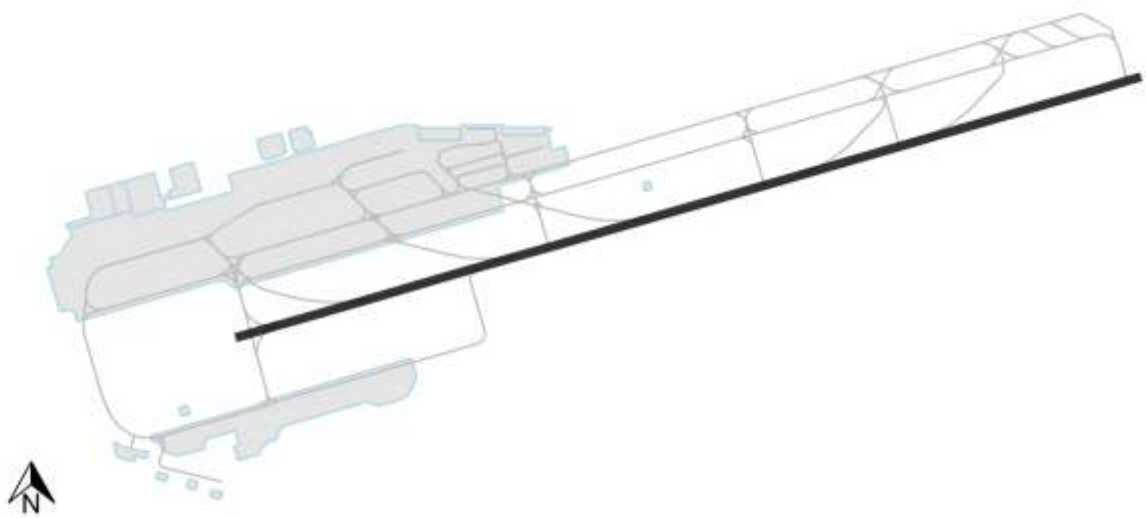



## 15.EDDS (STR) - Stuttgart

Stuttgart operates only one runway (07/25) in both directions mixed mode, with almost identical result in performance. There is however a significant difference between the PSR and the maximum throughput, which questions the validity of PSR as indication for capacity

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDS | Stuttgart | 132609 | 2 | 0.01 | 0.07 | 0.62 | 98.40% |

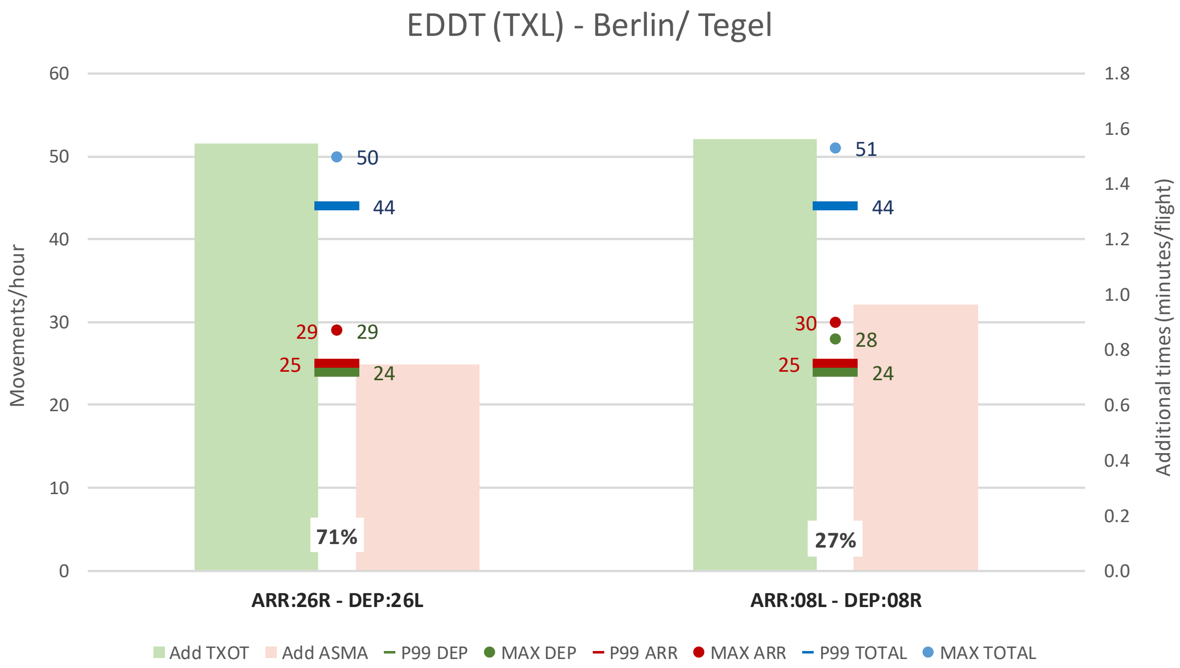


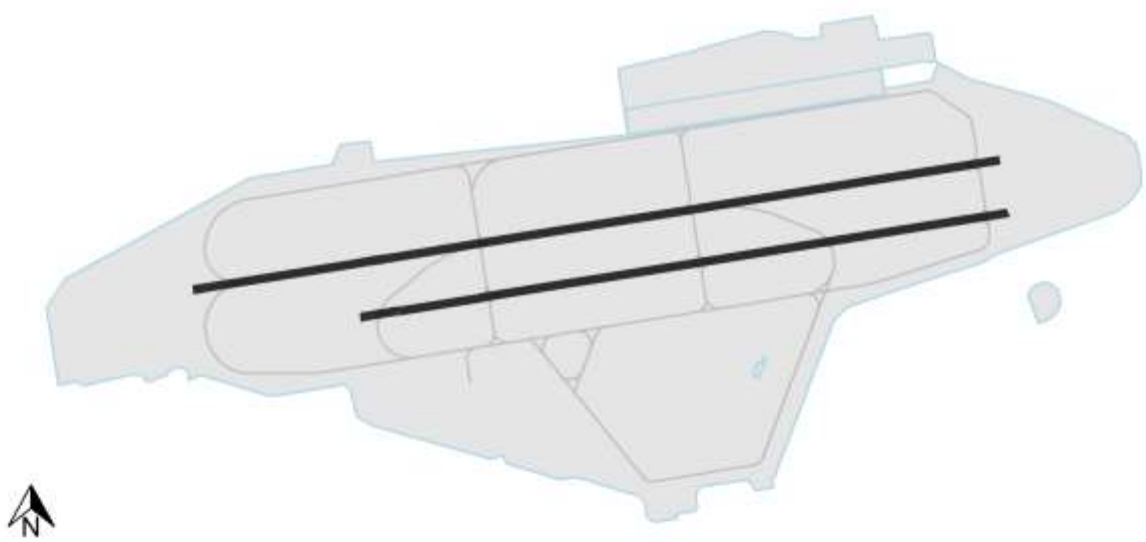



## 16.EDDT (TXL) - Berlin/ Tegel

Berlin Tegel has two parallel dependent runways operated in segregated mode, with very similar results in terms of throughput and performance. The only impact is observed in the additional ASMA times, higher for conf. ARR:08L-DEP:08R.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDT | Berlin/ Tegel | 191779 | 2 | 0.00 | 0.06 | 0.00 | 100.00% |

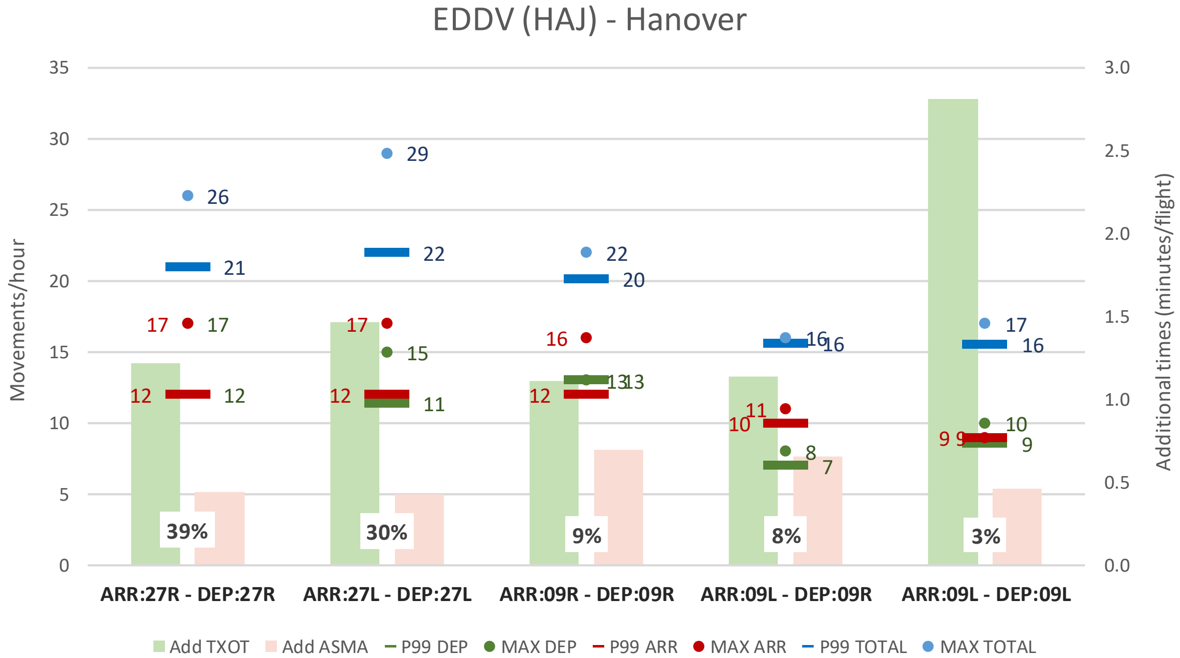


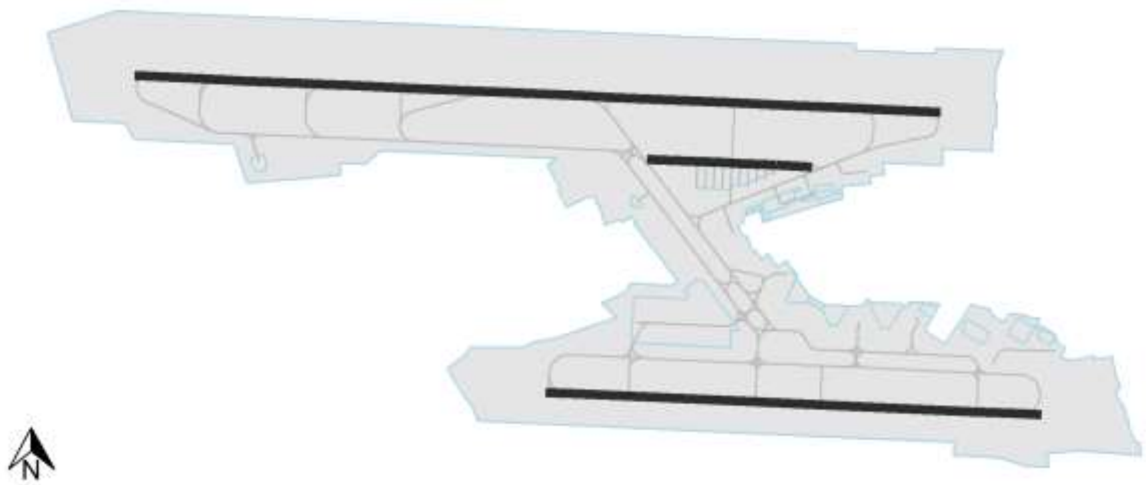



## 17.EDDV (HAJ) - Hanover

Like Leipzig (EDDP), Hanover airport has not that many movements and despite having two parallel runways, normally only one runway in mixed mode is operated (81% of the time). PSR shows only 1 or 2 movements difference for the most common configurations, and in fact it is lowest for the segregated conf ARR:09L-DEP:09R (8% share). There is some imbalance in performance, especially concerning the additional taxi-out times when using RWY 09L.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDV | Hanover | 64581 | 5 | 0.21 | 0.05 | 1.24 | 97.82% |

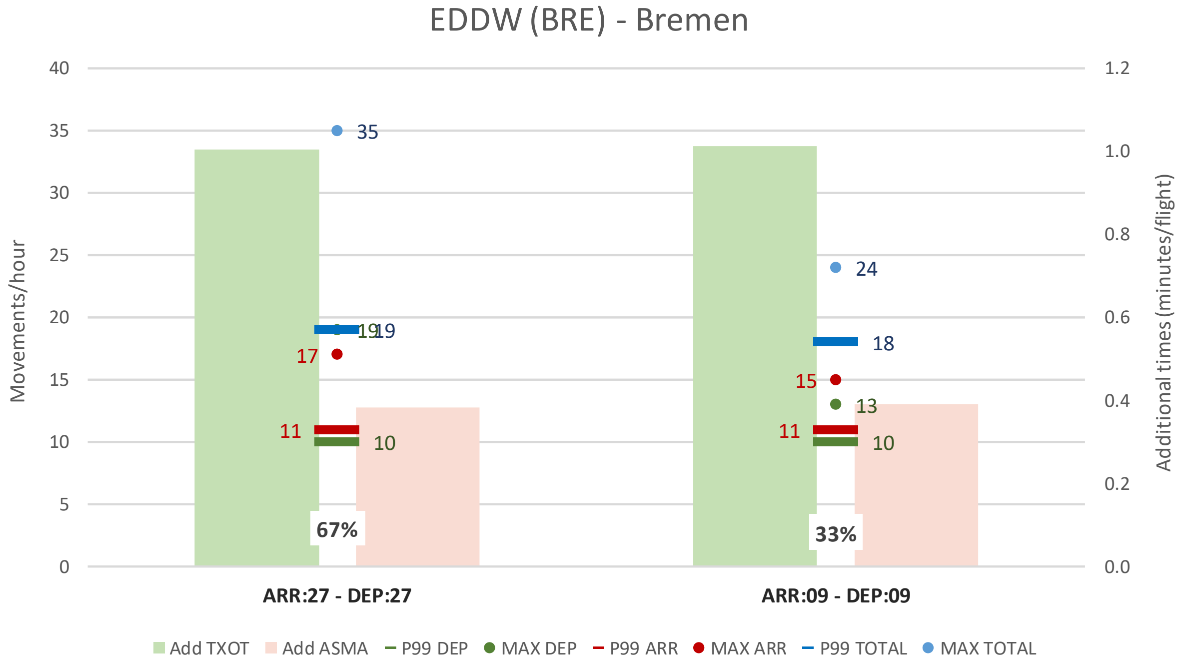


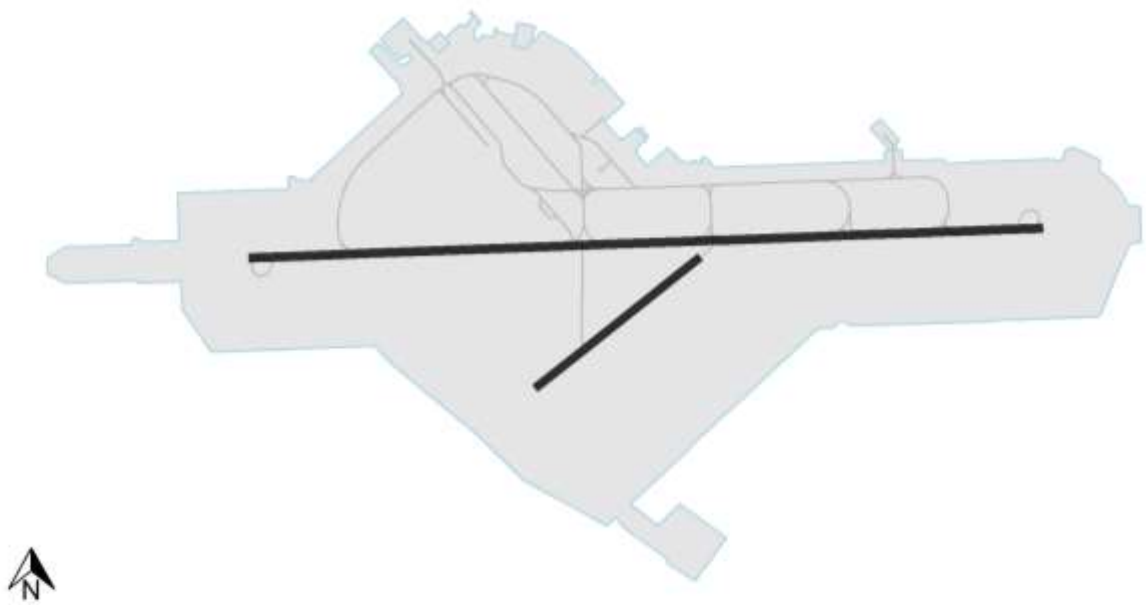



## 18. EDDW (BRE) - Bremen

Bremen operates only one runway (09/27) in both directions mixed mode, with identical result in performance. In terms of PSR the impact is very low (only 1 movement difference) but the big difference between the maximum observed throughput and the PSR signals the airport might be under utlilised which makes the PSR not a good proxy for capacity

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EDDW | Bremen | 29375 | 2 | 0.00 | 0.00 | 0.33 | 98.27% |

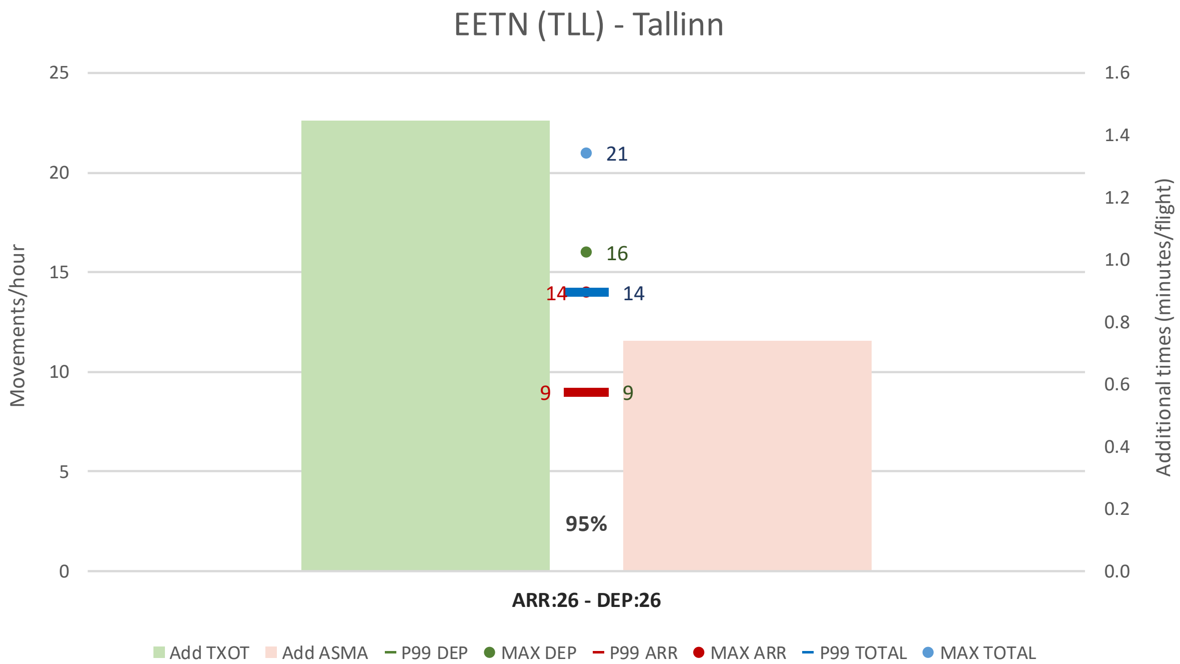


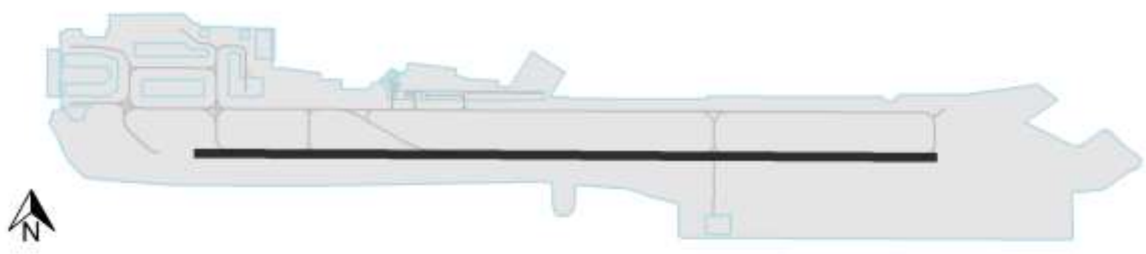



## 19.EETN (TLL) - Tallinn

Tallinn is a one runway airport with a layout that clearly favours one runway direction utilization. In fact, RWY26 is used (in mixed mode) 95% of the time in 2019. The other runway configuration is not used more than 3% of the time (with some time intervals being the transition between configurations or missing runway information) so it is not considerd representative and there is no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EETN | Tallinn | 43904 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

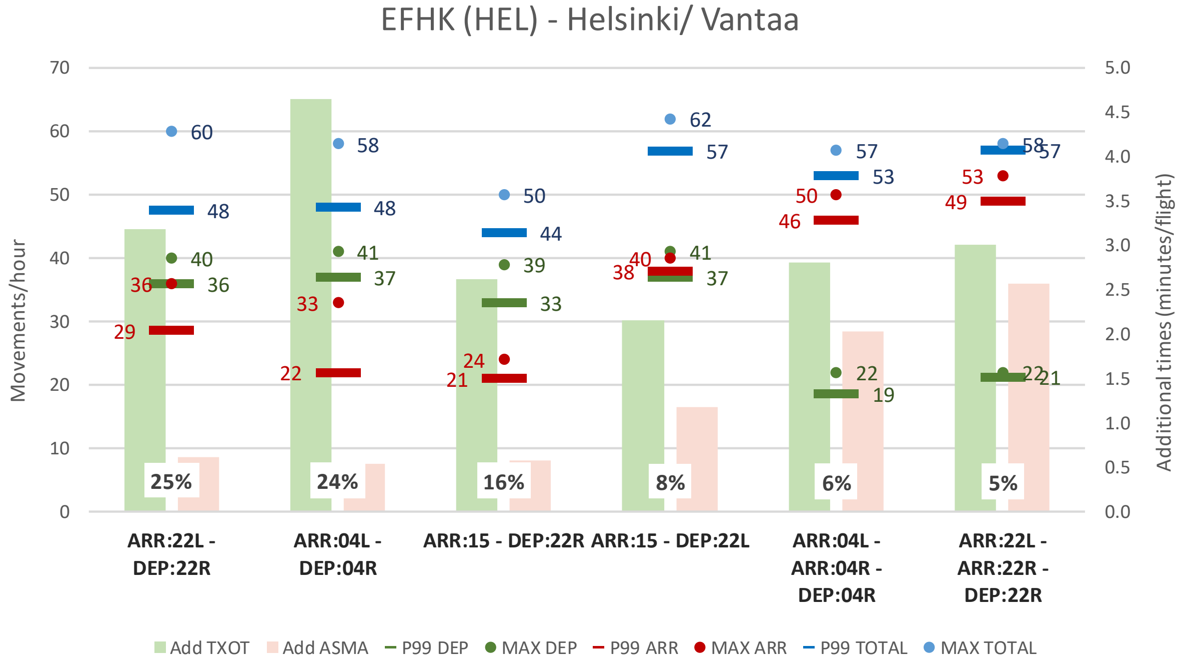


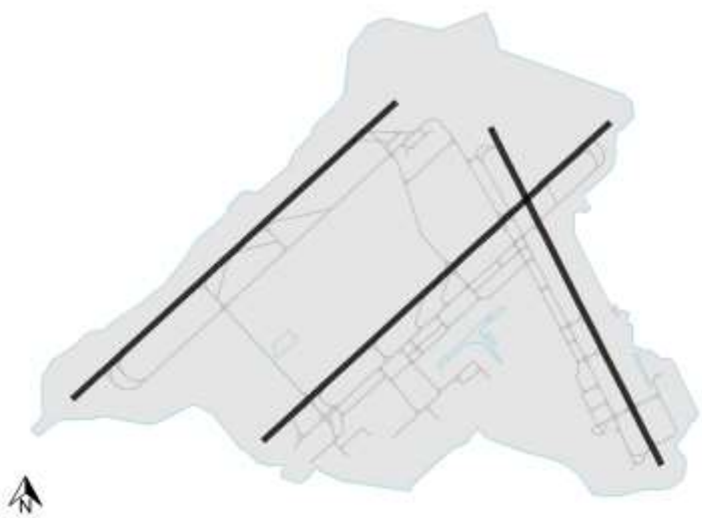



## 20. EFHK (HEL) - Helsinki/ Vantaa

Helsinki, with 3 runways (2 parallel plus one crossing) is operated in 6 representative configurations, mostly in segregated mode. The results show significant differences in both throughput and performance, where some configurations are clearly indicated for departure peaks and others for arrival peaks. The 3 most common configurations are used in the departure peaks and result in lower total throughput, higher additional taxi-out times and lower additional ASMA times. The two configurations for the arrival peaks allow for higher total throughput but naturally increased additional ASMA times. The most efficient configuration seems to be ARR:15-DEP22L (even if those are crossing runways), when the number of departures and arrivals is balanced, but it is in use only 8% of the time.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EFHK | Helsinki/ Vantaa | 194634 | 6 | 1.00 | 0.26 | 6.77 | 95.84% |

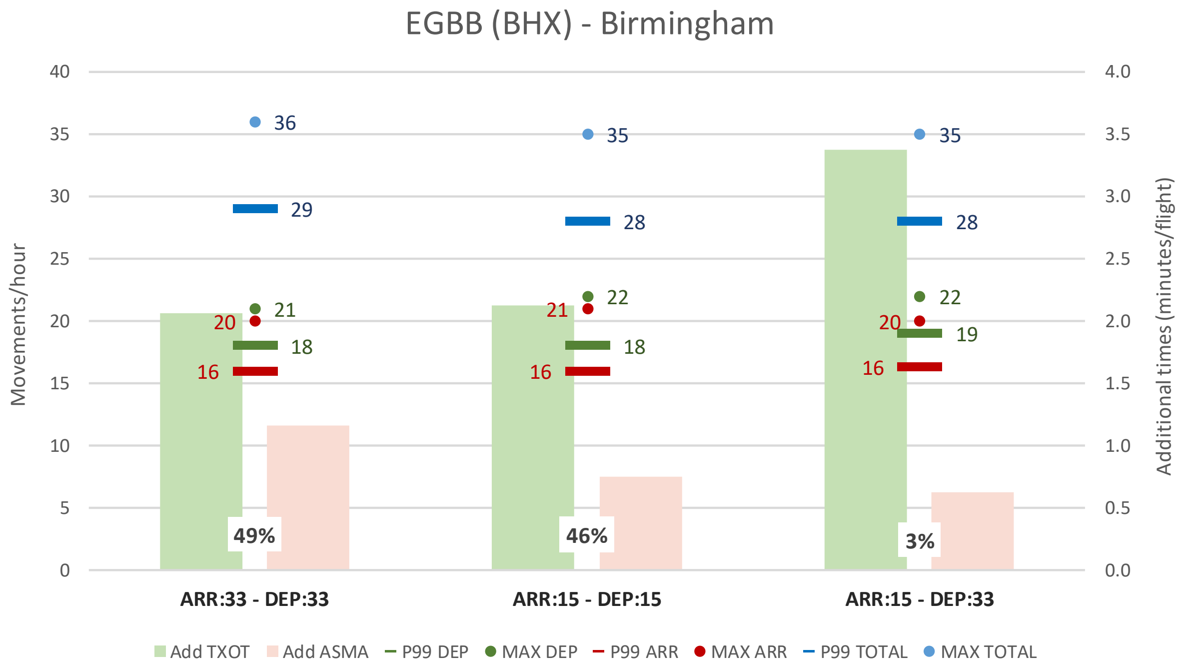


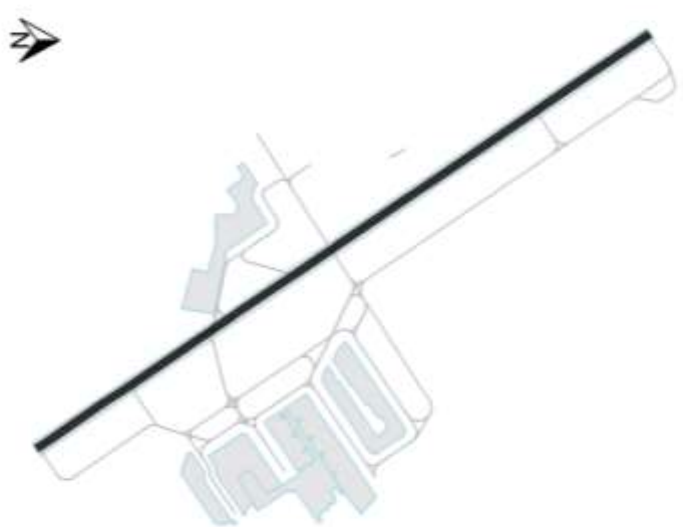



## 21.EGBB (BHX) - Birmingham

Birmingham only has one runway, that can be operated in both directions in mixed mode. The performance for both runway directions use is very similar in throughput and additional taxi-out time, and with higher additional ASMA for the most frequent configuration (RWY33). However, the analysis also identifies as representative a configuration that implies opposite use of the runway: ARR:15-DEP:33 (3% share). Normally this opposite use is observed of the periods of transition between runway configurations, but the share is always much lower in that case. Another surprising aspect is that the total throughput is almost the same for this configuration, and only additional taxi out time suffers a considerable increase. This particular configuration would require further detailed analysis.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGBB | Birmingham | 107768 | 3 | 0.07 | 0.32 | 0.49 | 98.42% |

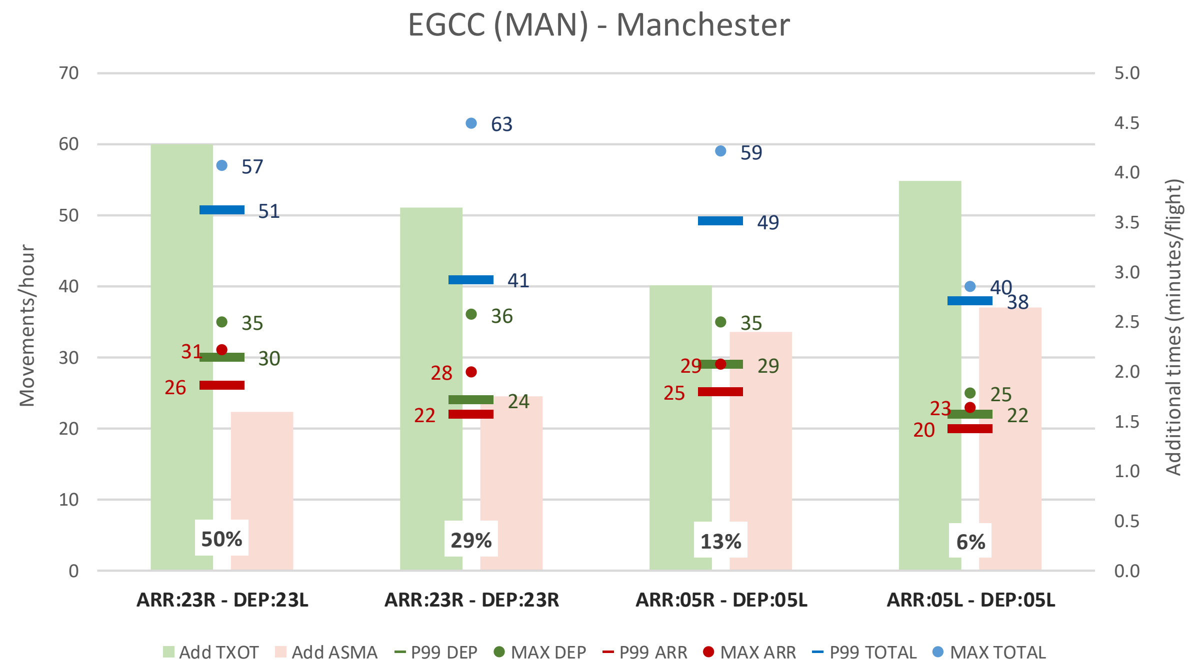


## 22.EGCC (MAN) - Manchester

Manchester, with 2 parallel dependent runways is operated in 4 configurations: 2 segregated (63% total share) and 2 using only one runway in mixed mode (35% total share). The PSR is clearly lower for the single runway use, and although performance is not much worse, maybe a segregated use in those periods (if possible) could have reduced the delays.

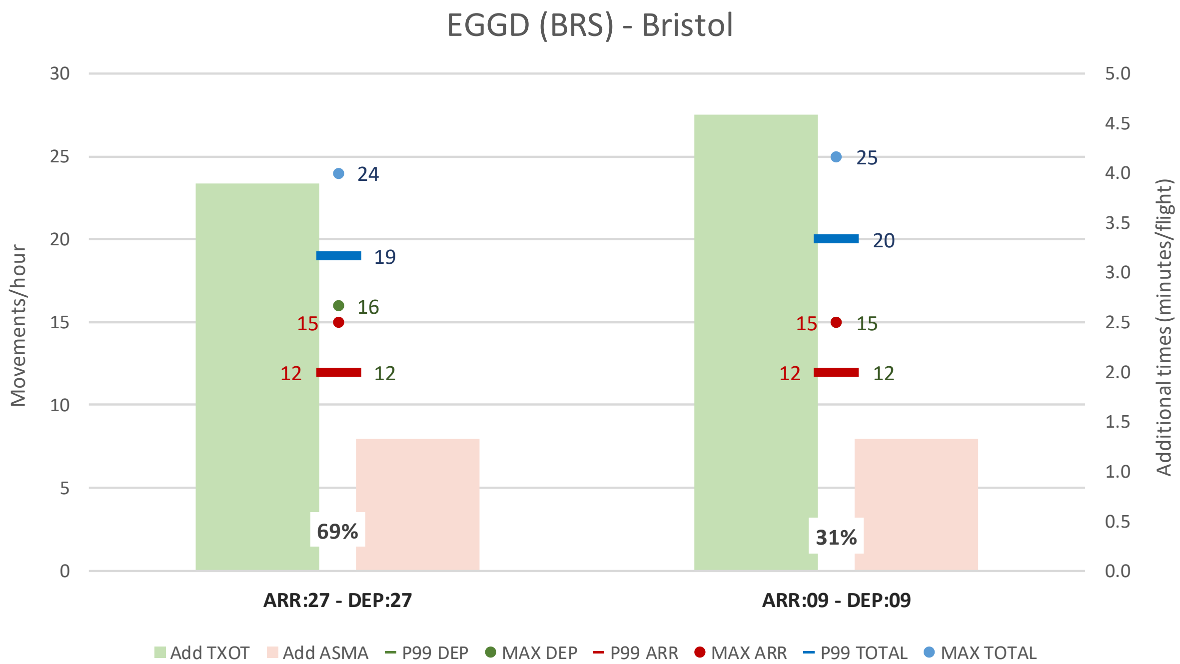
| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGCC | Manchester | 202935 | 4 | 1.01 | 0.21 | 3.82 | 94.32% |

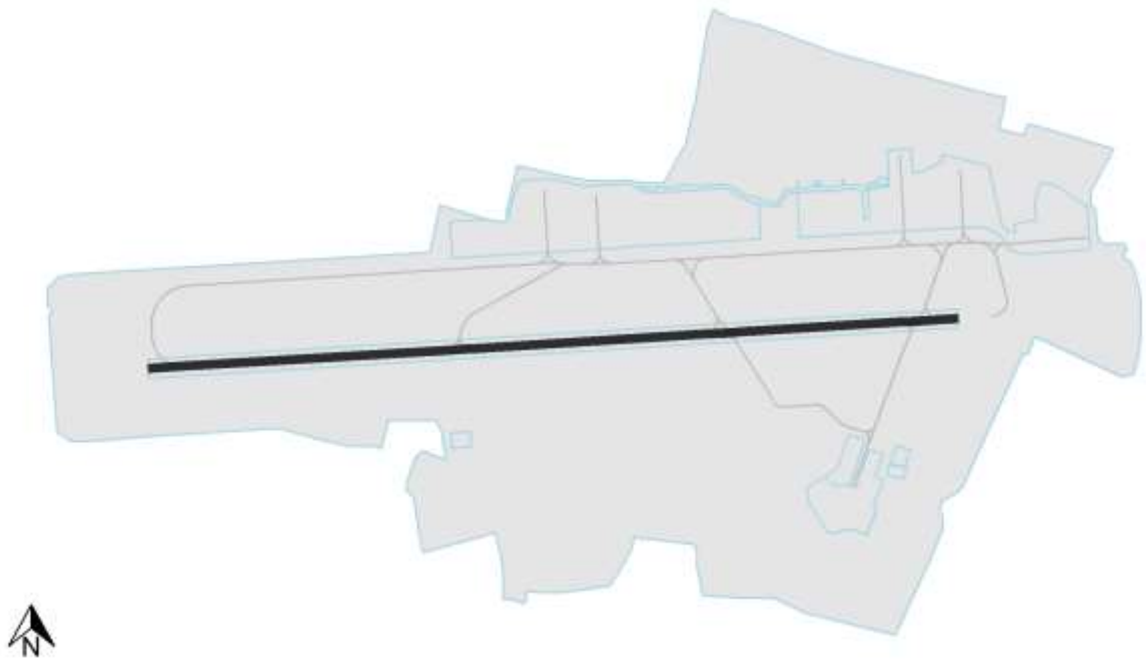



## 23.EGGD (BRS) - Bristol

Bristol is a single runway airport, operated in mixed mode in both directions, being RWY27 the preferential. Performance in terms of peak service rate differs in only 1 movement, and only additional taxi-out times show worse performance for the non-preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGGD | Bristol | 66393 | 2 | 0.21 | 0.00 | 0.69 | 96.55% |

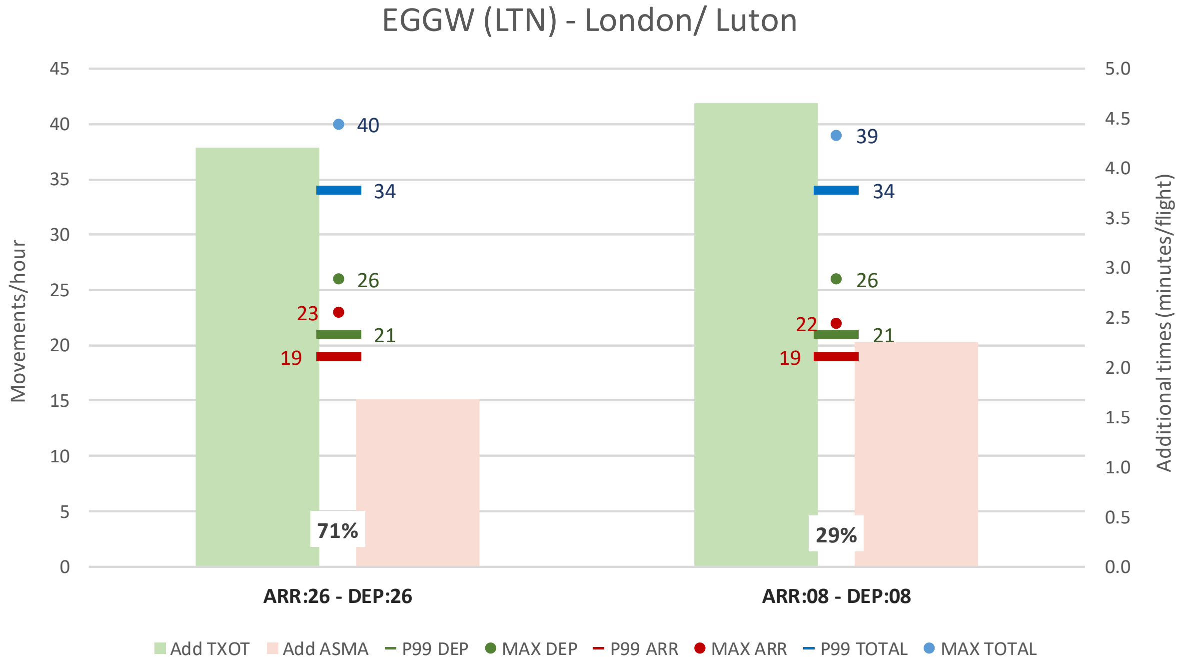


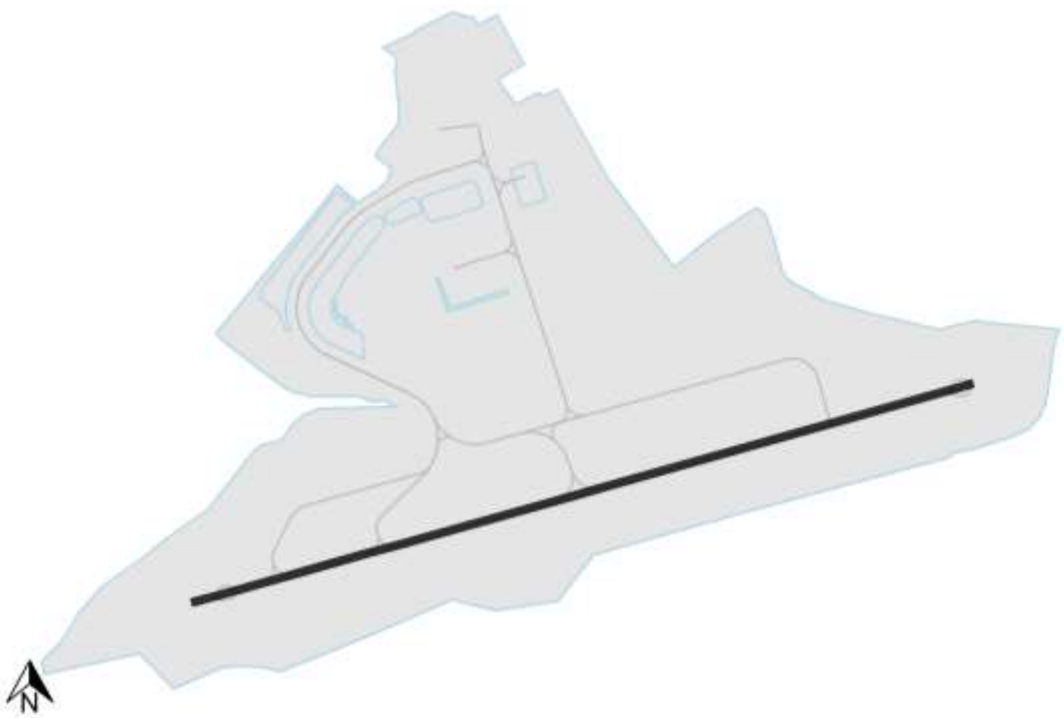



## 24.EGGW (LTN) - London/ Luton

Luton has only one runway (08/26) that operates in both directions mixed mode, with identical results in terms of PSR. The preferential runway (RWY26; 71% share) also has the lower additional times. In general terms, no important imbalance is observed at this airport.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGGW | London/ Luton | 140958 | 2 | 0.13 | 0.16 | 0.00 | 100.00% |

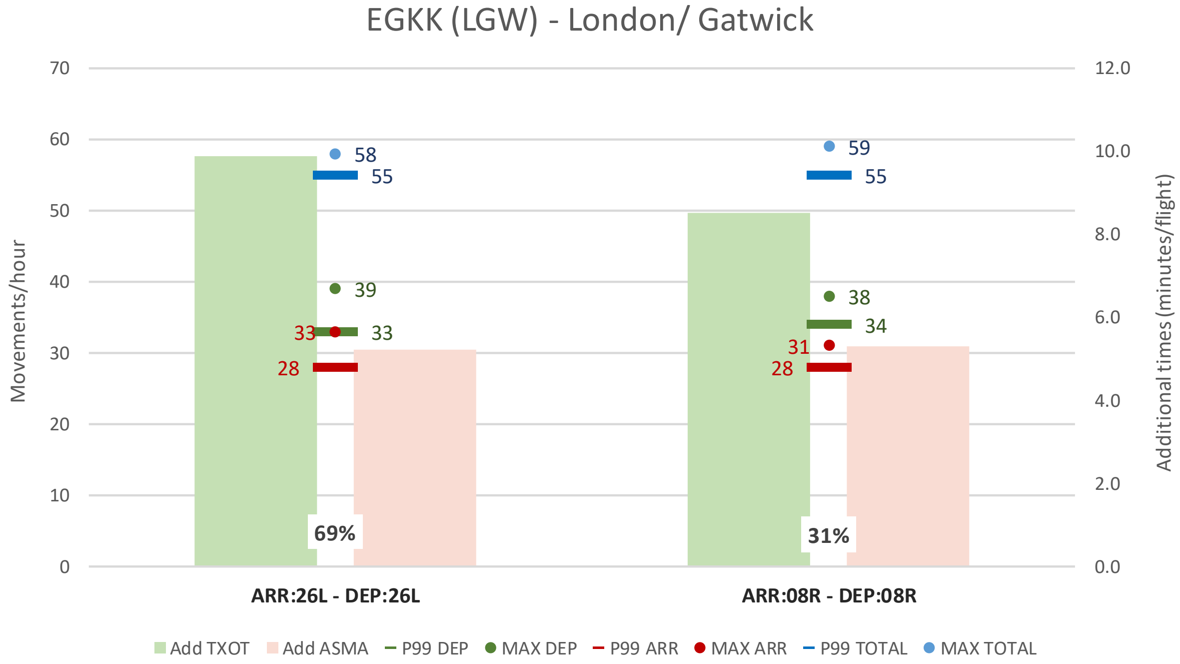


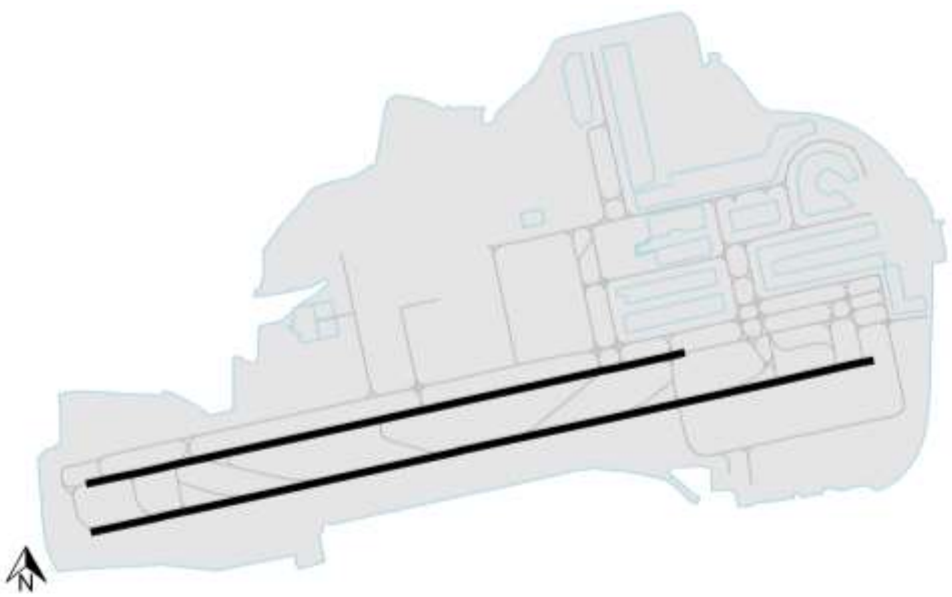



## 25.EGKK (LGW) - London/ Gatwick

Gatwick is the busiest airport in Europe that is always operated with one runway in single mode. Given the saturation, the PSR is a very good indication for capacity, and shows perfect symmetry in the operation in terms of throughput. Additional taxi-out times however are impacted by the runway use, being more than a minute higher for the most common runway configuration (RWY26L).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGKK | London/ Gatwick | 284916 | 2 | 0.93 | 0.03 | 0.00 | 100.00% |

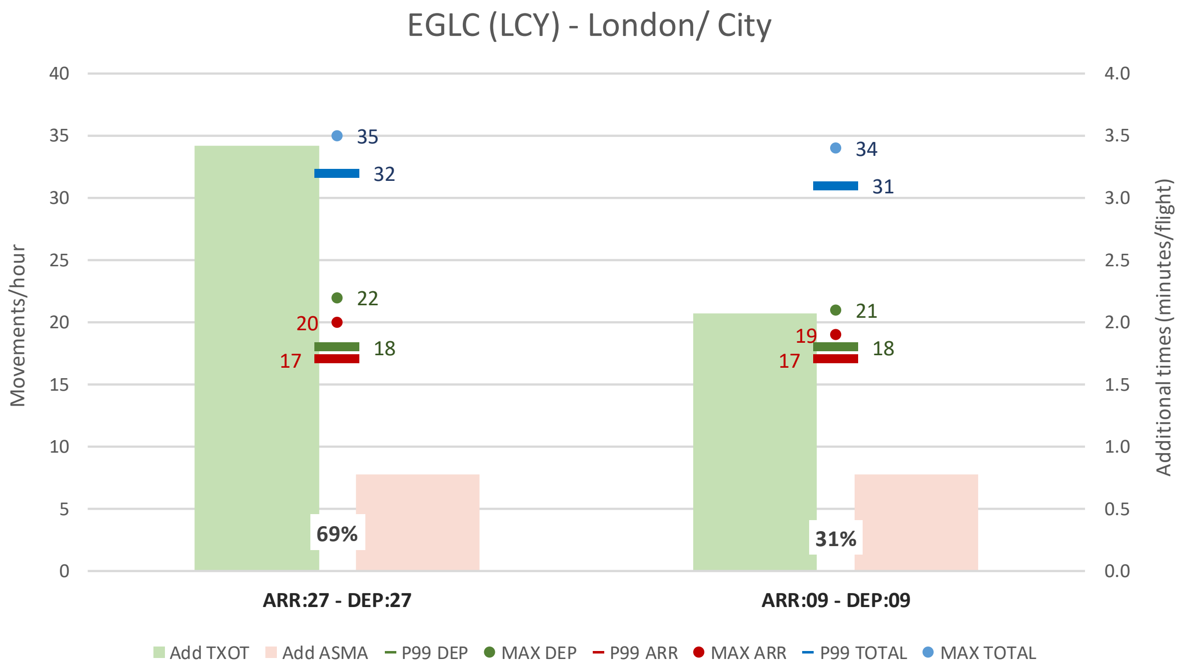


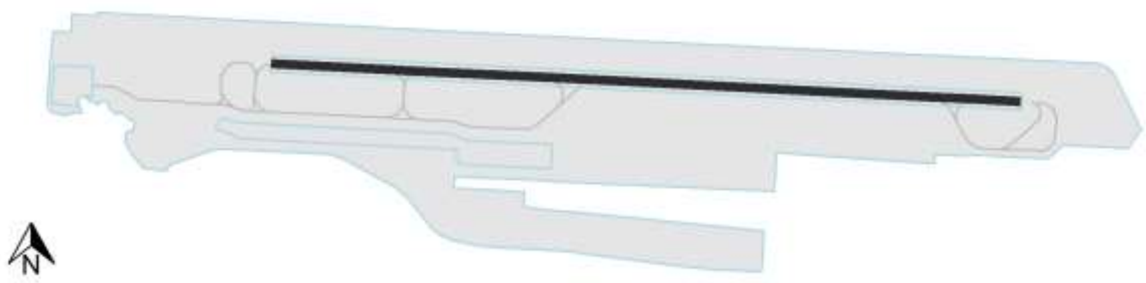



## 26.EGLC (LCY) - London/ City

London City, with only one runway operated in both directions in mixed mode, shows nearly symmetric PSR. Additional taxi-out time though, are considerably higher for most common runway in use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGLC | London/ City | 84208 | 2 | 0.93 | 0.00 | 0.31 | 99.03% |

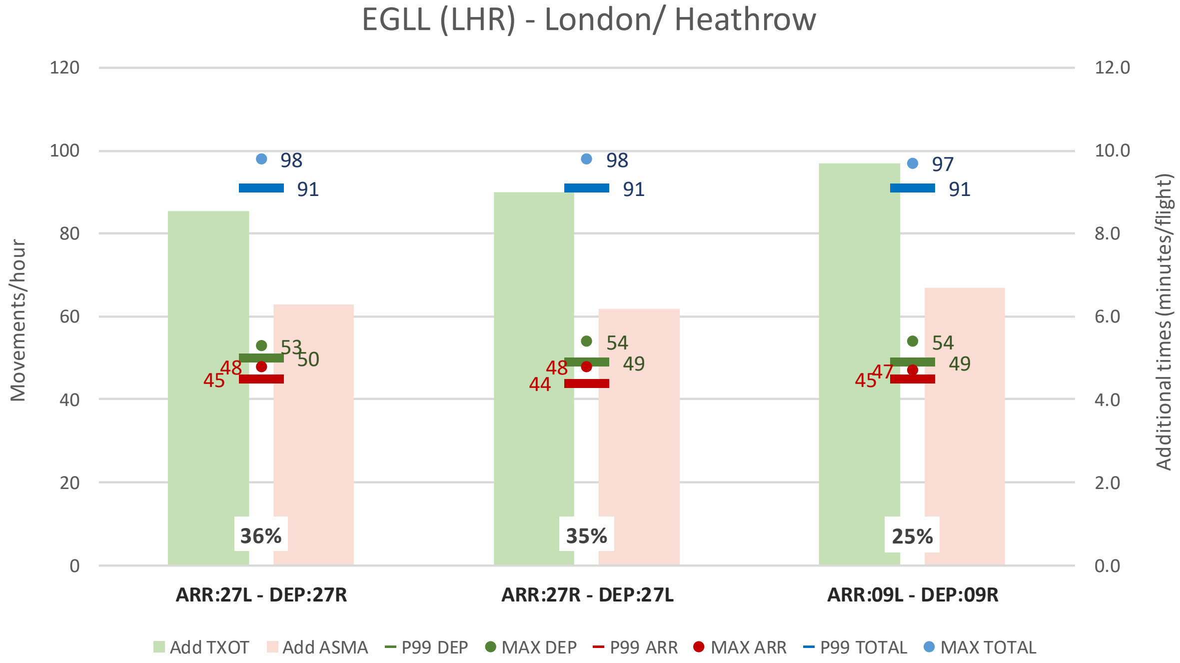


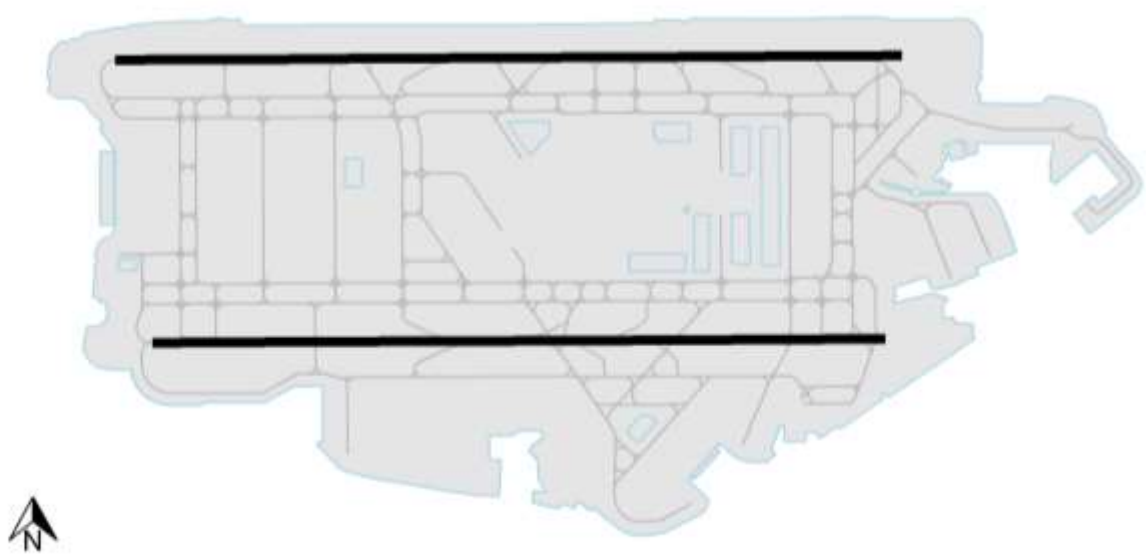



## 27.EGLL (LHR) - London/ Heathrow

London Heathrow has two parallel runways operated always in segregated mode. The most common runway direction is 27 alternating the arrivals and departures on 27R and 27L. While there is a perfect symmetry in the PSR, performance results show very similar additional times, with additional taxi-out times a little bit more impacted by the change of runway condiguration.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGLL | London/ Heathrow | 478081 | 3 | 0.45 | 0.16 | 0.00 | 100.00% |

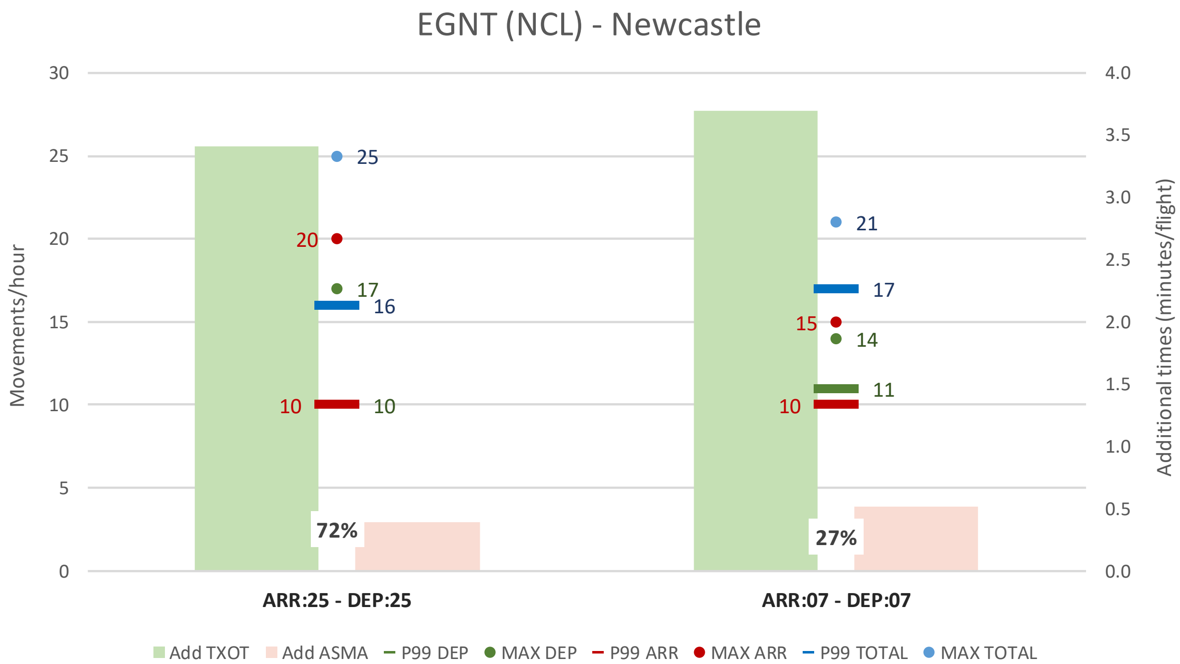


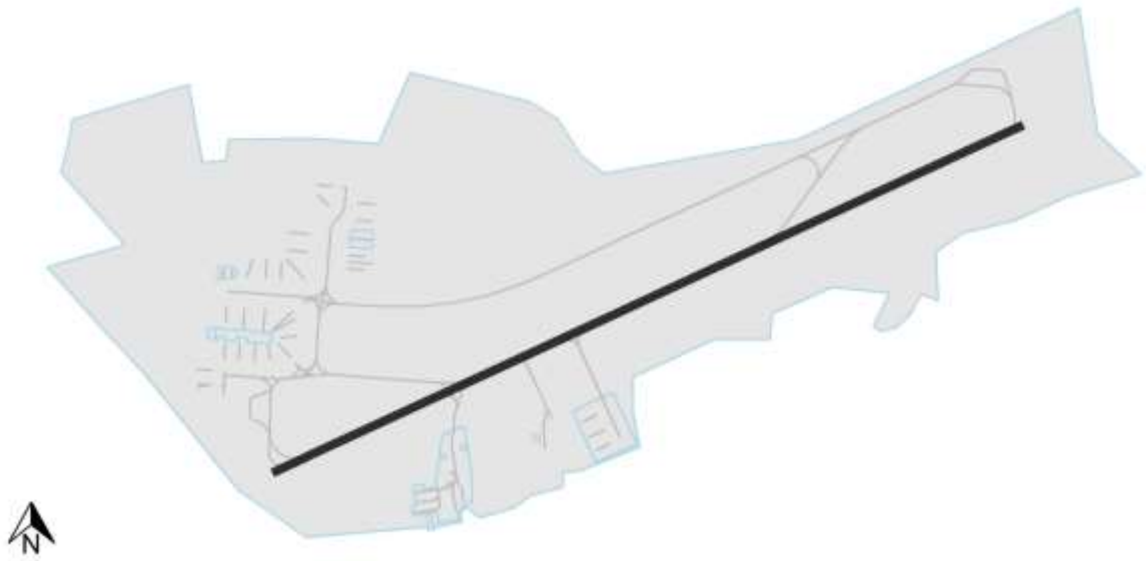



## 28.EGNT (NCL) - Newcastle

Newcastle is a single runway airport, operated in mixed mode in both directions, being RWY25 the preferential. Performance in terms of peak service rate differs in only 1 movement, and only additional taxi-out times show worse performance for the non-preferential runway use. The big difference between the maximum observed throughput and the PSR for the preferential runway use signals the airport might be under utlilised which makes the PSR not a good proxy for capacity

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGNT | Newcastle | 43438 | 2 | 0.08 | 0.03 | 0.72 | 95.74% |

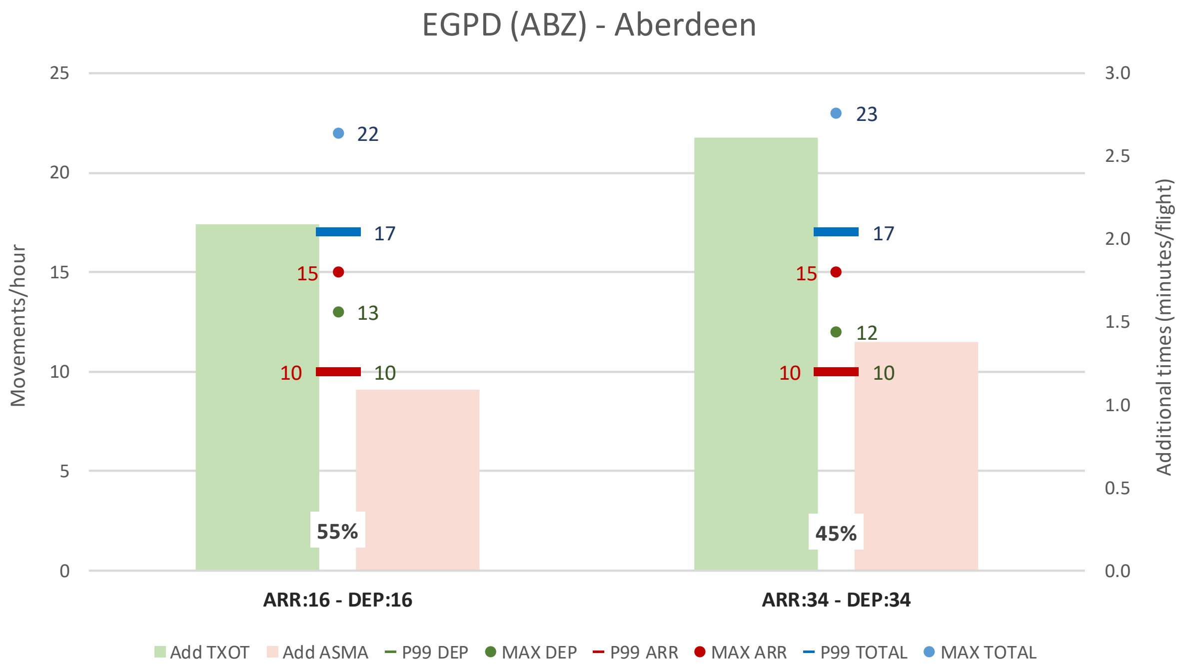


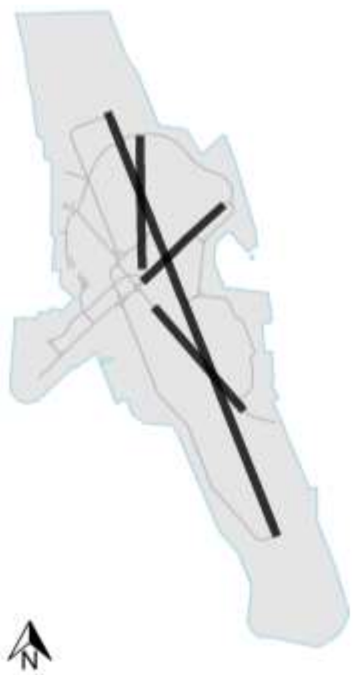



## 29.EGPD (ABZ) - Aberdeen

Aberdeen is a single runway airport (plus three helipads), operated in mixed mode in both directions, with a very even use of both runway directions (55%-45%). Performance in terms of peak service rate is identical for both configurations, but runway 34 shows longer additional times, mainly in the taxi-out phase.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGPD | Aberdeen | 51233 | 2 | 0.23 | 0.13 | 0.00 | 100.00% |

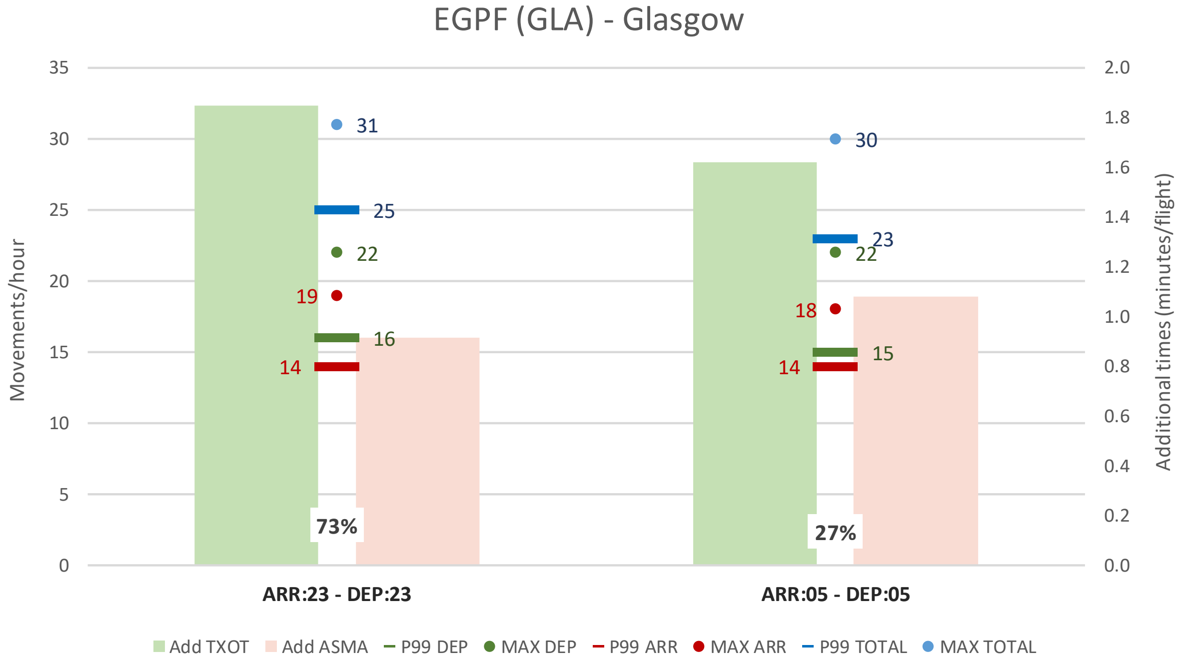


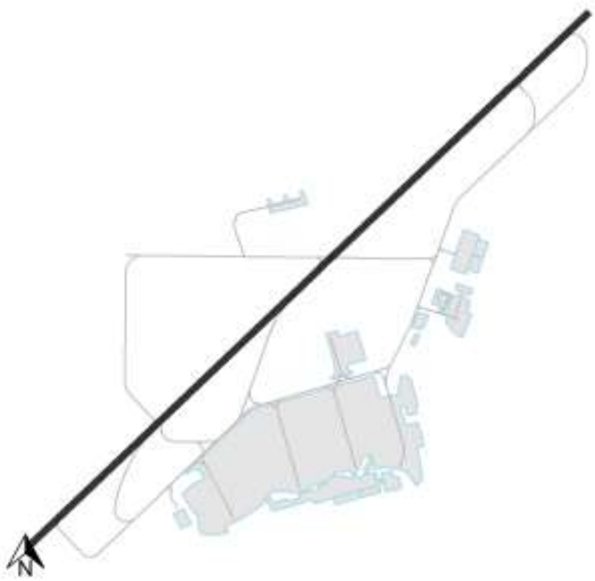



## 30.EGPF (GLA) - Glasgow

Glasgow only has one runway, that can be operated in both directions in mixed mode. The performance for both runway directions use is similar in throughput (2 movements less for the secondary runway use) showing higher taxi-out times for RWY 23 and higher additional ASMA times for RWY 05. Nevertheless there is still a significant difference between the maximum throughput and the PSR that might suggest the percentile 99 is not the best proxy for capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGPF | Glasgow | 84345 | 2 | 0.16 | 0.04 | 0.54 | 97.86% |

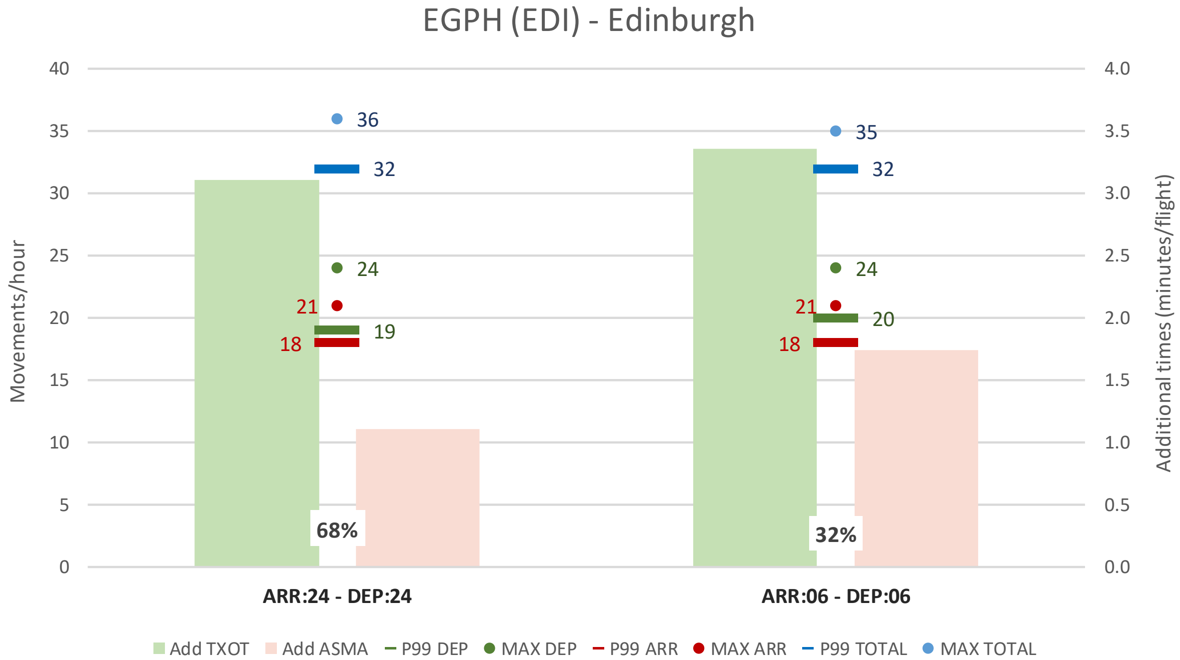


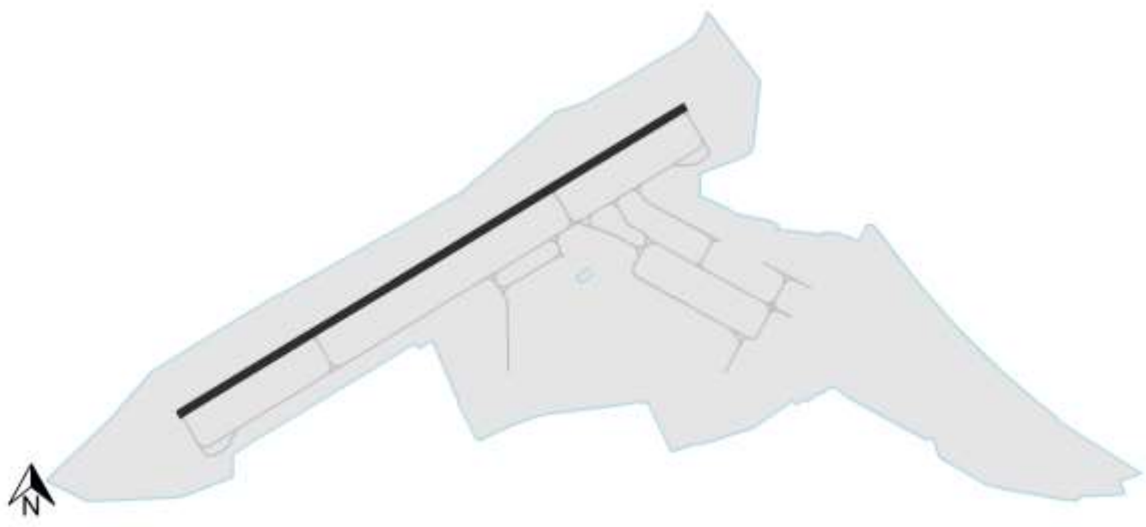



## 31.EGPH (EDI) - Edinburgh

Edinburgh is a single runway airport, operated in mixed mode in both directions, with almost identical performance in terms of peak service rate . Additional times are slightly higher for the non preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGPH | Edinburgh | 131457 | 2 | 0.08 | 0.20 | 0.00 | 100.00% |

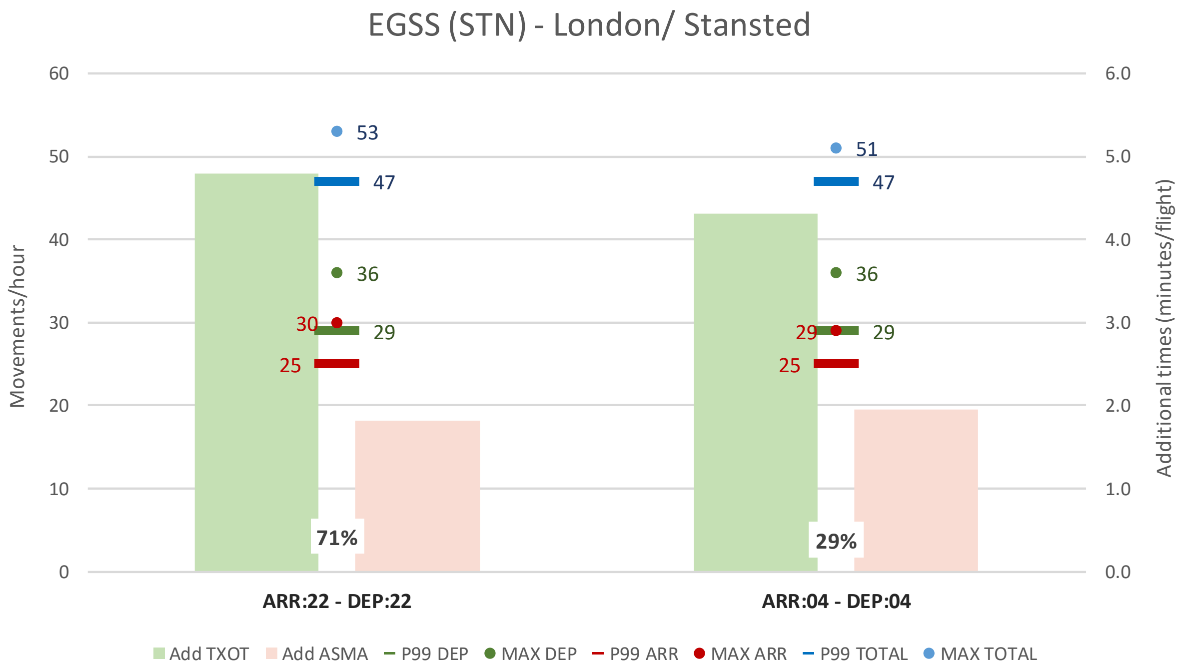


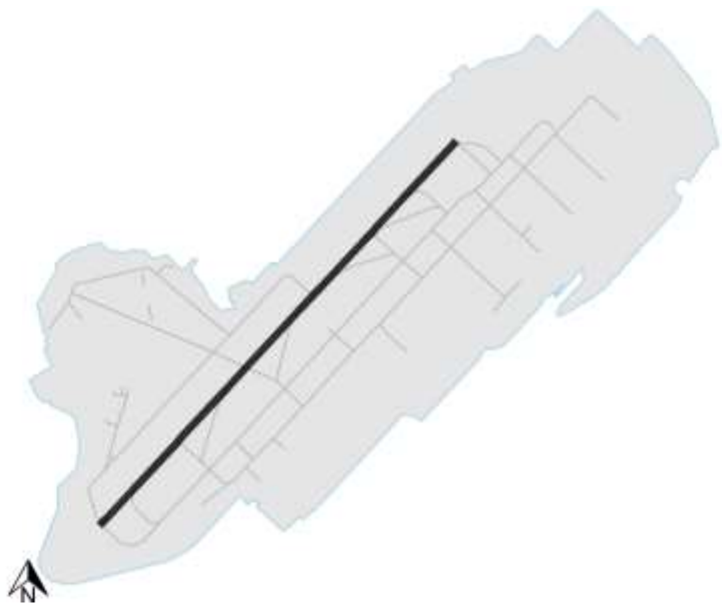



## 32.EGSS (STN) - London/ Stansted

Stansted is one of the top 30 airports in Europe, and it is a single runway airport. The runway is operated in both directions in mixed mode, being RWY22 the most commonly used (71% share) Performance in terms of throughput is completely symmetric, and additional times are very similar, although the additional taxi out times are slightly higher for the preferential runway.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EGSS | London/ Stansted | 198511 | 2 | 0.33 | 0.04 | 0.00 | 100.00% |

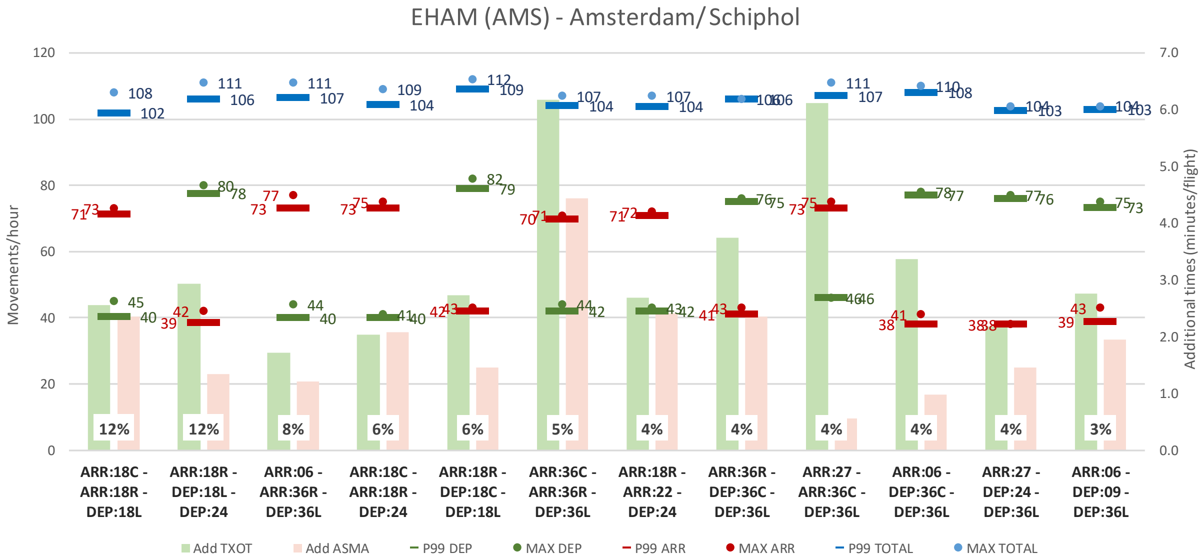


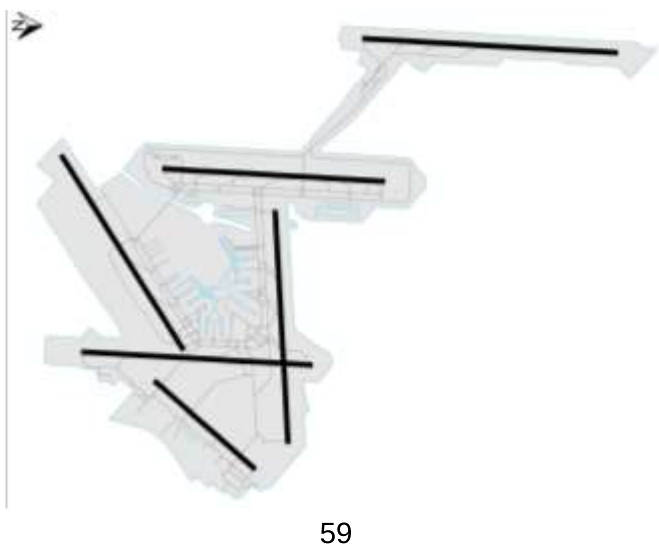



## 33.EHAM (AMS) - Amsterdam/ Schiphol

Amsterdam has 6 runways (more than any other airport in Europe) translating into many different possible configurations. In addition, the 15 minutes intervals might not be long enough for all active runways to be used in the interval. Nevertheless, the algortithm detects all the 8 runway configurations declared in the Airport Corner, and 4 additional ones. The usage of the configurations is quite distributed, not having a clear preferential one. Although the PSR of total movements is quite similar for all configurations, looking at the PSR for arrivals or departures it can be easily deducted the configurations are used either for arrival peaks or departure peaks, not having any where the mix is more balanced. In terms of performance, there are significant differences in both additional ASMA and additional taxi-out times amongst most of the configurations, with configuration ARR:36C;ARR:36R-DEP:36L showing the worst results (more than double compared to other configurations).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EHAM | Amsterdam/ Schiphol | 509185 | 12 | 1.00 | 0.96 | 2.84 | 99.22% |

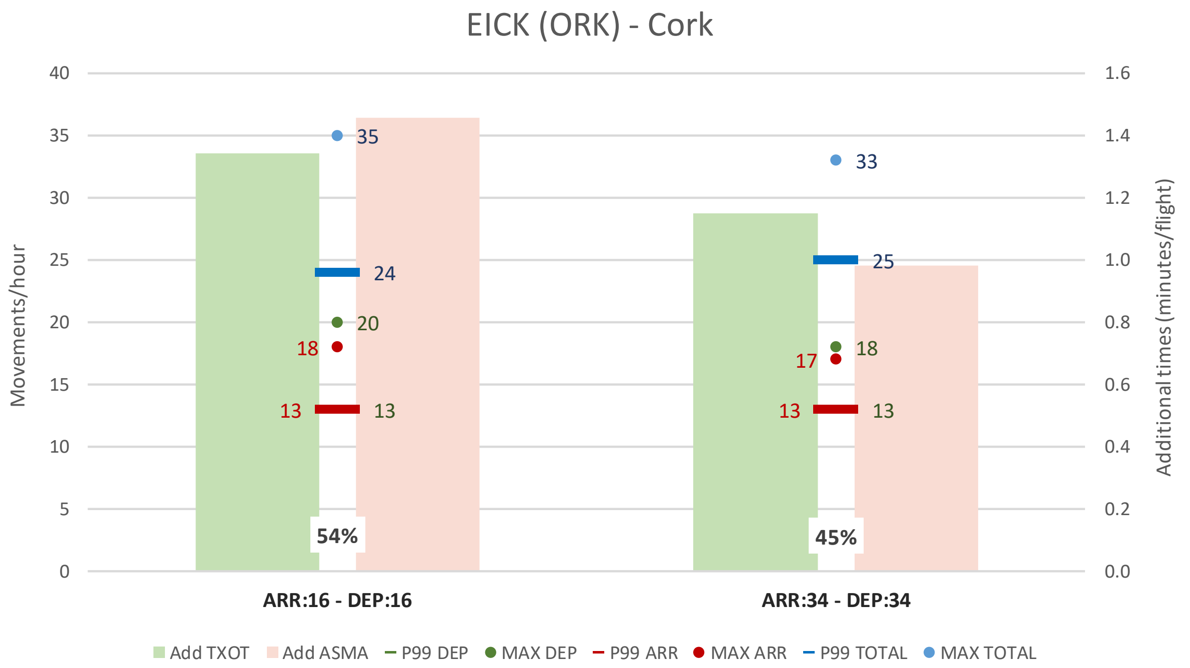


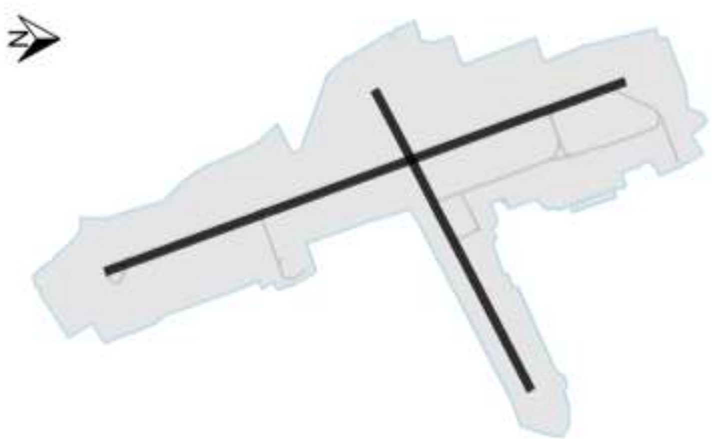



## 34.EICK (ORK) - Cork

Cork has two crossing runways but it only operates the longest one in mixed mode, with a very even use of both runway directions (54%-45%). Performance in terms of peak service rate is almost identical for both configurations, but RWY16 shows longer additional times, both in the approach and the taxi-out phase.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EICK | Cork | 27002 | 2 | 0.10 | 0.26 | 0.52 | 97.90% |

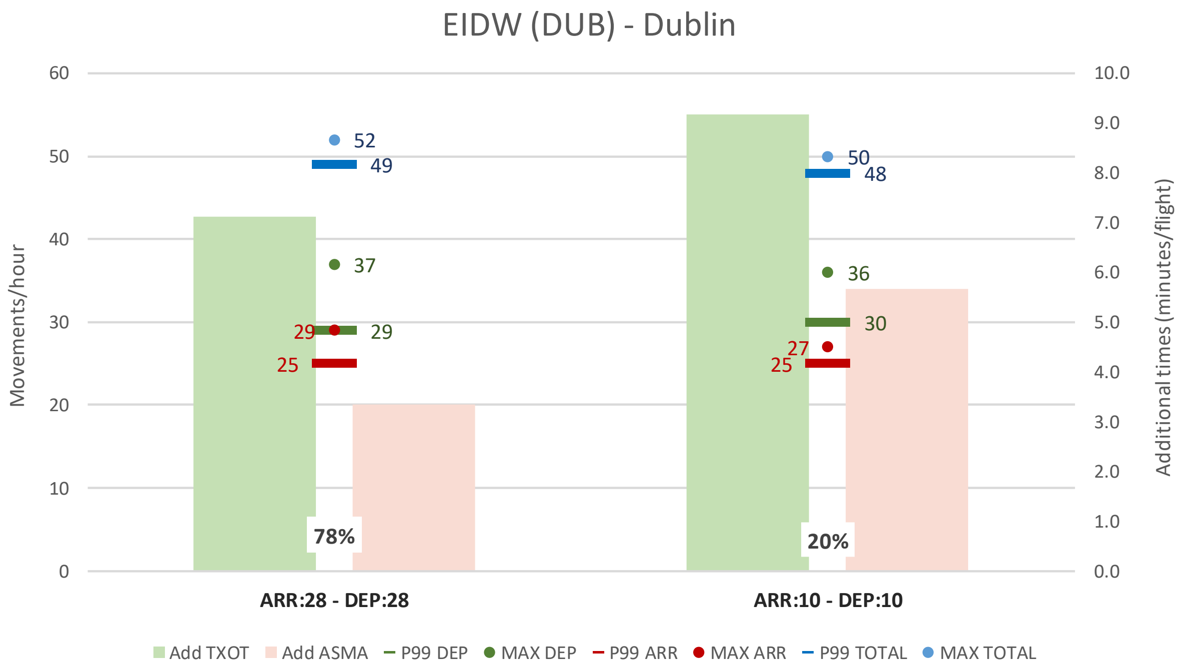


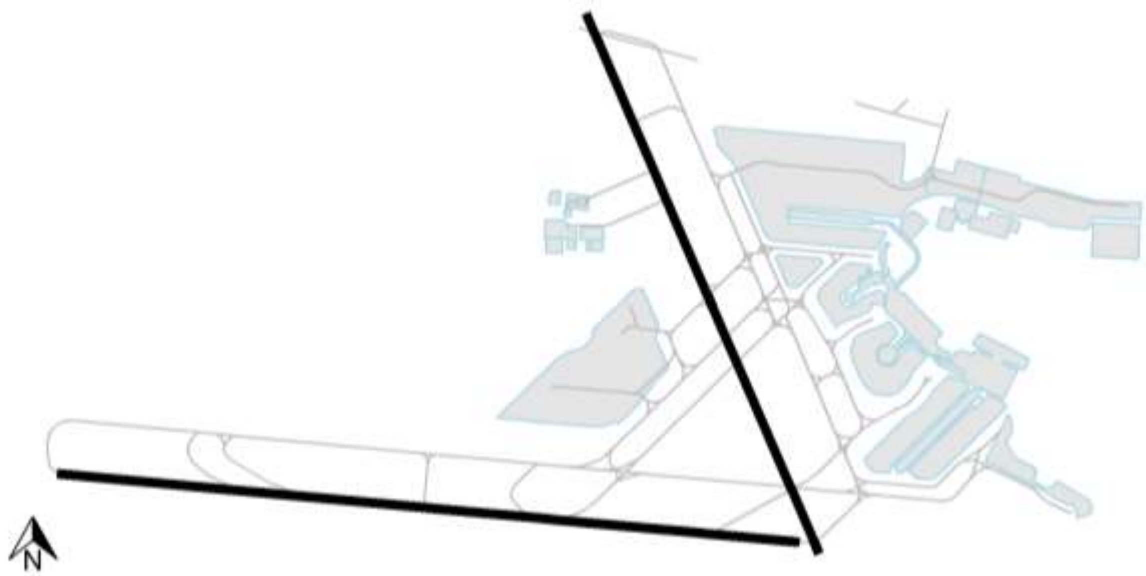



## 35.EIDW (DUB) - Dublin

Dublin has two runways but operates only one of them in both directions mixed mode, with RWY28 as preferential (78% share). The PSR is almost identical for both configurations, but there is a clear impact on performance when using RWY10, both in additional taxi-out times (bottleneck in the departure queue for RWY10) and in ASMA times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EIDW | Dublin | 238044 | 2 | 0.42 | 0.47 | 0.20 | 99.59% |

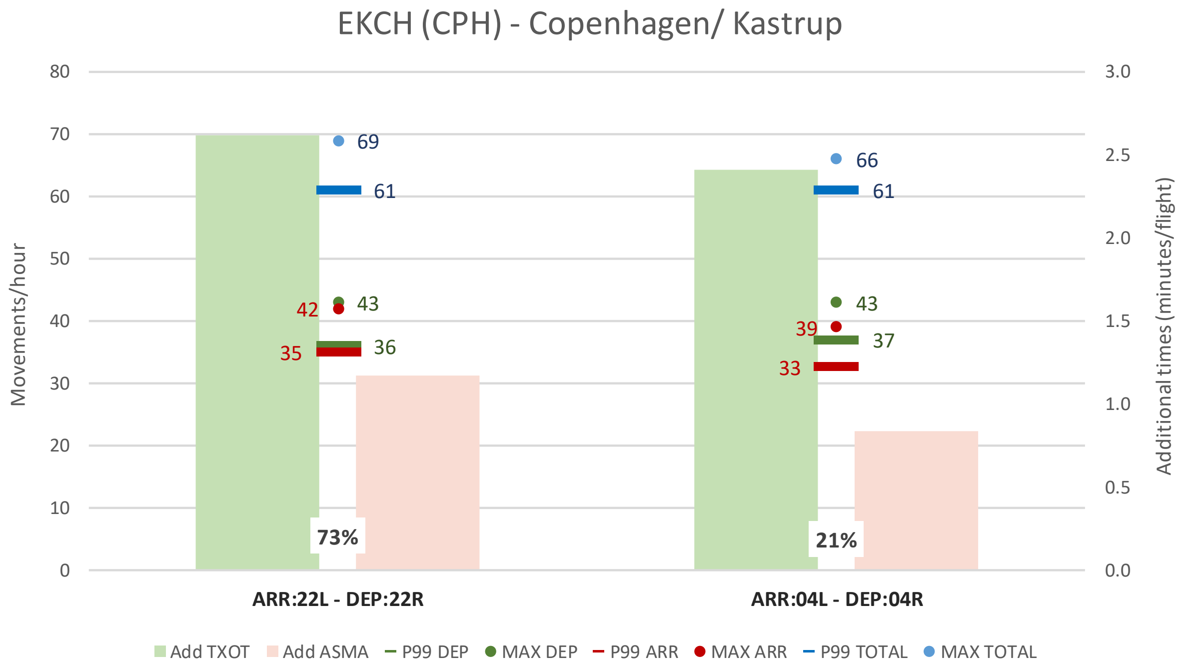


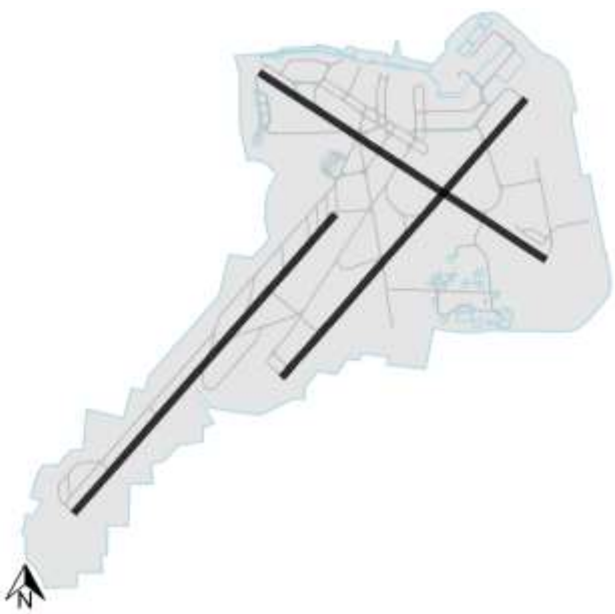



## 36.EKCH (CPH) - Copenhagen/ Kastrup

Copenhagen has 2 parallel runways and one crossing, but the crossing runway 12/30 is rarely used. The two representative configurations use the parallel runways in segregated mode, with identical total PSR. The preferential runway use ARR:22L-DEP:22R (73% share) shows slightly higher additional times, both in the approach and the taxi-out phase.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EKCH | Copenhagen/ Kastrup | 263434 | 2 | 0.15 | 0.25 | 0.00 | 100.00% |

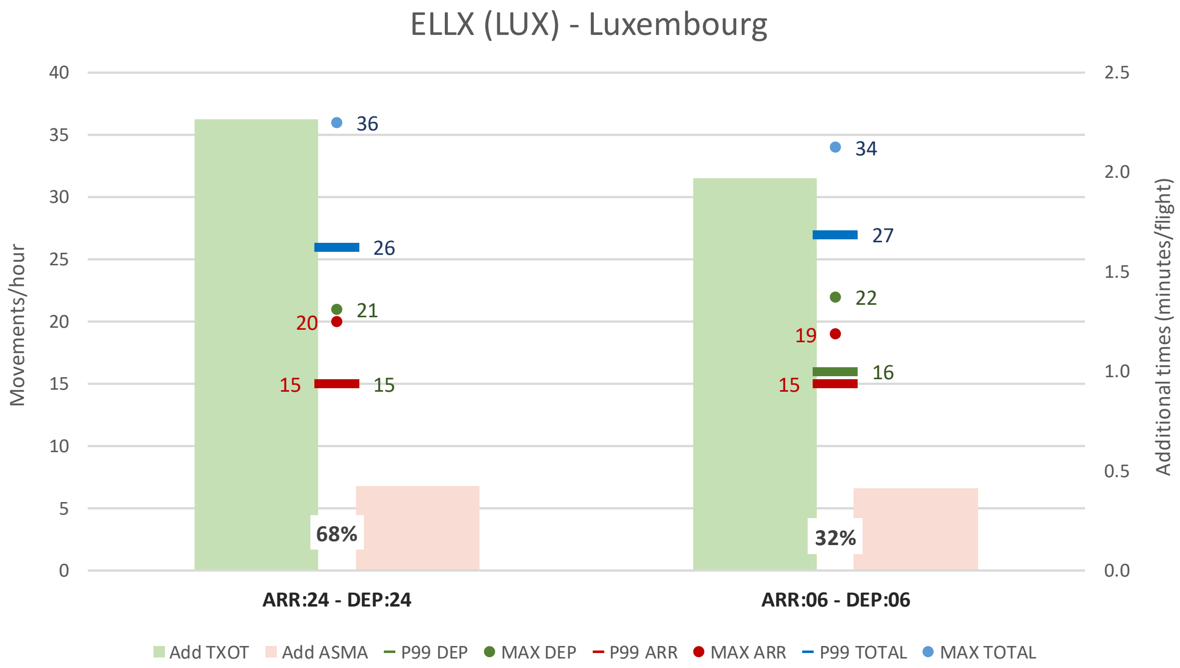


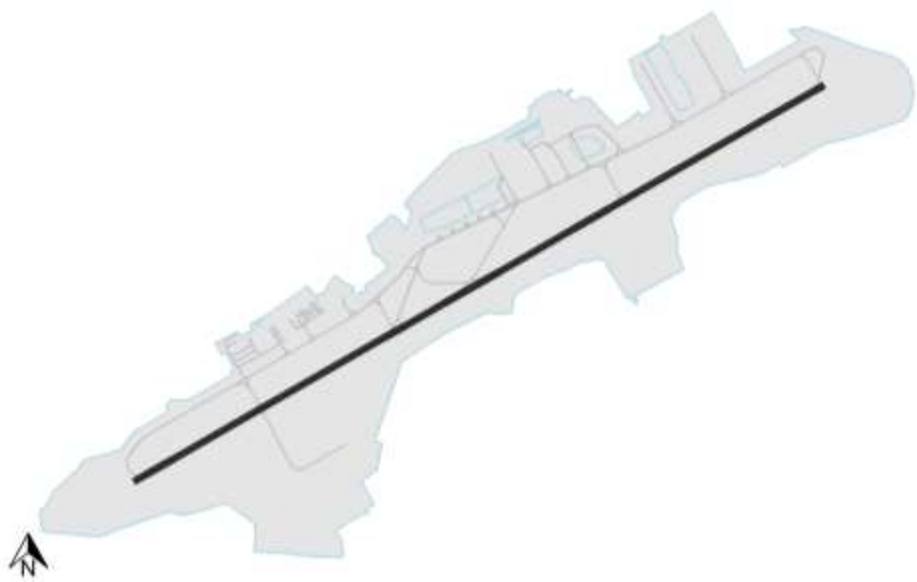



## 37.ELLX (LUX) - Luxembourg

Luxembourg is a single runway airport, operated in mixed mode in both directions, being RWY24 the most commonly used (68% share). Performance in terms of peak service rate differs in only 1 movement, and only additional taxi-out times show slightly worse performance for the preferential runway use. The big difference between the maximum observed throughput and the PSR for the preferential runway use signals the airport might be under utlilised which makes the PSR not a good proxy for capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| ELLX | Luxembourg | 76300 | 2 | 0.20 | 0.01 | 0.68 | 97.50% |

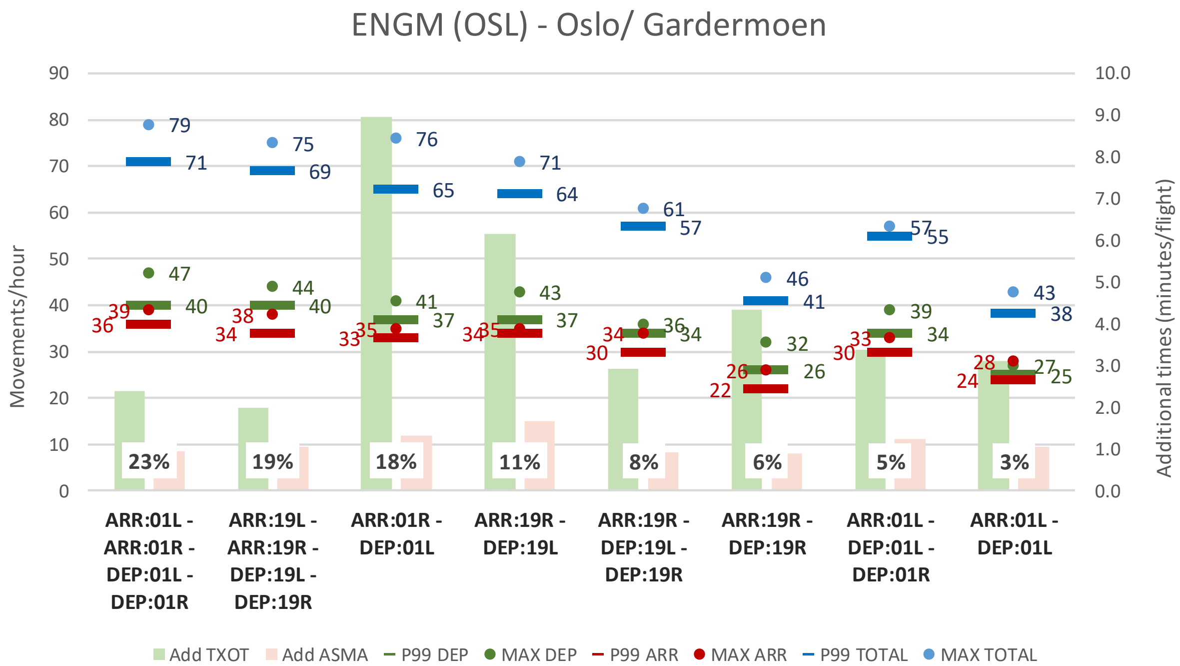


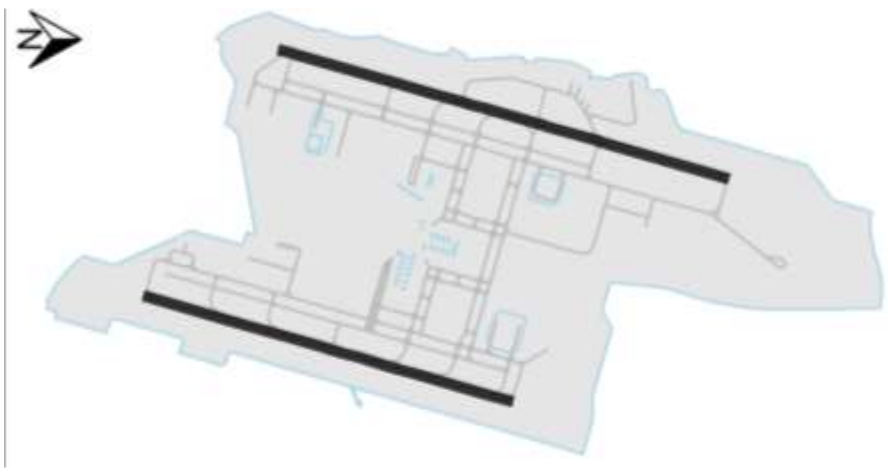



## 38.ENGM (OSL) - Oslo/ Gardermoen

Oslo has two parallel independent runways and operates them in many different ways, resulting in 8 configurations. About 42% of the time the runways are used in mixed mode independent, resulting in the highest throughput and lower delays in the taxi-out and approach phases, but the other configurations, using the runways as segregated, show lower PSR and especially much higher additional taxi-out times (up to 7 minutes higher than other configurations for conf ARR:01R-DEP:01L) This results in the highest impact on the additional taxi-out times of all 90 airports analysed. For about 9% of the time the airport also operates only RWY01L/19R (as single runway mixed mode), reducing the PSR by more than 30 movements with respect to the reference capacity. Although this could be due to a lack of demand, ithese configurations also observe worse additional taxi-out times than the independent use of both runways.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| ENGM | Oslo/ Gardermoen | 251872 | 8 | 2.13 | 0.23 | 6.95 | 97.49% |

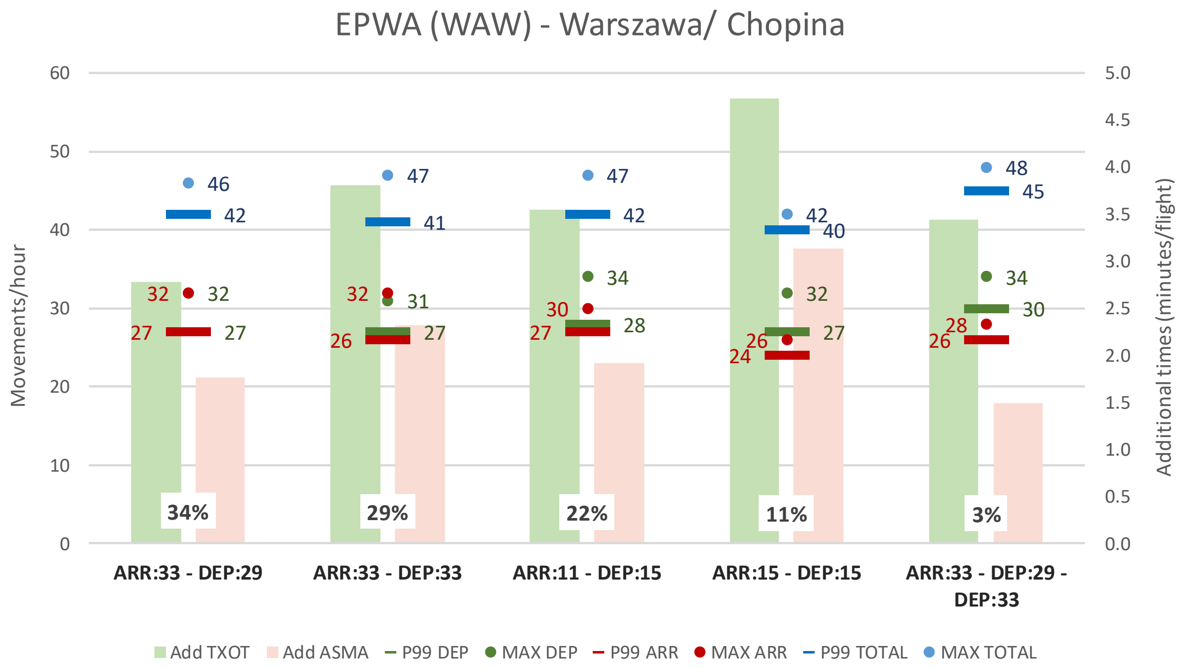


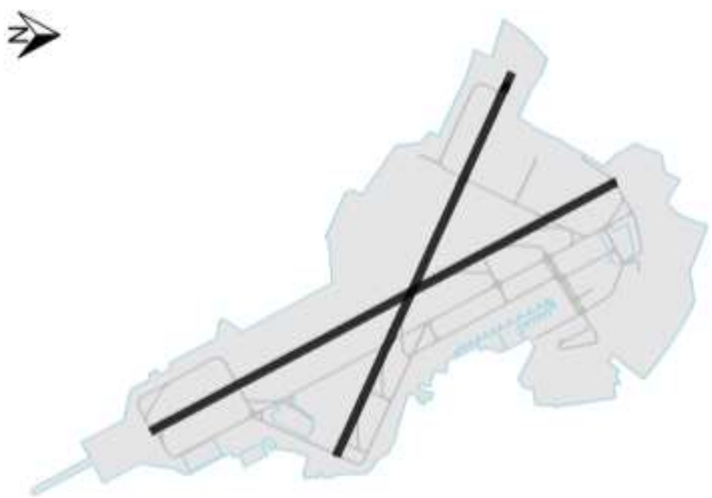



## 39.EPWA (WAW) - Warszawa/ Chopina

Warsaw has 2 crossing runways operated in 5 different configurations. The high saturation level ensures the PSR is a good proxy for capacity. The configuration that shows the best PSR (ARR:33-DEP:29;DEP:33) is used only 3% of the time. In 2019, for about 40% of the time only RWY15/33 was in use in mixed mode due to works on the other runway and although the impact on PSR was not very high, the additional times were significantly longer, especially when using RWY15.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EPWA | Warszawa/ Chopina | 194160 | 5 | 0.70 | 0.61 | 3.40 | 97.42% |

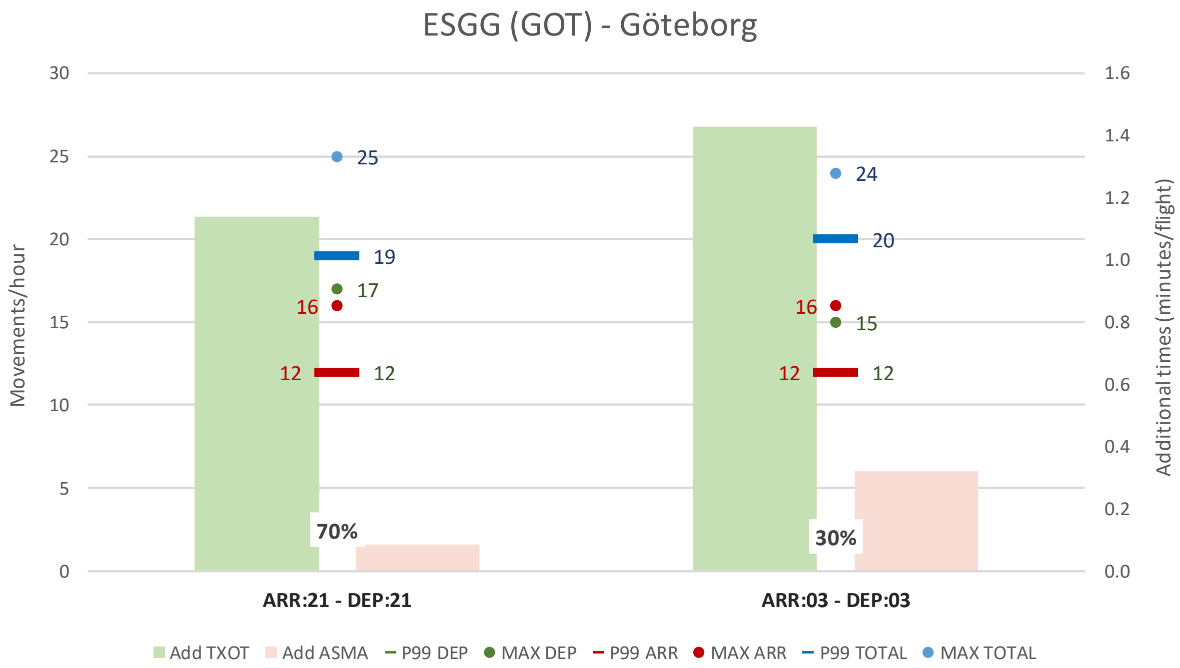


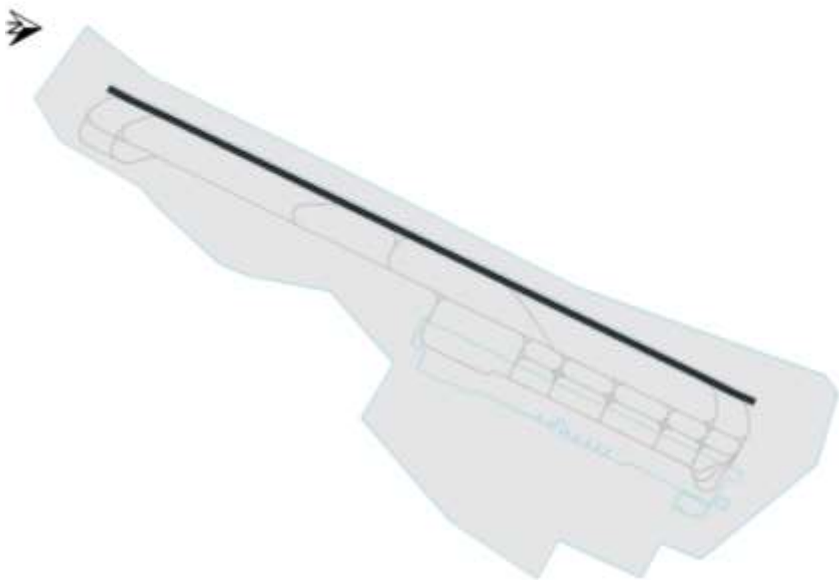



## 40.ESGG (GOT) - Göteborg

Göteborg is a single runway airport, operated in mixed mode in both directions, being RWY21 the most commonly used (70% share). Performance in terms of peak service rate differs in only 1 movement, and additional times show slightly worse performance for the non-preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| ESGG | Göteborg | 69265 | 2 | 0.08 | 0.07 | 0.70 | 96.50% |

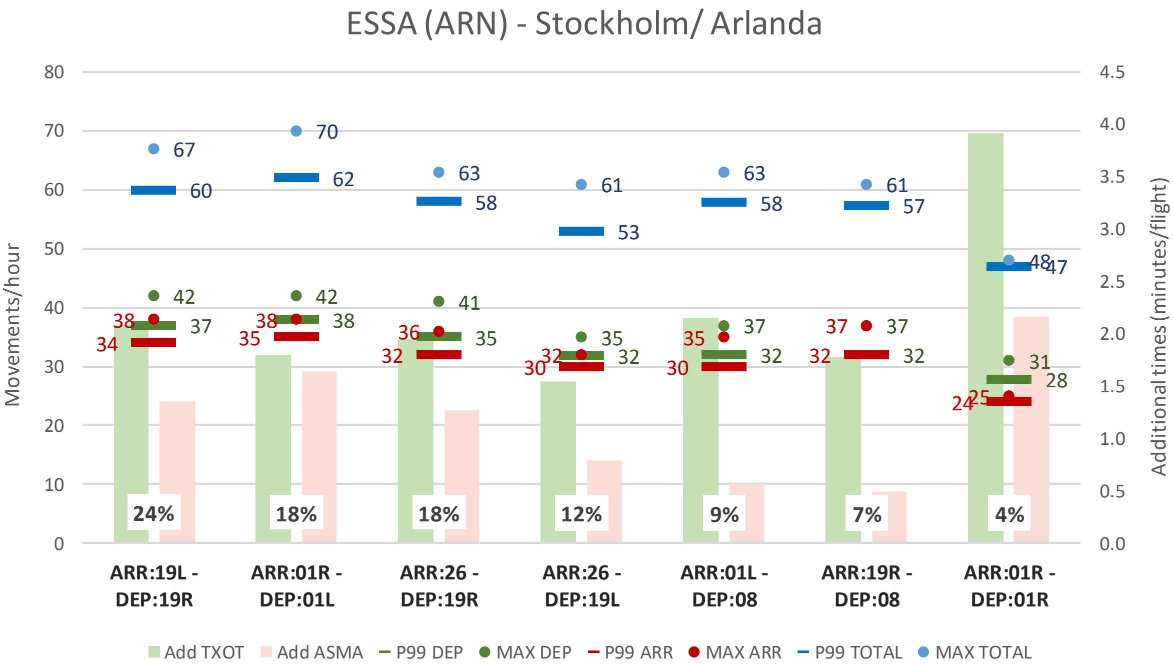


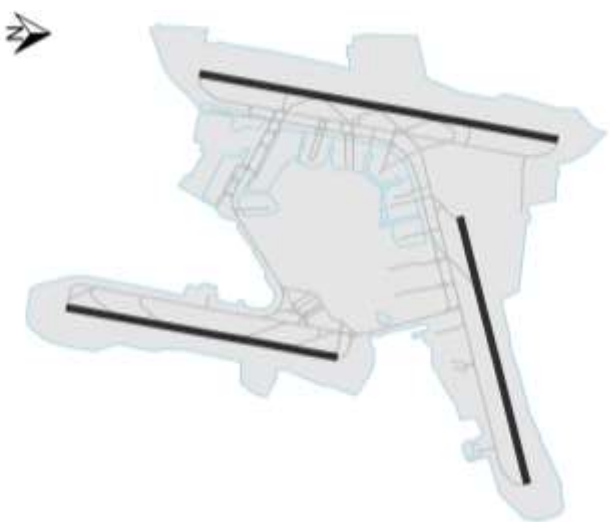



## 41.ESSA (ARN) - Stockholm/ Arlanda

Stockholm has three runways, two of them parallel. The analysis yields a maximum of two runways are used at a time, always in segregated mode, except for a 4% of the time that only RWY01R is used, in mixed mode seems, and resulting in a significantly reduced PSR with consequent much higher additional times. Even when using two runways is there is a considerable lower PSR for configuration ARR:26-DEP19L. Nevertheless, this configuration shows the lowest additional taxi-out times and relatively low additional ASMA times, indicating that this configuration might be simply used in periods with lower demand. In general the difference between the maximum throughput and the PSR signals that congestion at Stockholm might not be enough to consider the PSR a good proxy for capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| ESSA | Stockholm/ Arlanda | 233007 | 7 | 0.42 | 0.67 | 3.67 | 98.19% |

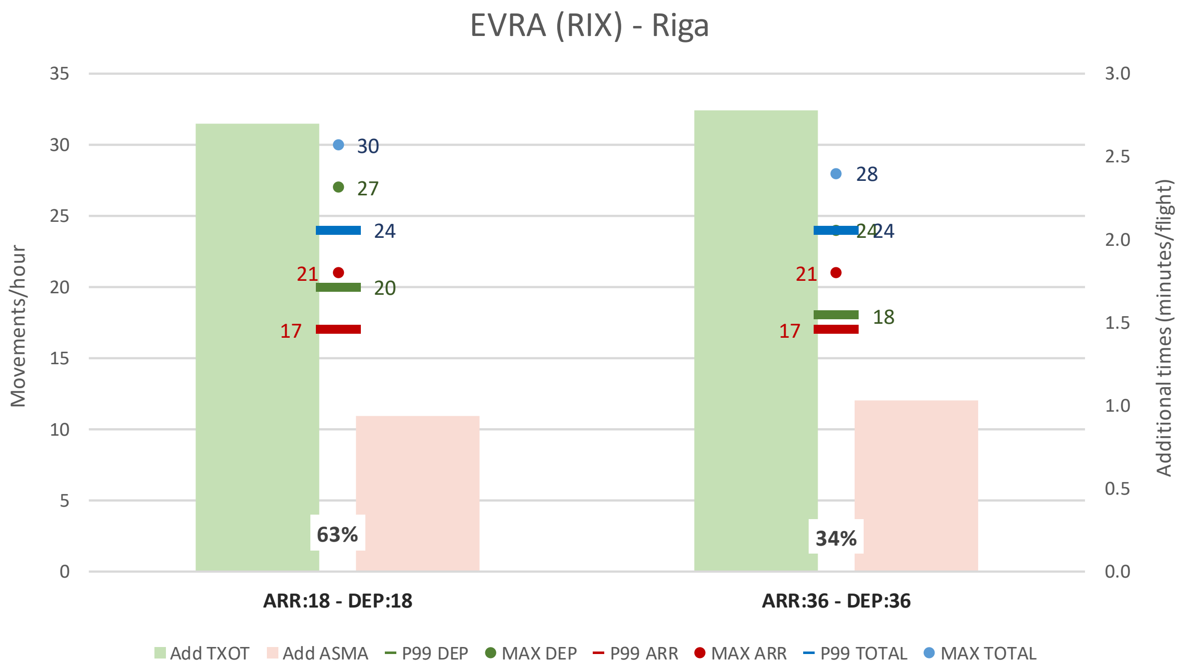


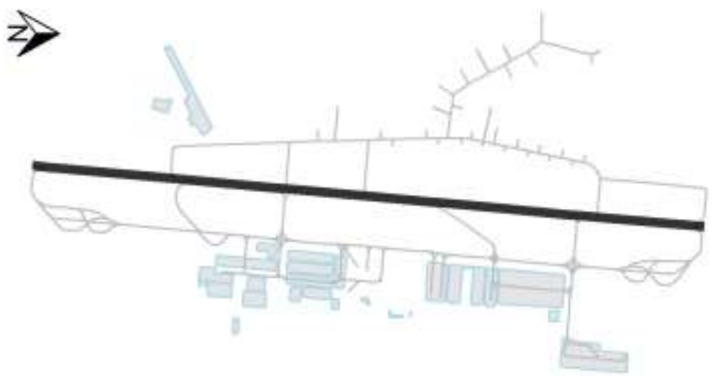



## 42.EVRA (RIX) - Riga

Riga is a single runway airport, operated in mixed mode in both directions, with almost identical performance in terms of peak service rate . Additional times are slightly higher for the non preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EVRA | Riga | 86646 | 2 | 0.03 | 0.03 | 0.00 | 100.00% |

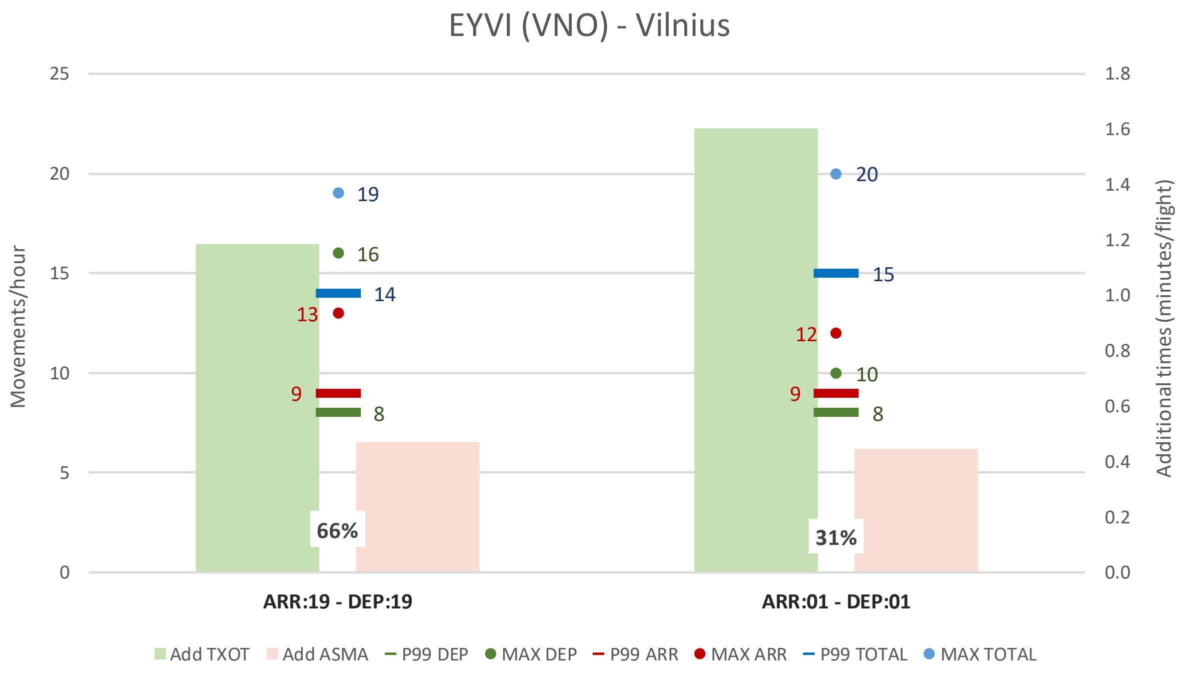


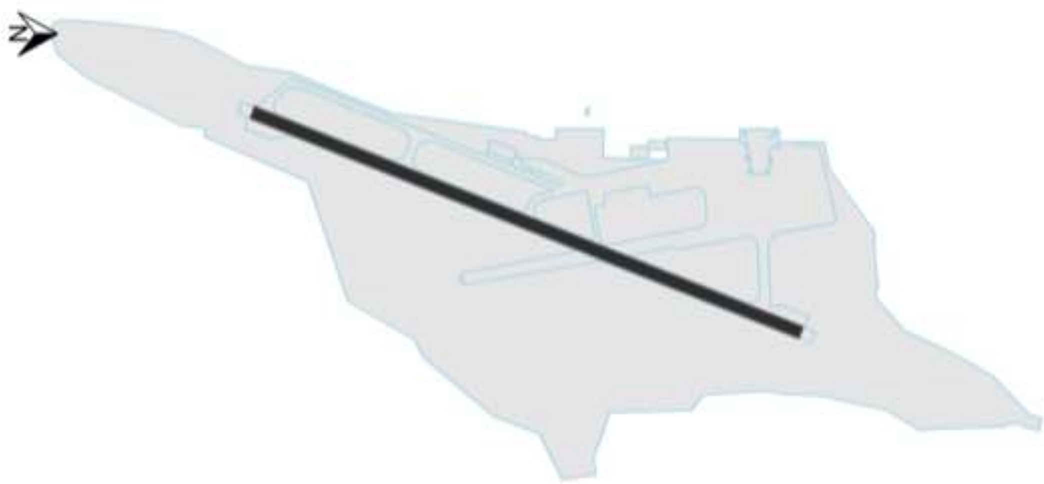



## 43.EYVI (VNO) - Vilnius

Vilnius, with only one runway operated in both directions in mixed mode, shows very similar PSR (only one movement difference) and additional ASMA times. Additional taxi-out time though, are higher for RWY01.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| EYVI | Vilnius | 46775 | 2 | 0.13 | 0.02 | 0.66 | 95.59% |

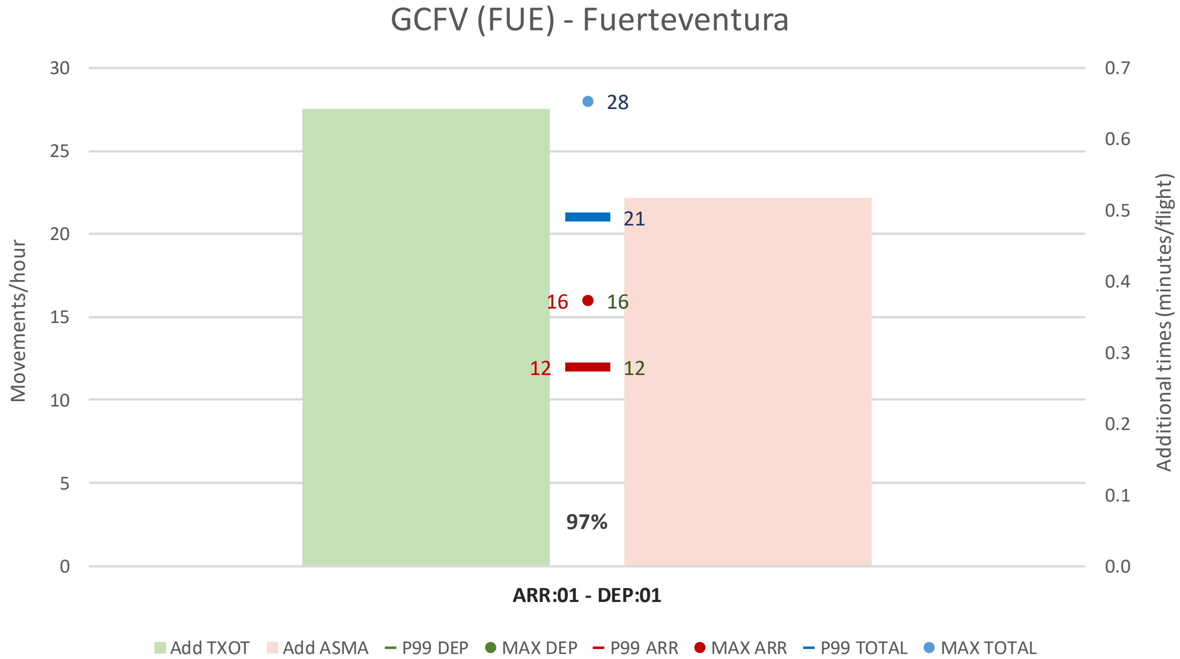


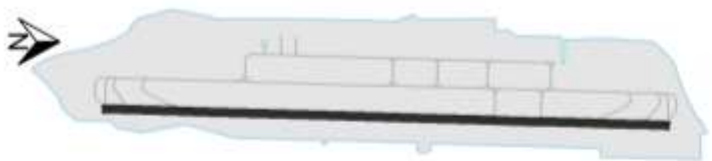



## 44.GCFV (FUE) - Fuerteventura

Fuerteventura is a one runway airport with conditions that clearly favour one runway direction utilization. In fact, RWY01 is used (in mixed mode) 97% of the time in 2019. The other runway configuration is not used more than 3% of the time (with some time intervals being the transition between configurations or missing runway information) so it is not considerd representative and there is no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| GCFV | Fuerteventura | 46356 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

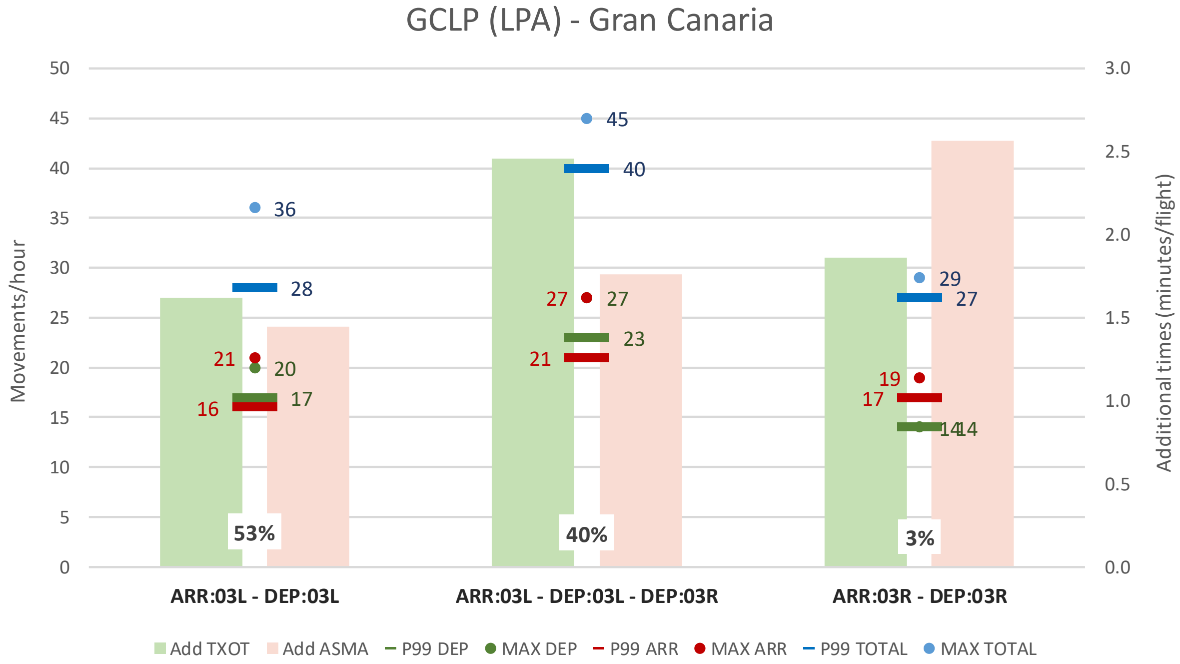


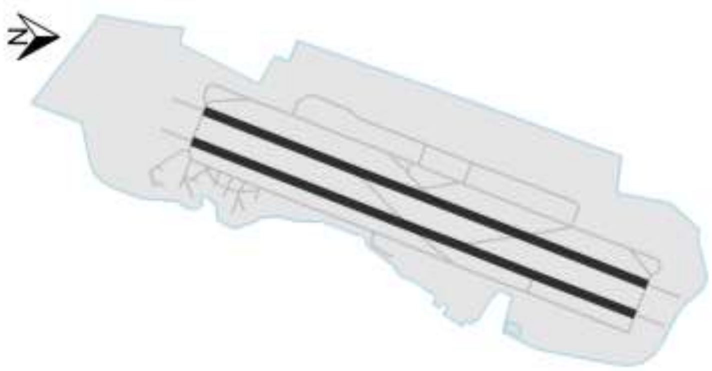



## 45.GCLP (LPA) - Gran Canaria

Gran Canaria has two dependent parallel runways. For 56% of the time, only one of these two runways are in use, in mixed mode, showing a much lower troughput than the combined use: conf ARR:03L-DEP:03L;DEP:03R. This configuration shows the highest throughput but also the highest additional taxi-out times, which might indicate is used for demand peaks.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| GCLP | Gran Canaria | 124152 | 3 | 0.34 | 0.16 | 6.77 | 84.15% |

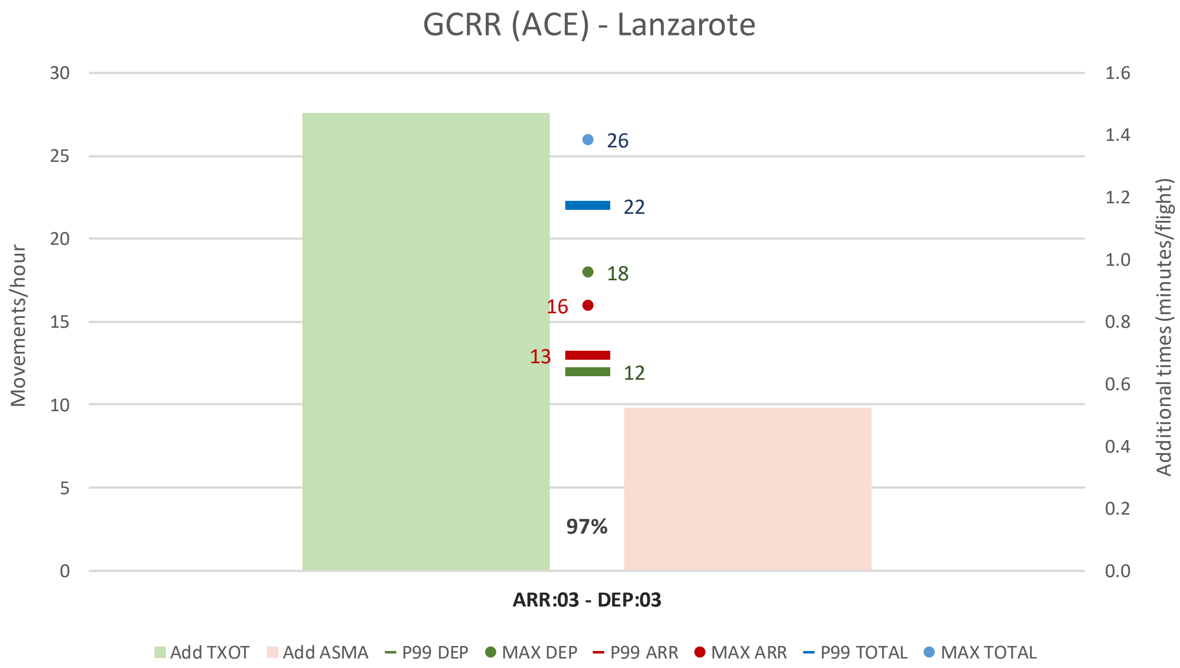


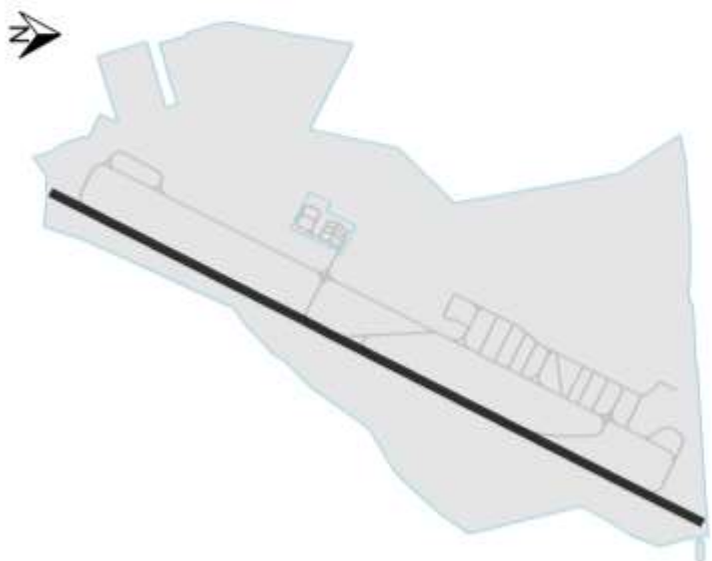



## 46.GCRR (ACE) - Lanzarote

Lanzarote is a one runway airport with conditions that clearly favour one runway direction utilization. In fact, RWY03 is used (in mixed mode) 97% of the time in 2019. The other runway configuration is not used more than 3% of the time (with some time intervals being the transition between configurations or missing runway information) so it is not considerd representative and there is no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| GCRR | Lanzarote | 59130 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

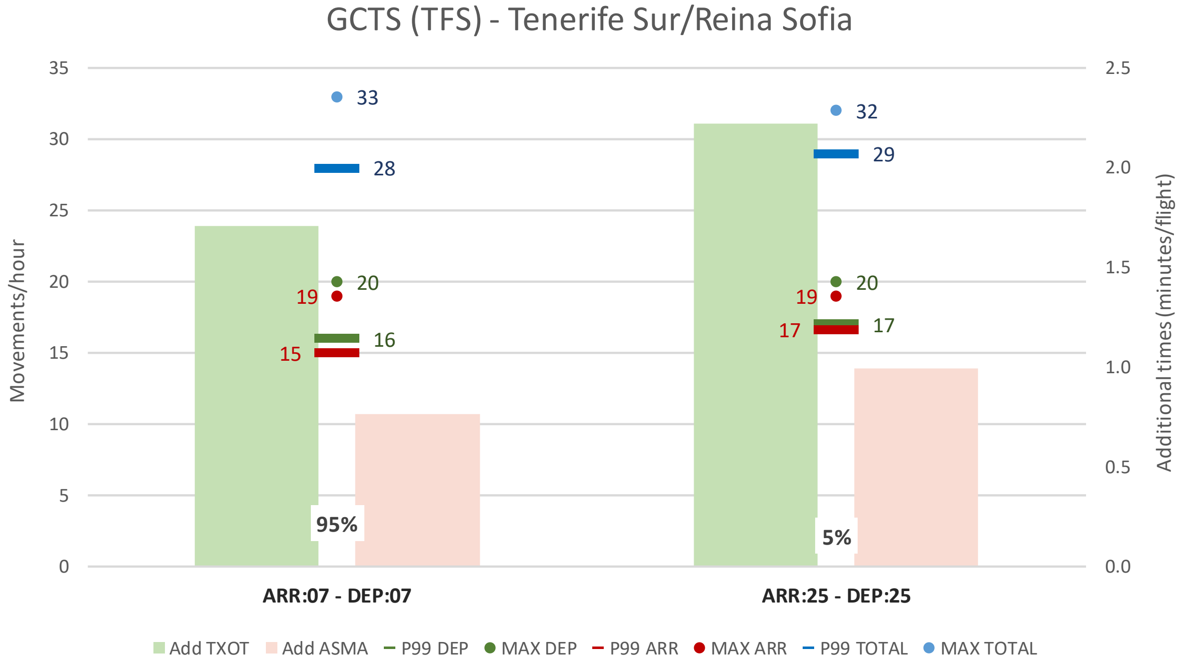


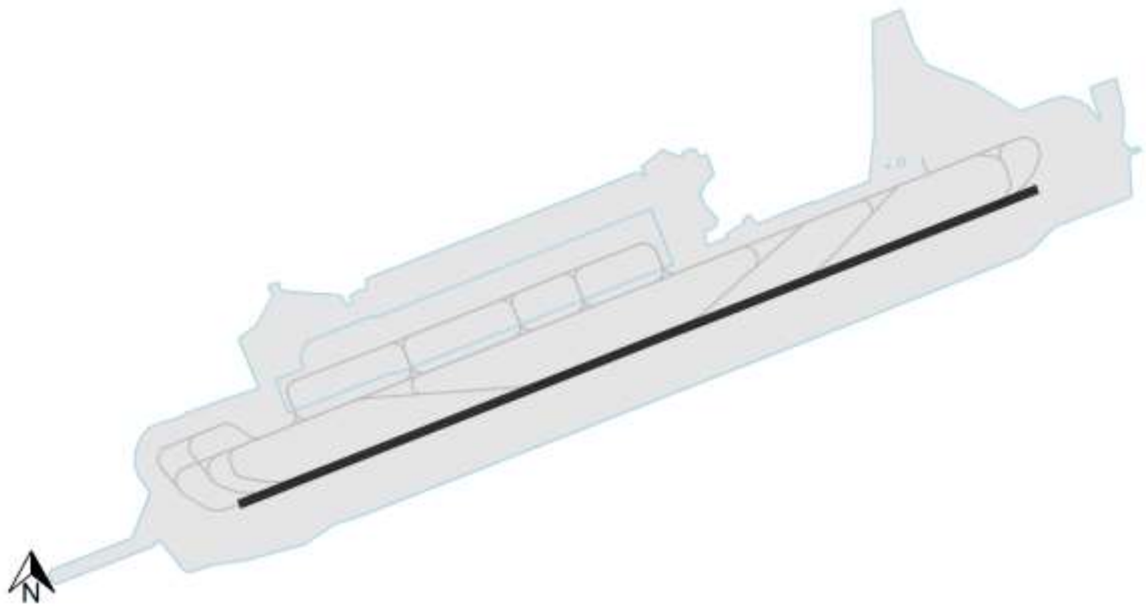



## 47.GCTS (TFS) - Tenerife Sur/Reina Sofia

Tenerife Sur has only one runway operated in both directions in mixed mode and conditions that clearly favour one runway direction utilization (RWY07:95% share). The results shows very similar PSR (only one movement difference) but additional times are higher for RWY25, although with low impact due to the share (5%).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| GCTS | Tenerife Sur/Reina Sofia | 68636 | 2 | 0.03 | 0.01 | 0.95 | 96.72% |

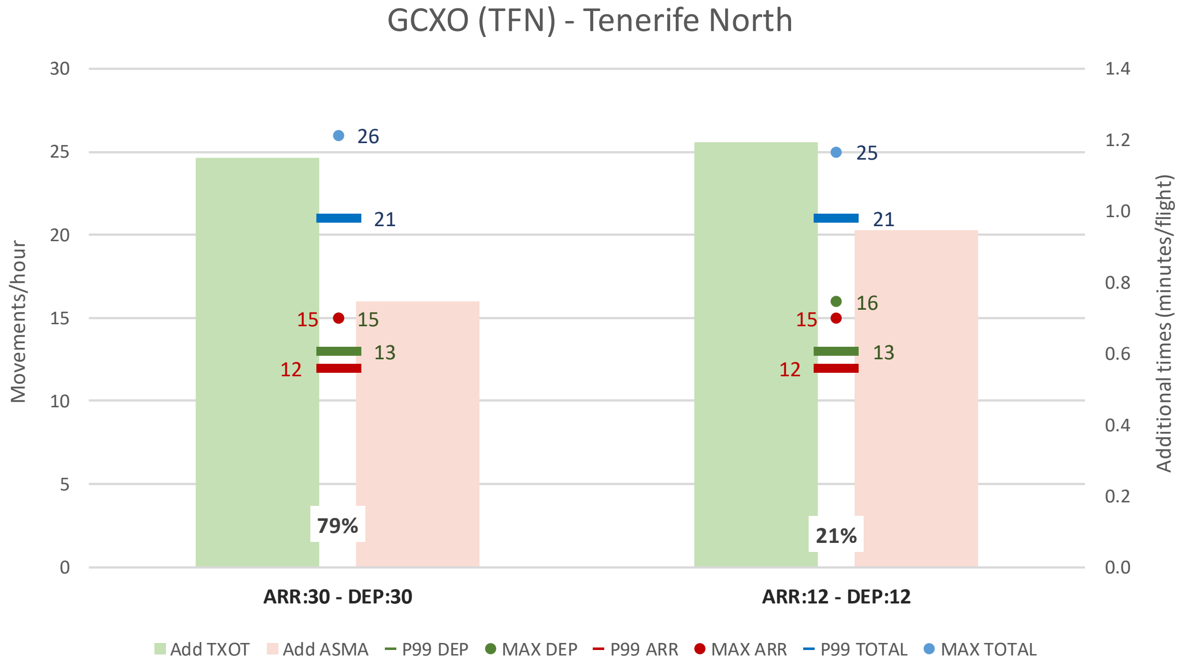


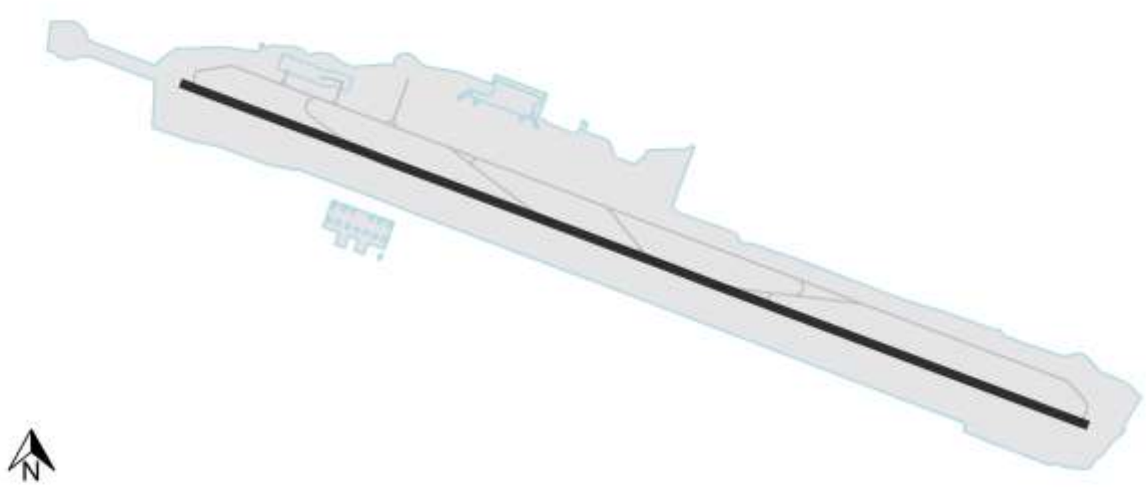



## 48.GCXO (TFN) - Tenerife North

Tenerife North is a single runway airport operated in mixed mode in both directions, being RWY30 the most commonly used (79% share). The PSR is identical for both configurations but additional times are slightly higher for the non preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| GCXO | Tenerife North | 72597 | 2 | 0.01 | 0.04 | 0.00 | 100.00% |

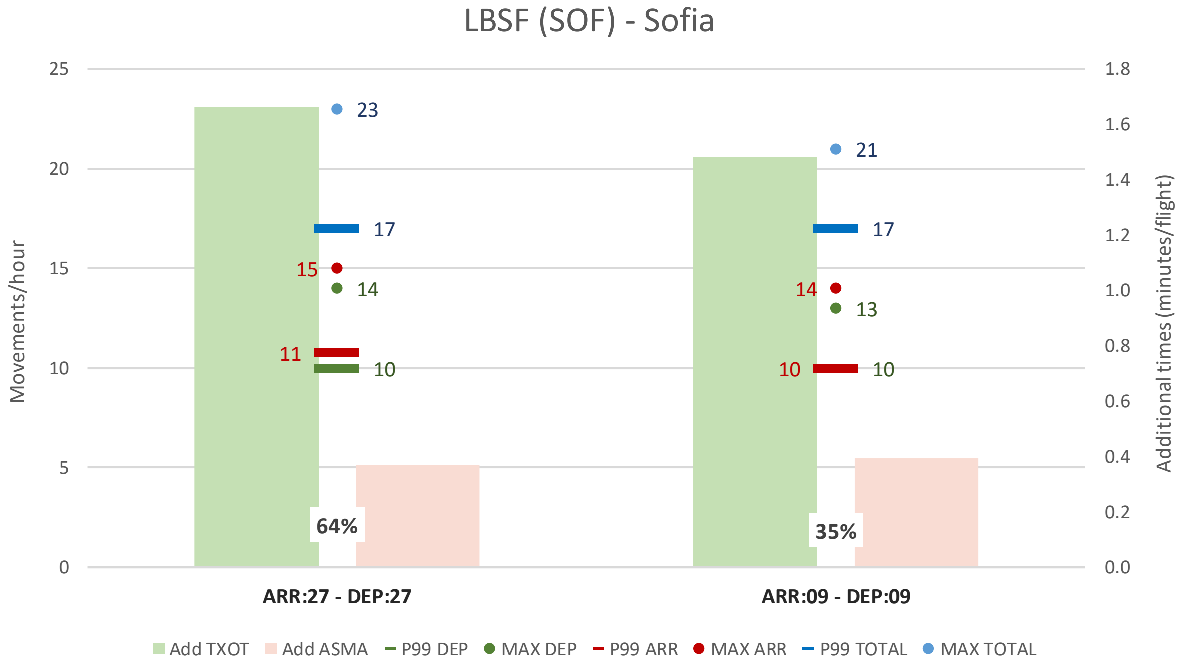


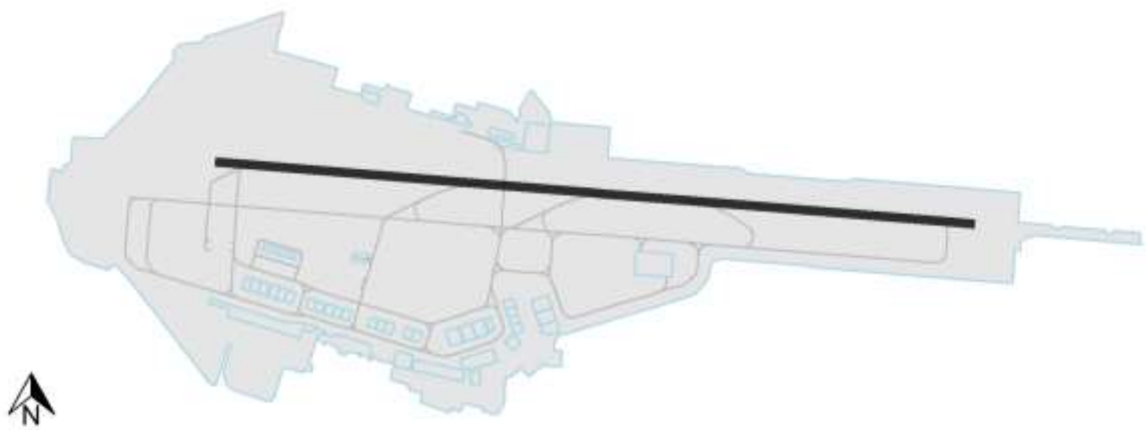



## 49.LBSF (SOF) - Sofia

Sofia operates only one runway (09/27) in both directions mixed mode, with almost identical result in PSR. In terms of performance a slight increase of additional taxi-out times can be observed when using RWY27 (64% share).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LBSF | Sofia | 60266 | 2 | 0.12 | 0.01 | 0.00 | 100.00% |

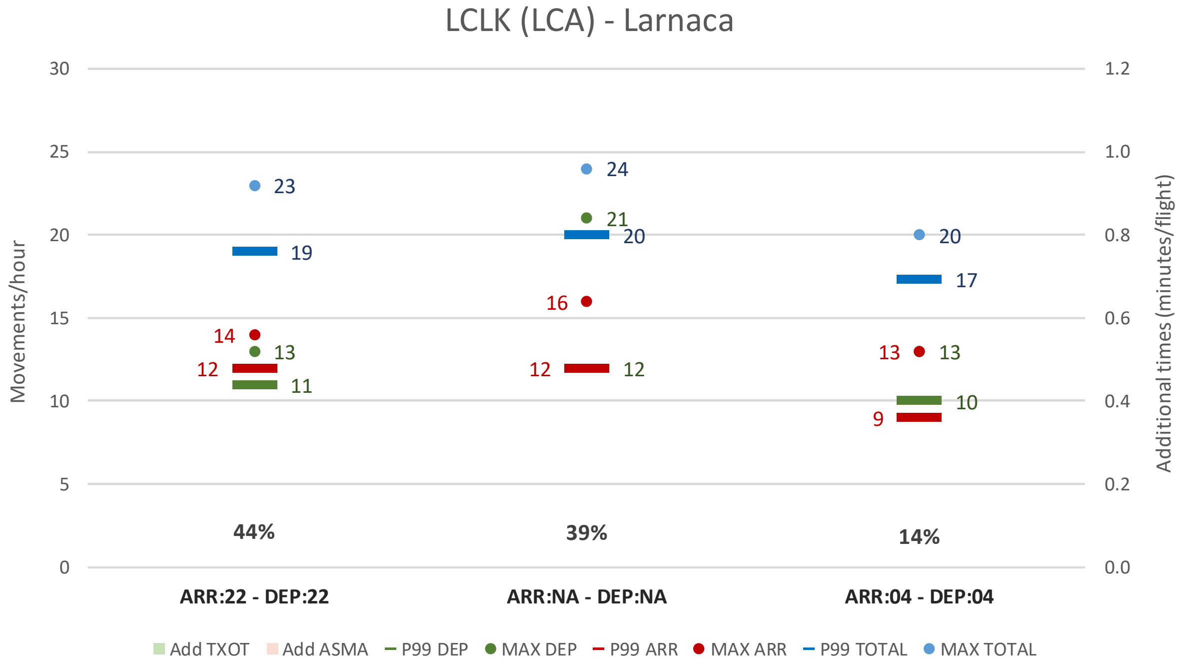


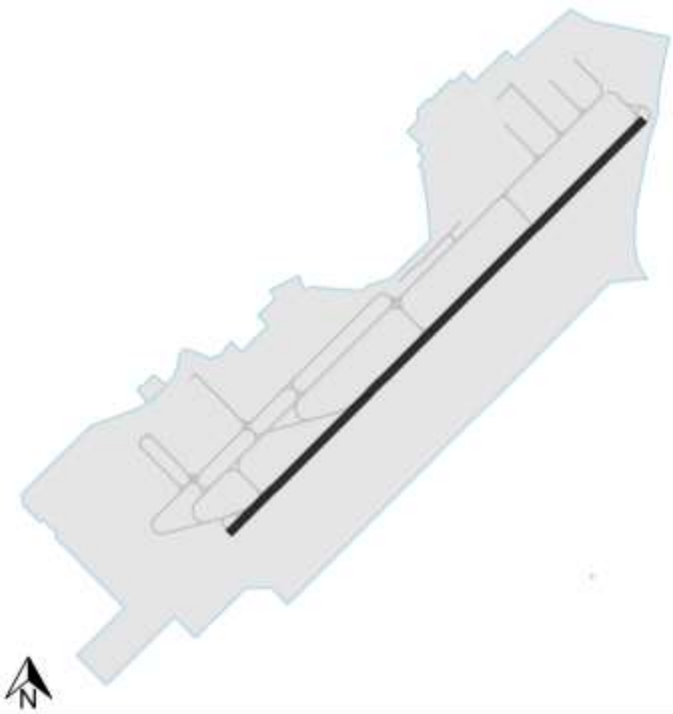



## 50.LCLK (LCA) - Larnaca

The data provided by Larnaca airport does not allow for the calculation of the performance indicators (additional times) and the runway information is missing for 39% of the time, so the analysis in this case cannot be performed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LCLK | Larnaca | 60657 | 3 | | | 0.81 | 97.78% |

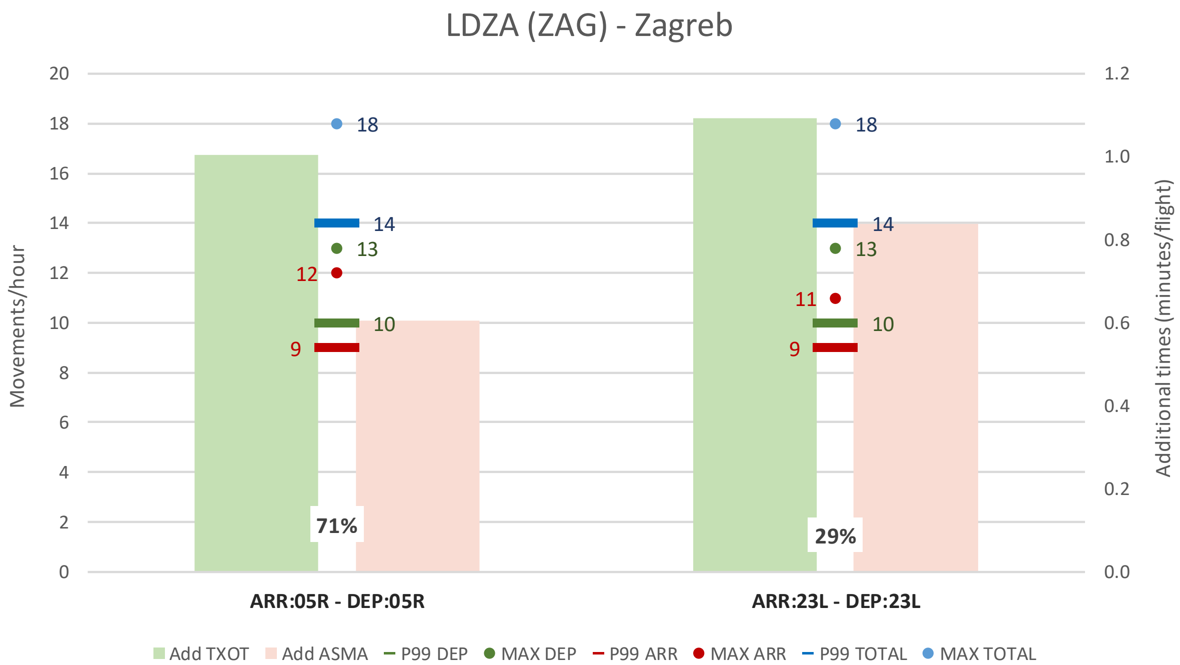


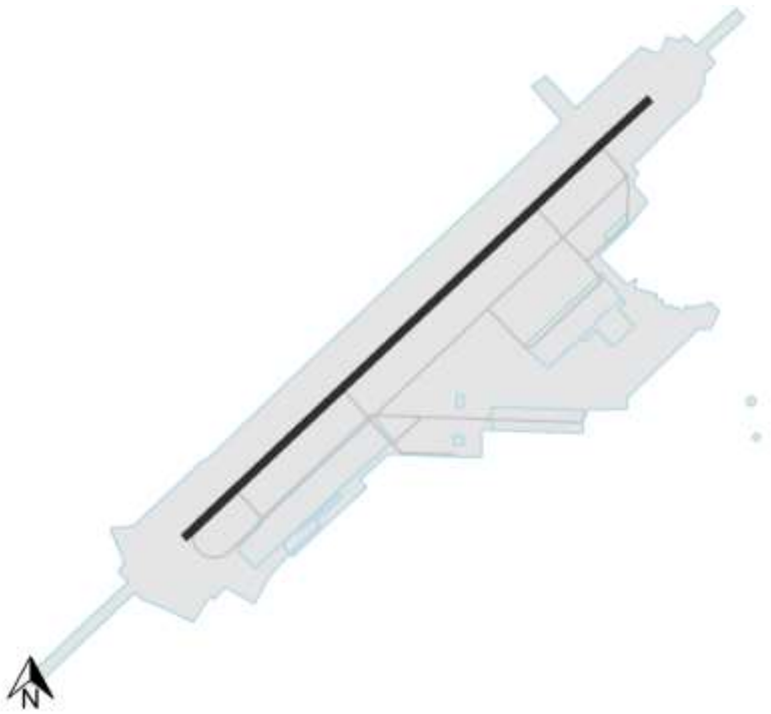



## 51.LDZA (ZAG) - Zagreb

Zagreb is a single runway airport operated in mixed mode in both directions, being RWY05R the most commonly used in 2019 (71% share). The PSR is identical for both configurations but additional times are slightly higher for the non preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LDZA | Zagreb | 44307 | 2 | 0.03 | 0.07 | 0.00 | 100.00% |

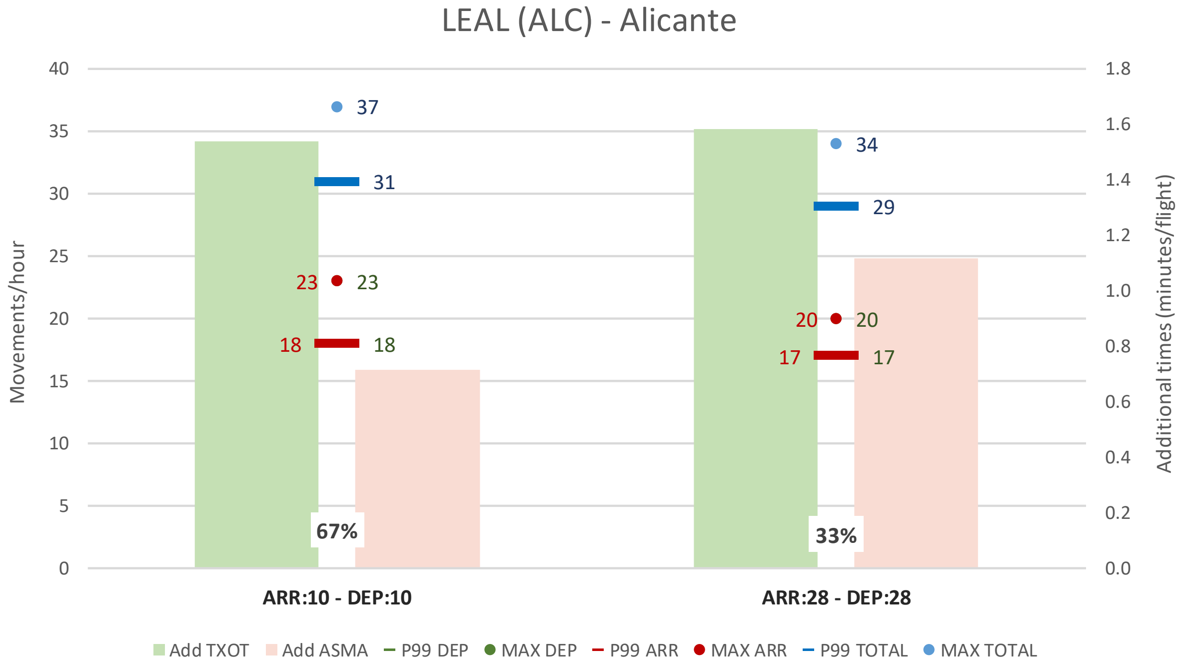


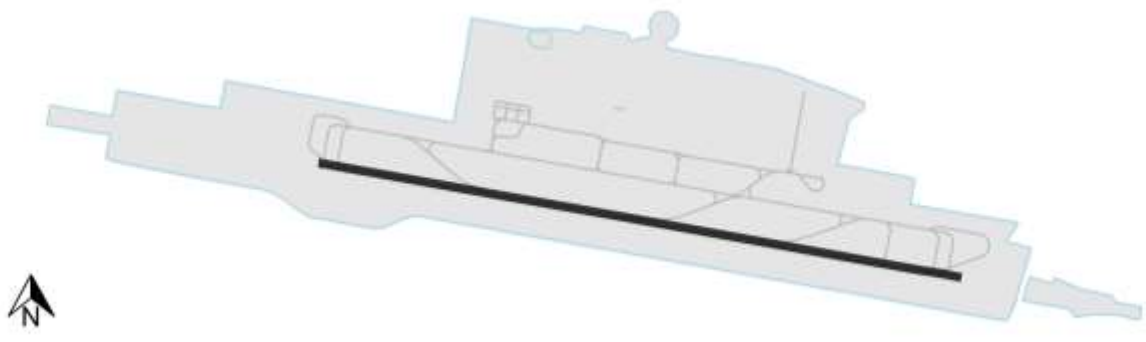



## 52.LEAL (ALC) - Alicante

Alicante has one runway (10/28) that can only be operated in mixed mode in both directions. PSR is 2 movements higher for RWY10 (67% share) and performance in terms of additional taxi-out times is very similar, Additional ASMA time when using RWY28 (33% share) are slightly higher.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEAL | Alicante | 101210 | 2 | 0.01 | 0.13 | 0.65 | 97.89% |

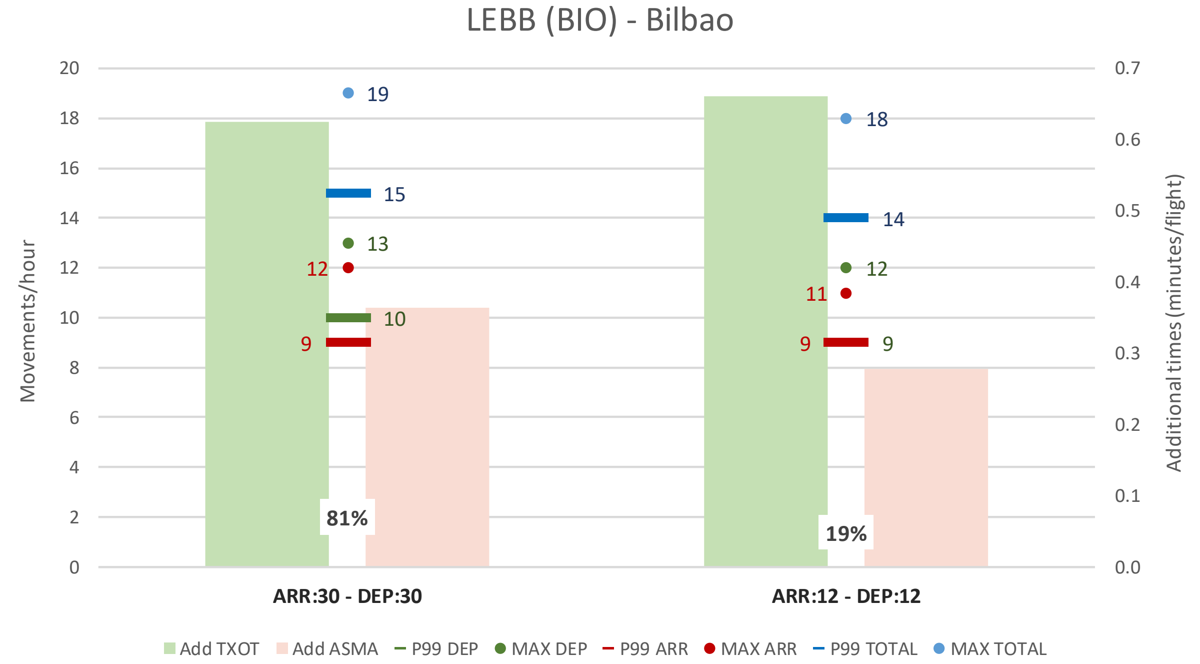


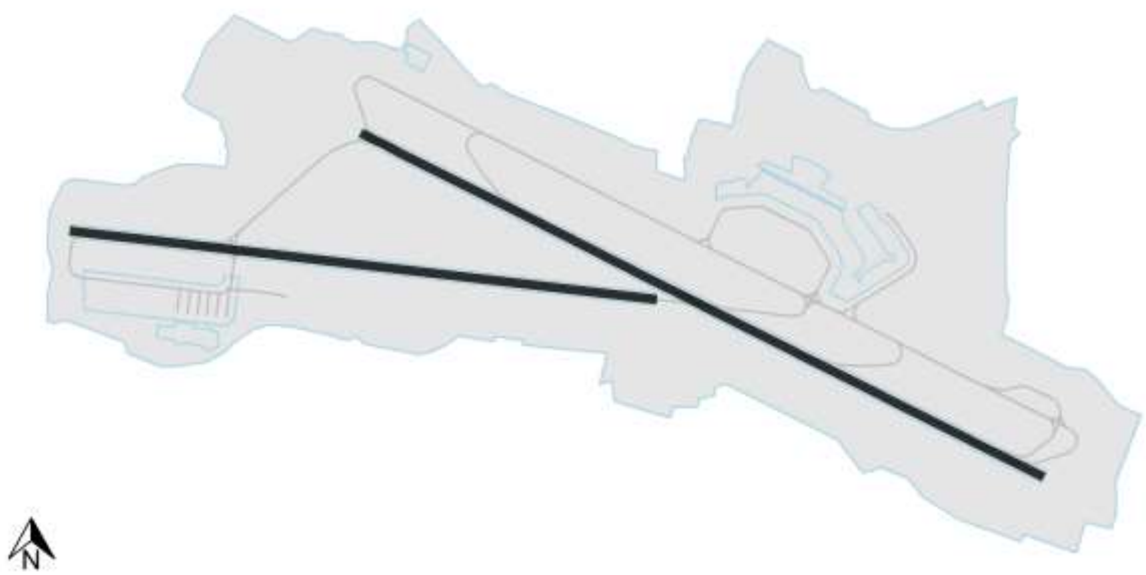



## 53.LEBB (BIO) - Bilbao

Bilbao has two runways but it normally uses only the longest one, operating it in mixed mode in both directions. RWY30 is in use most of the time (81% share). Performance in terms of peak service rate differs in only 1 movement, and RWY30 observed higher additional ASMA times while RWY12 shows higher additional taxi-out times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEBB | Bilbao | 48984 | 2 | 0.01 | 0.07 | 0.19 | 98.74% |

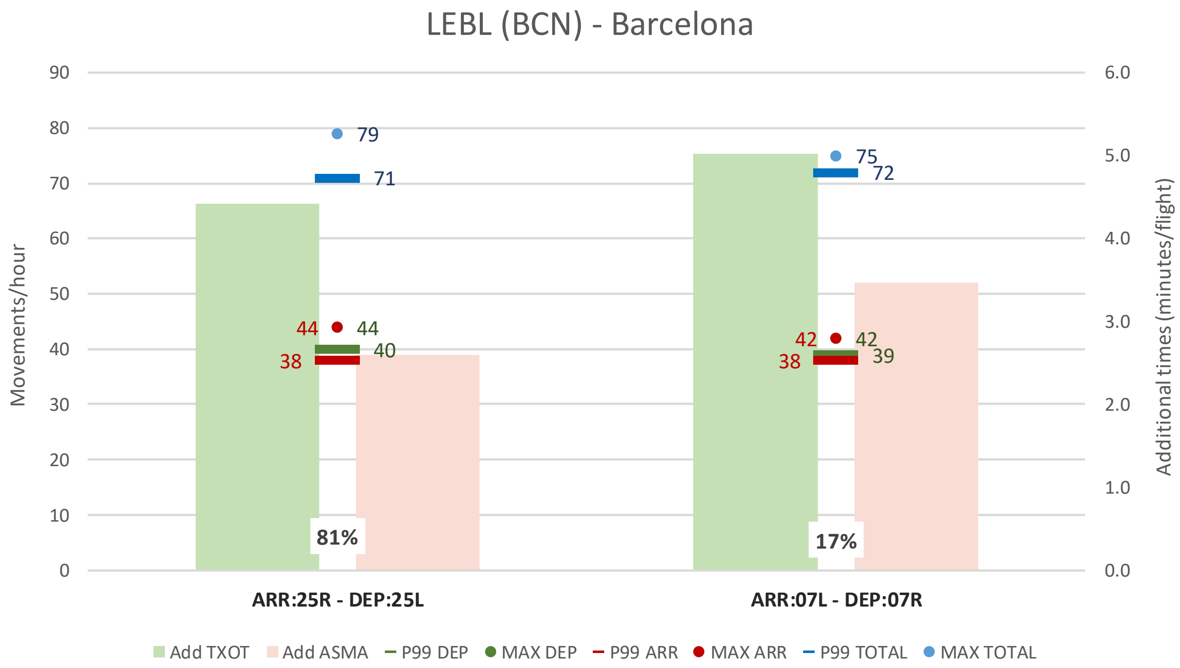


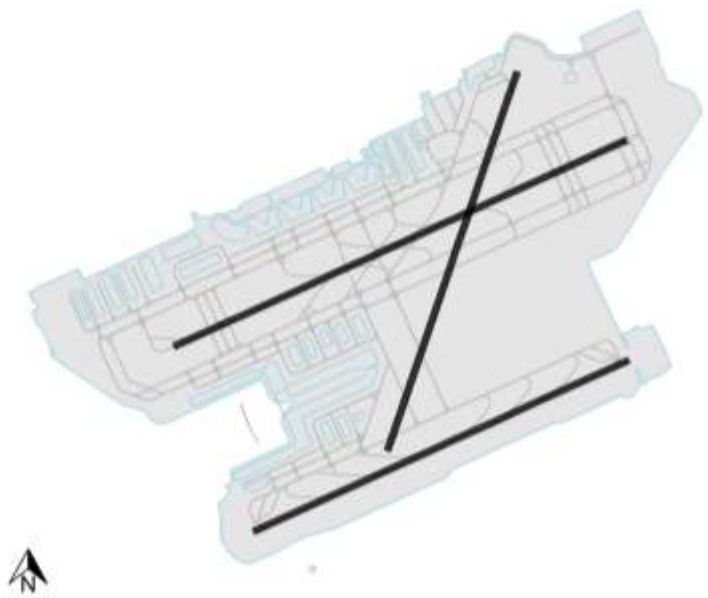



## 54.LEBL (BCN) - Barcelona

Barcelona has two parallel runways and one crossing, this last one normally used only sometimes before 10h and after 19h, not reaching the 3% threshold of representative configurations for the period analysed. The most common use is in segregated mode with a clear preference for direction 25 (ARR:25R-DEP:25L; 81% share). This configuration shows a PSR one movement lower than the opposite direction, but higher maximum throughput and lower additional times both in the approach and in the taxi-out phase.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEBL | Barcelona | 344508 | 2 | 0.10 | 0.15 | 0.81 | 98.87% |

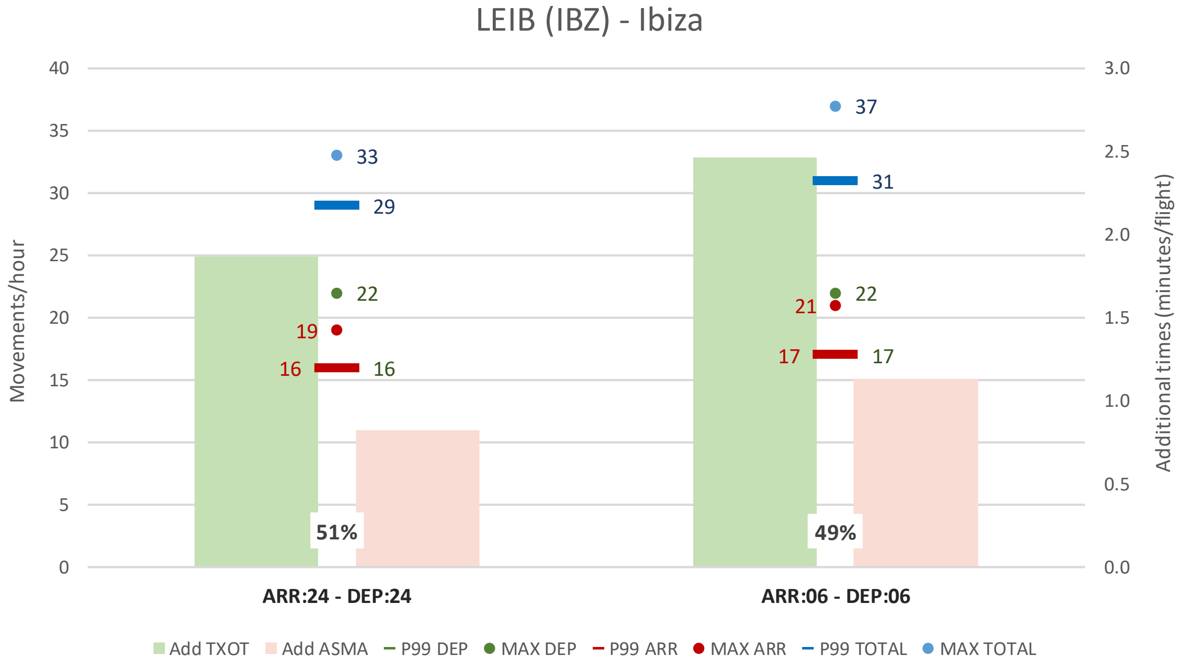


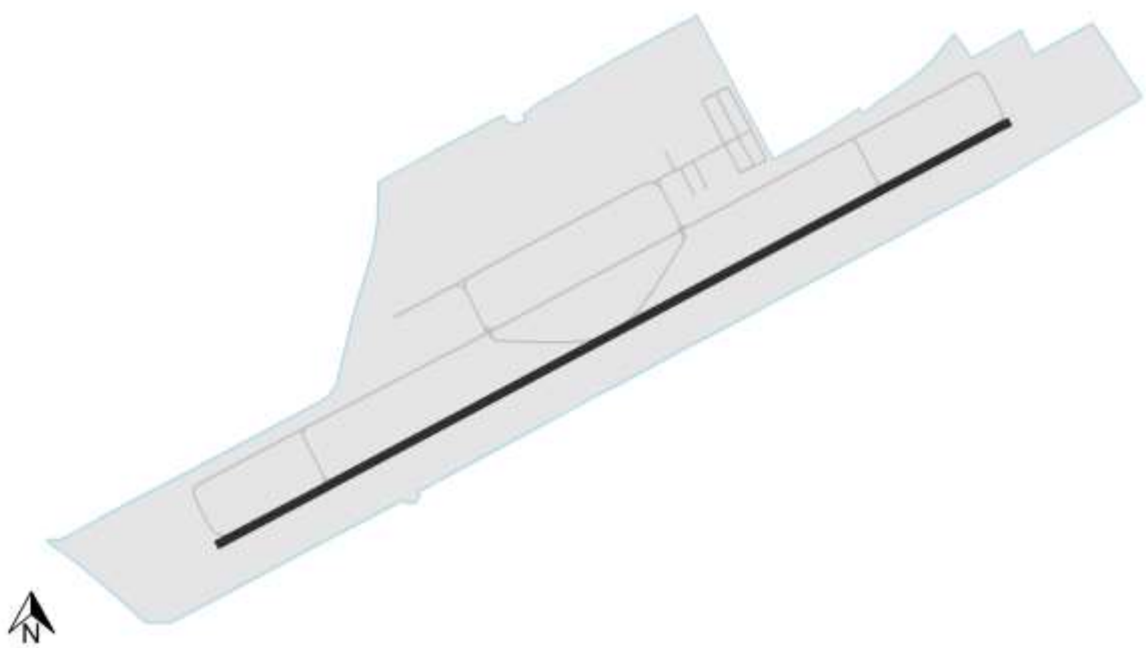



## 55.LEIB (IBZ) - Ibiza

Ibiza is a single runway airport, operated in mixed mode and using equally both runway directions (51%-49%). Performance in terms of peak service rate differs in 2 movements, and although RWY06 shows the highest throughputs, it also shows higher additional ASMA and taxi-out times, which leads to think that it is the configuration that was used when there was higher demand.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEIB | Ibiza | 73356 | 2 | 0.29 | 0.15 | 1.02 | 96.71% |

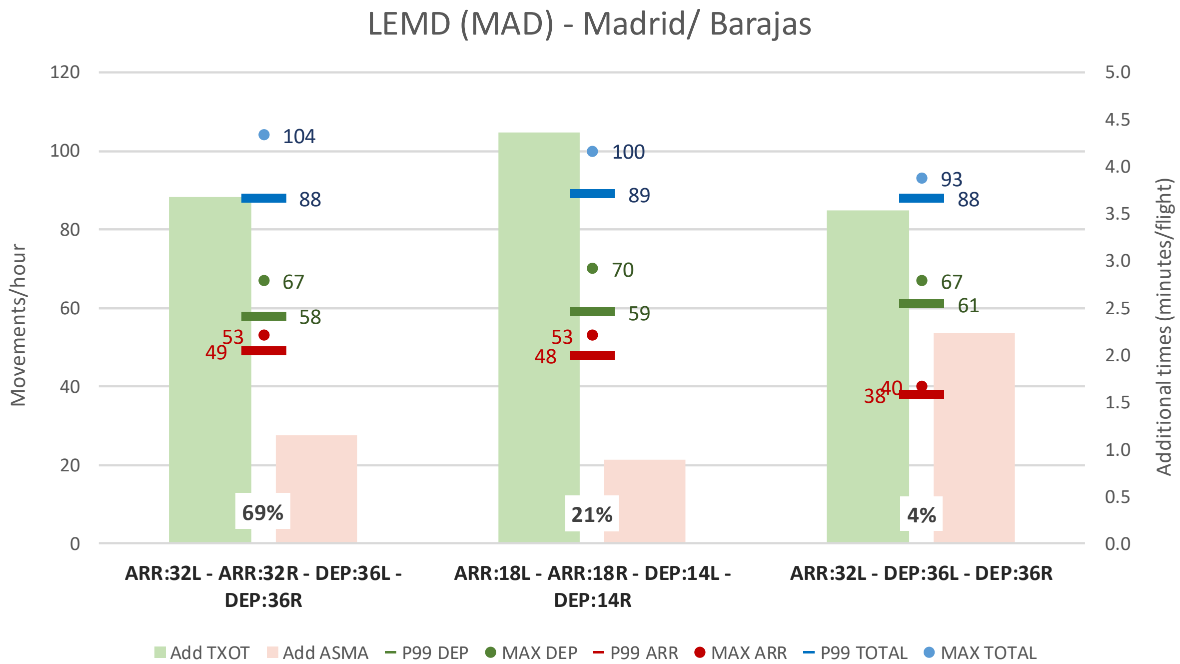


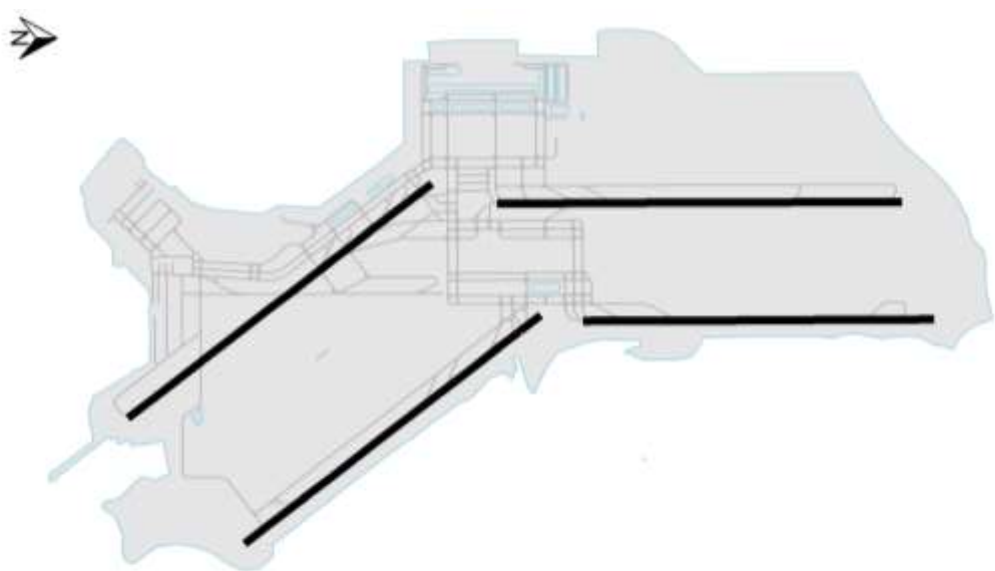



## 56.LEMD (MAD) - Madrid/ Barajas

Madrid has four runways , parallel two by two and operated in independent mode. The North configuration is the preferred one (ARR:32L;ARR:32R-DEP36L;DEP36R; 69% share). The PSR differs between configurations in one movement, but the significant difference between the maximum throughput and the PSR signals the capacity might be higher than the percentile 99. In terms of additional times, the best combined performance is found for the preferred configuration, having the South configuration the worst additional taxi-out times and the configuration ARR:32L-DEP36L;DEP36R almost triple the additional ASMA times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEMD | Madrid/ Barajas | 426185 | 3 | 0.27 | 0.24 | 0.73 | 99.23% |

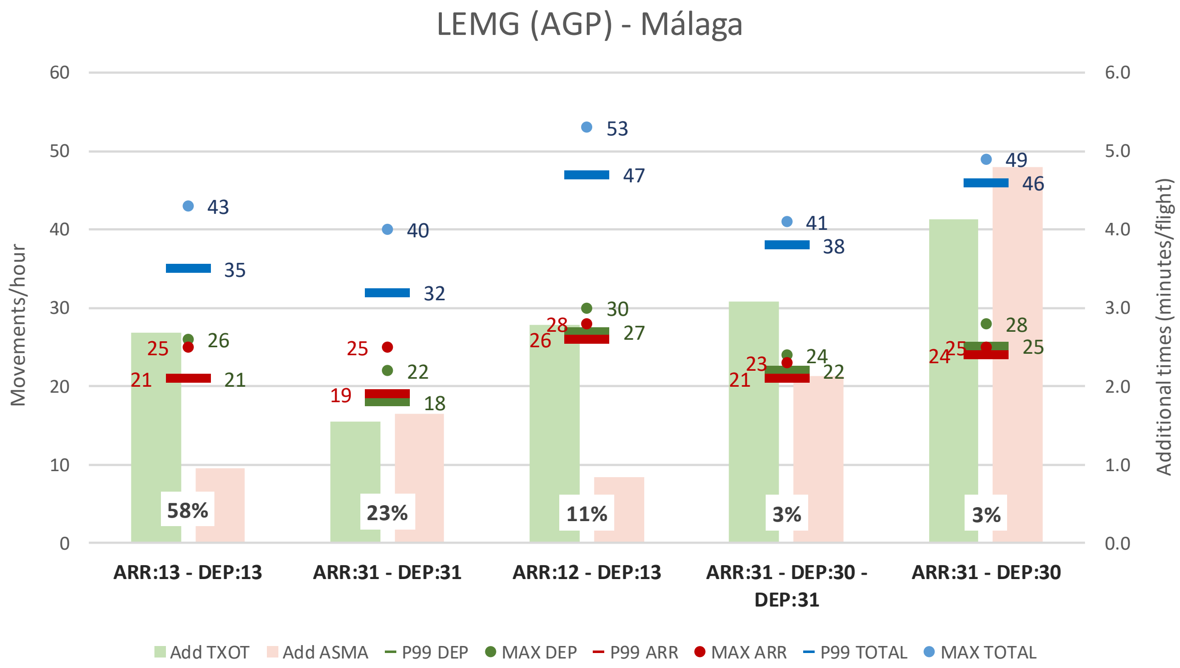


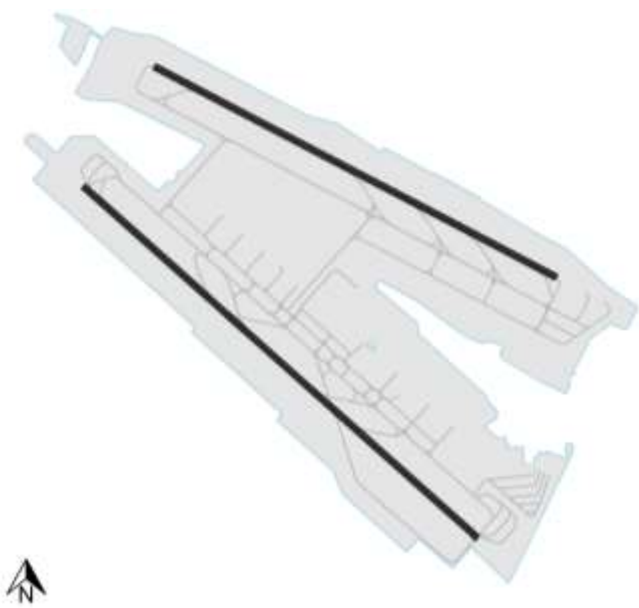



# 57.LEMG (AGP) - Málaga

Málaga has two non parallel runways, but for 81% of the time the airport is operated as a single runway in mixed mode using only RWY13/31. Being a seasonal airport is is clear that for most of the time the single runway use does not pose a problem, and although for these configurations the throughput is much lower, it is probably just due to the lack of demand. For the segregated use configurations, there are two (ARR:12-DEP:13 and ARR:31-DEP30) that have the highest peak service rates (only one movement difference) but a significant imbalance in terms of additional times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEMG | Málaga | 140721 | 5 | 0.93 | 0.42 | 10.86 | 85.10% |

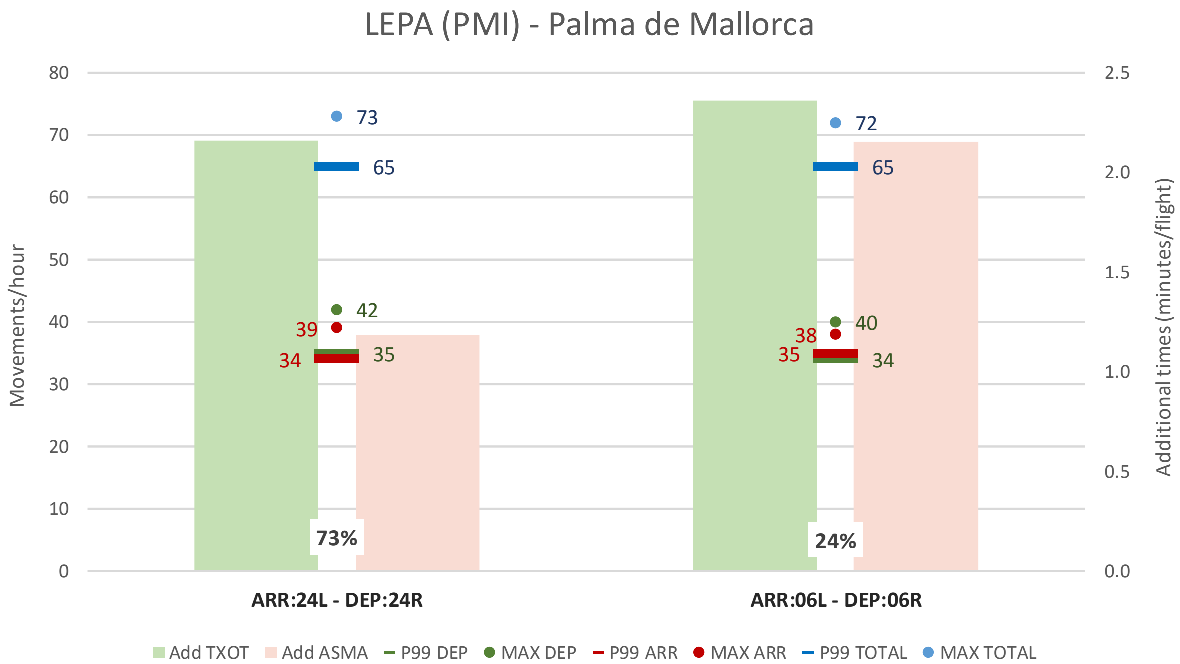


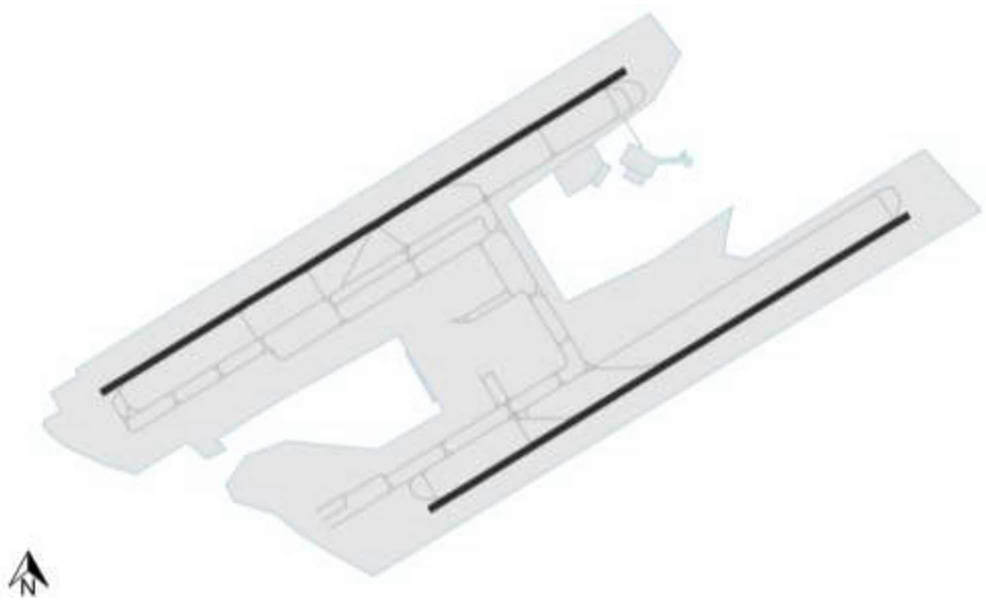



## 58.LEPA (PMI) - Palma de Mallorca

Palma de Mallorca has two parallel runways most generally used in segregated mode, being direction 24 the preferred one (73% share). The PSR is almost identical for both configurations but performance in terms of additional times is clearly better for configuration ARR:24L-DEP:24R, especially in the approach. Being the most seasonal airport in the study, it would be interesting to analyse the PSR only for the busiest months, that would probably be a better indication of the actual capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEPA | Palma de Mallorca | 217096 | 2 | 0.05 | 0.23 | 0.00 | 100.00% |

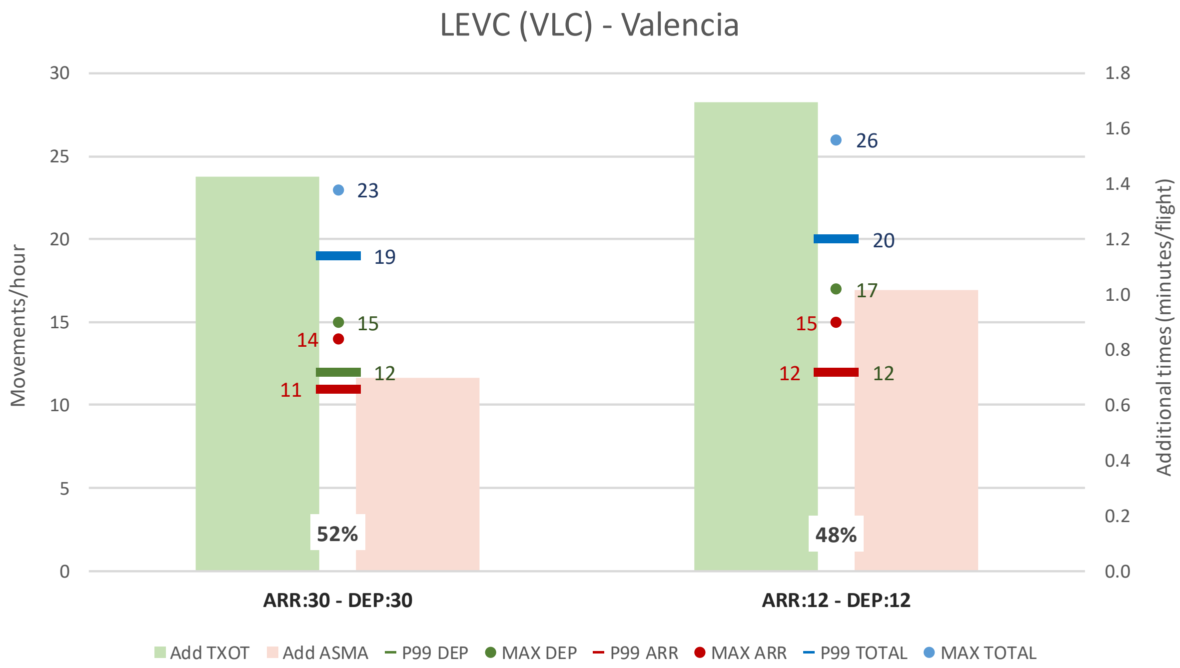


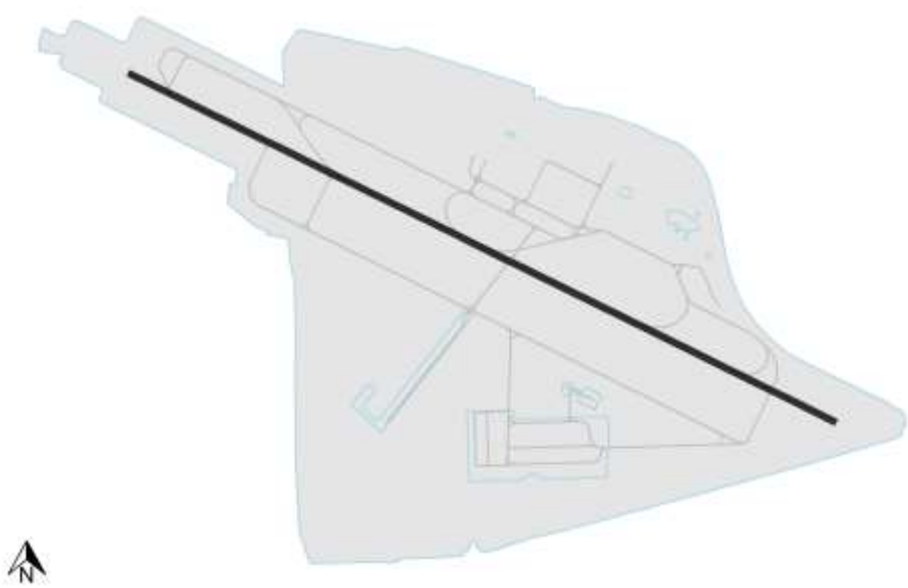



## 59.LEVC (VLC) - Valencia

Valencia is a single runway airport, operated in mixed mode and using almost equally both runway directions (52%-48%). Performance in terms of peak service rate differs in one movement, and although RWY12 shows the highest throughputs, it also shows higher additional ASMA and taxi-out times, which leads to think that it is the configuration that was used when there was higher demand.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEVC | Valencia | 72464 | 2 | 0.13 | 0.15 | 0.52 | 97.39% |

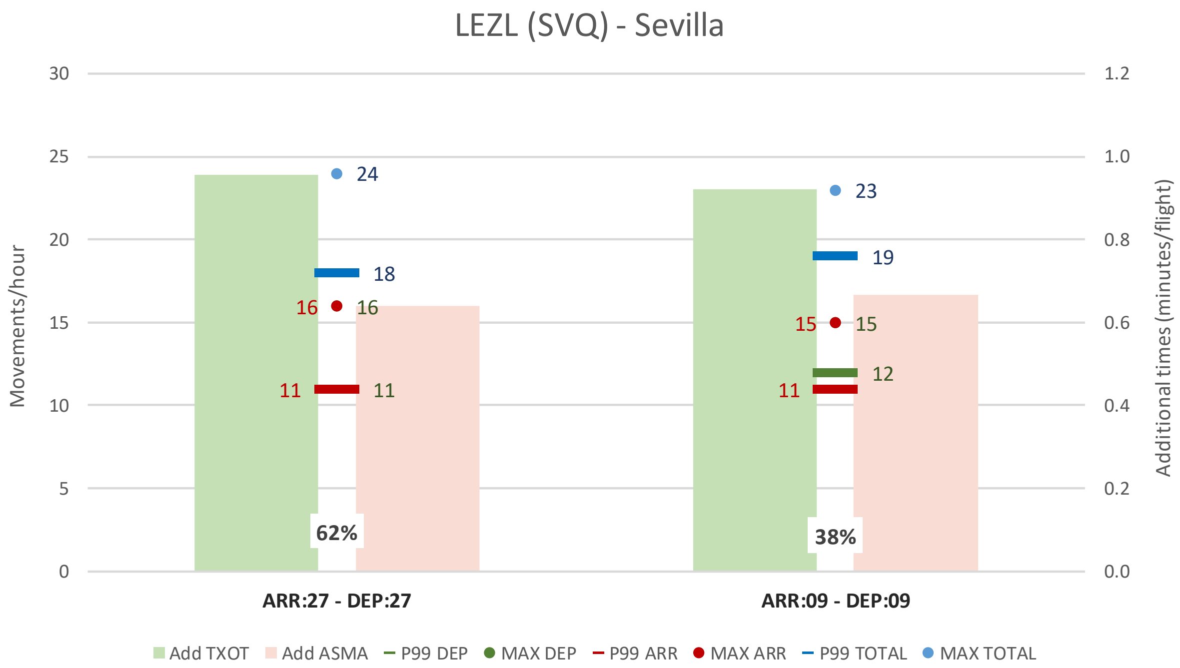


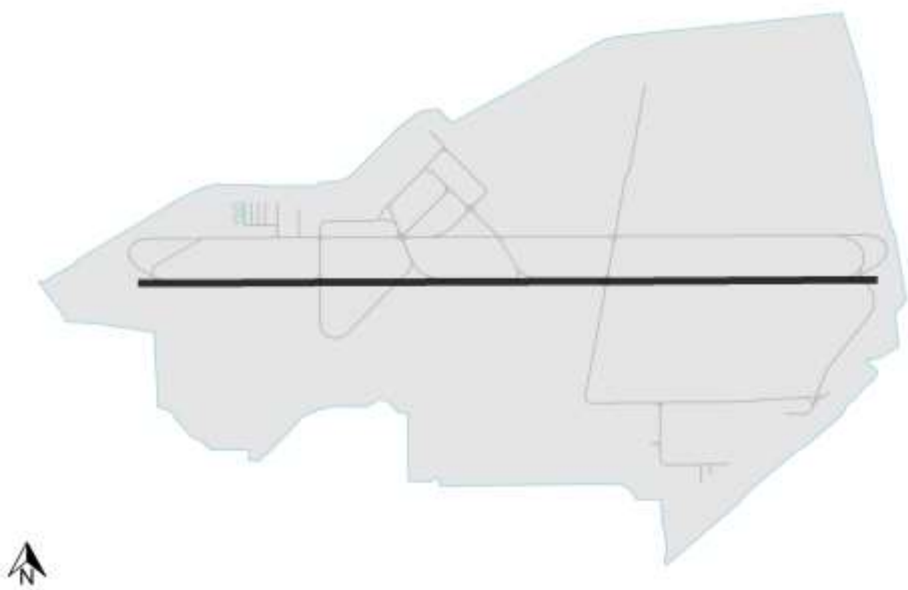



## 60.LEZL (SVQ) - Sevilla

Sevilla is a single runway airport, operated in mixed mode in both directions. The peak service rate for both runway directions differs in one movement, but performance in terms of additional times is nearly identical, showing no real imbalance.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LEZL | Sevilla | 58721 | 2 | 0.02 | 0.01 | 0.62 | 96.73% |

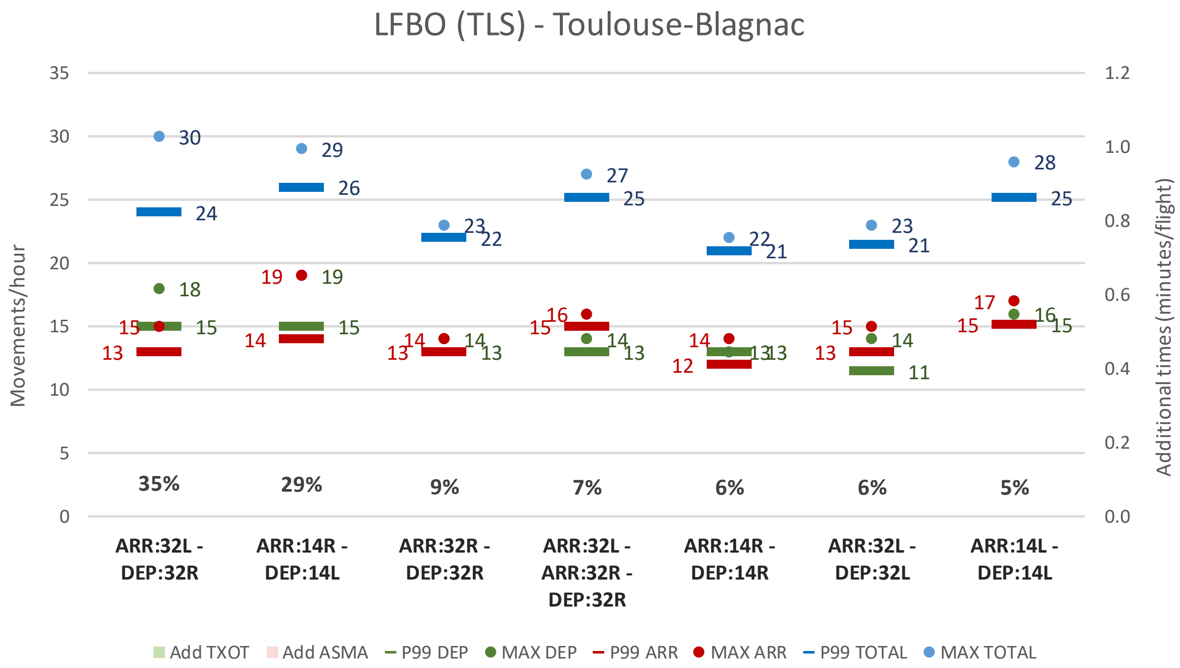


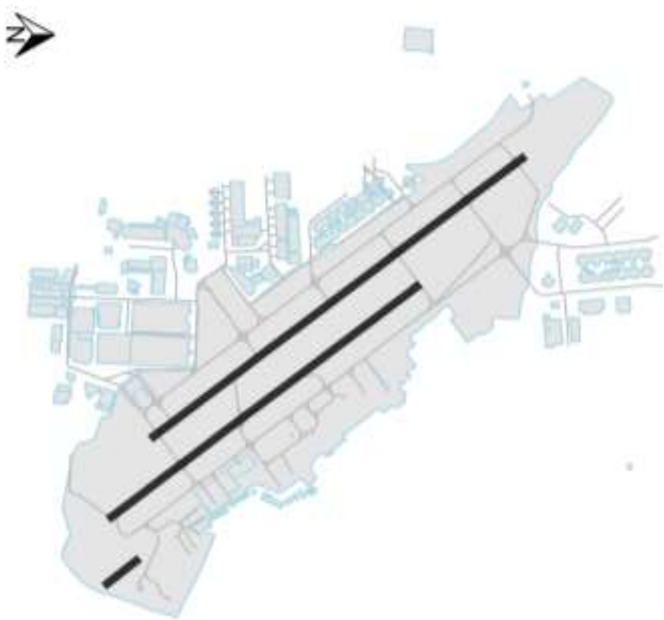



## 61.LFBO (TLS) - Toulouse-Blagnac

Toulouse airport has two parallel runways (plus one helipad) operated in several different ways, from segregated to single runway use in mixed mode, being the share quite distributed in 7 configurations. There are several movements difference in throughput between configurations and the highest PSR value is observed for conf ARR:14R-DEP:14L (29% share).The data provision from Toulouse does not allow the analysis of the additional times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFBO | Toulouse-Blagnac | 95665 | 7 | | | 1.76 | 97.29% |

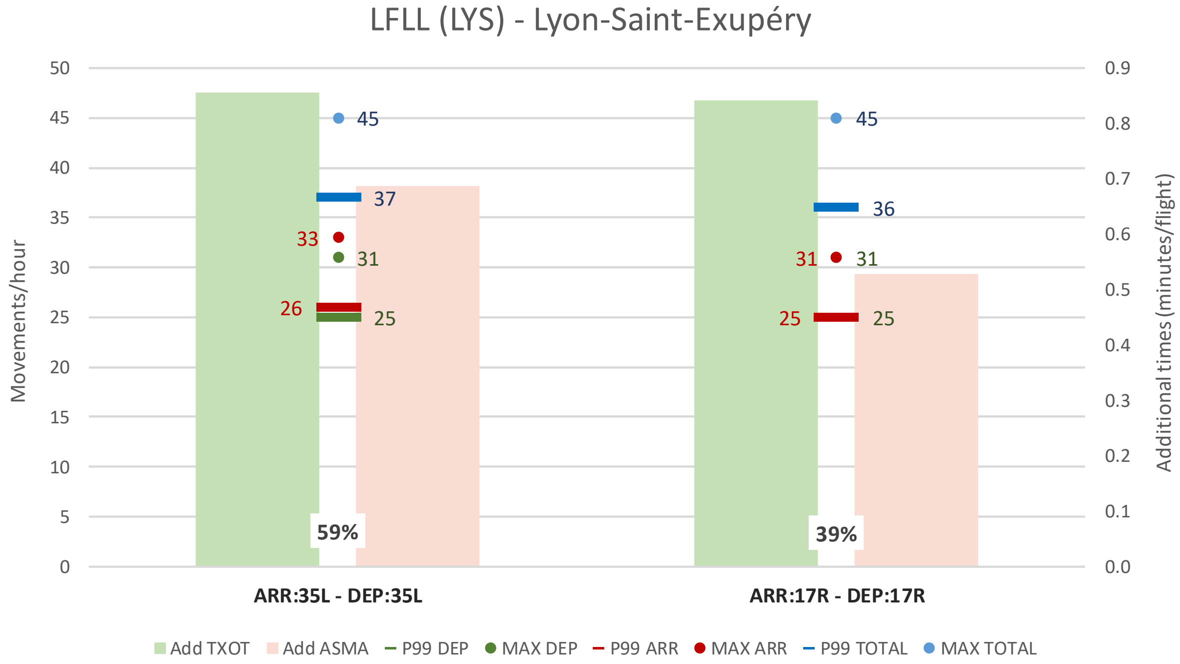


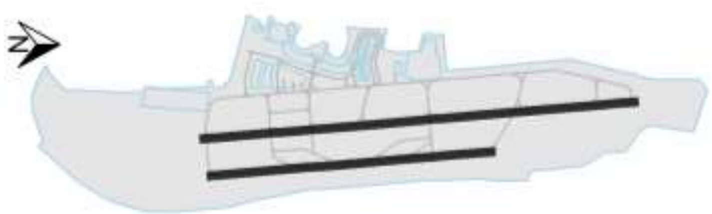



## 62.LFLL (LYS) - Lyon-Saint-Exupéry

Lyon has two parallel runways but it normally operates only the longest one in mixed mode, in either direction. The PSR only differs in one movement, and performance in terms of additional times is very similar, with only slightly higher additional ASMA times for RWY 35L (59% share). The usage of only one runway plus the deviation between PSR and maximum throughput signal that congestion might be too low to consider the PSR a good proxy for capacity.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFLL | Lyon-Saint-Exupéry | 116451 | 2 | 0.01 | 0.09 | 0.39 | 98.95% |

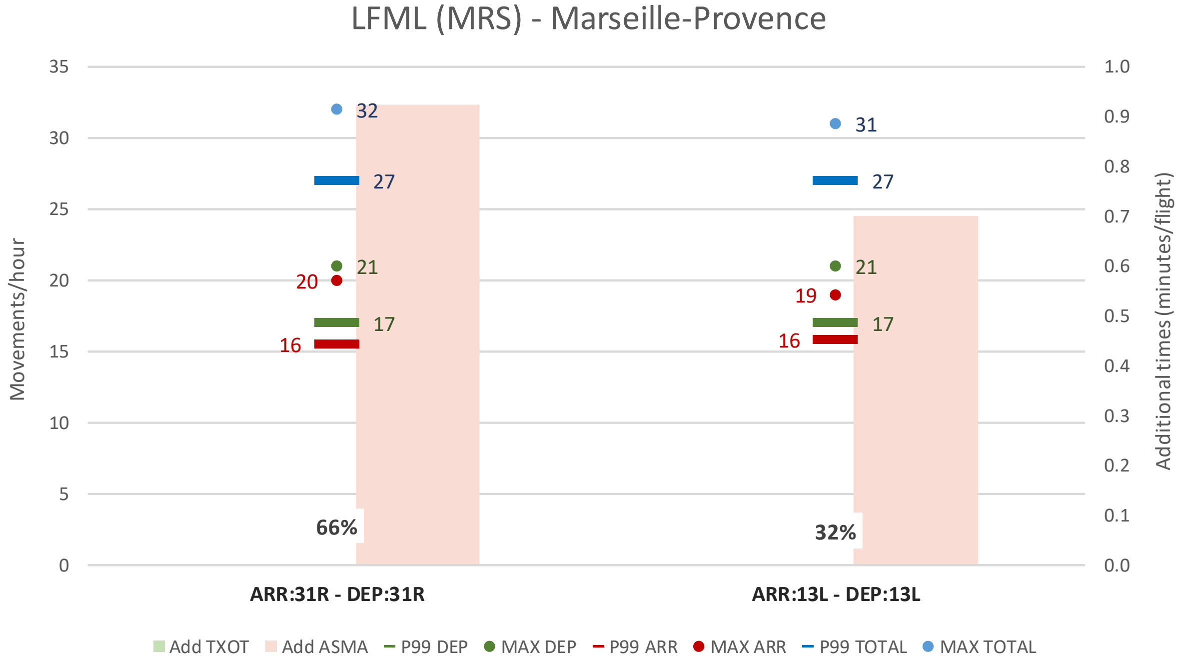


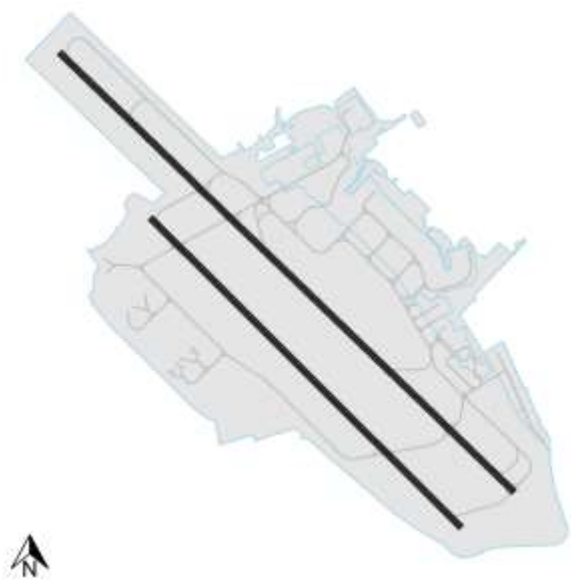



## 63.LFML (MRS) - Marseille-Provence

Marseille has two parallel runways but like Lyon it normally operates only the longest one in mixed mode, in both directions. Performance in terms of PSR is identical with slightly higher additional ASMA times for RWY 31R (66% share). The data provision from Marseille does not allow for the analysis of the additional taxi-out times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFML | Marseille-Provence | 102011 | 2 | | 0.15 | 0.00 | 100.00% |

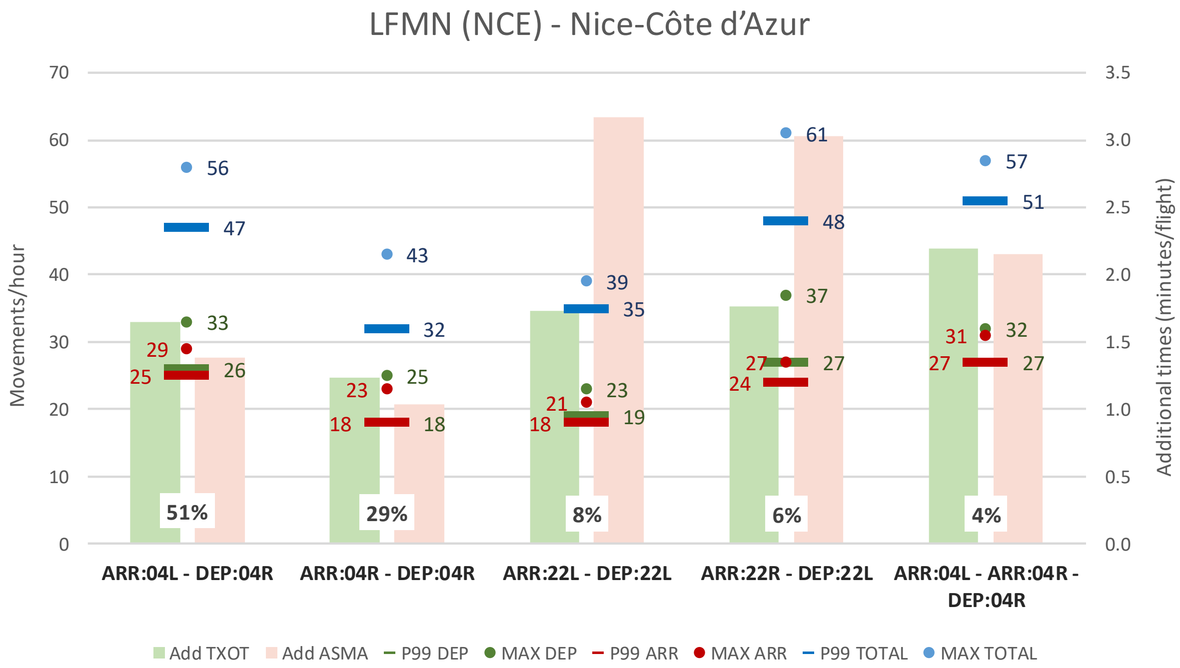


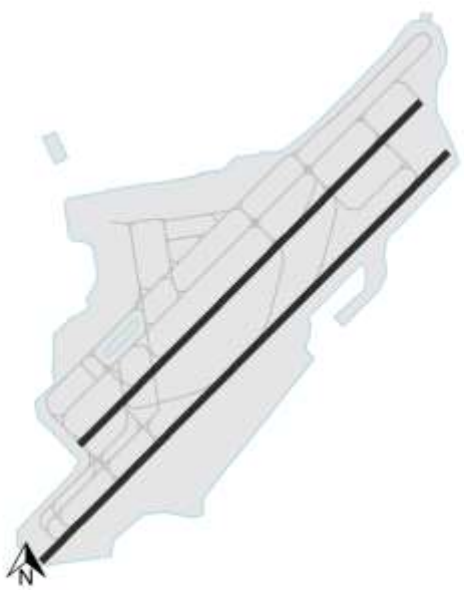



## 64.LFMN (NCE) - Nice-Côte d'Azur

Nice airport has two parallel runways operated in several different ways, from segregated to single runway use in mixed mode, with very different results in throughput. However it is important to consider the high seasonality of Nice, and in fact the most common single runway use (RWY04R; 29% share) shows the lowest PSR but a significantly higher maximum throughput and the best performance in terms of additional times, so it is probably a configuration used in low demand. The two condigurations using the direction 22 show much higher additional times in the approach.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFMN | Nice-Côte d'Azur | 145645 | 5 | 0.33 | 0.52 | 8.99 | 89.15% |

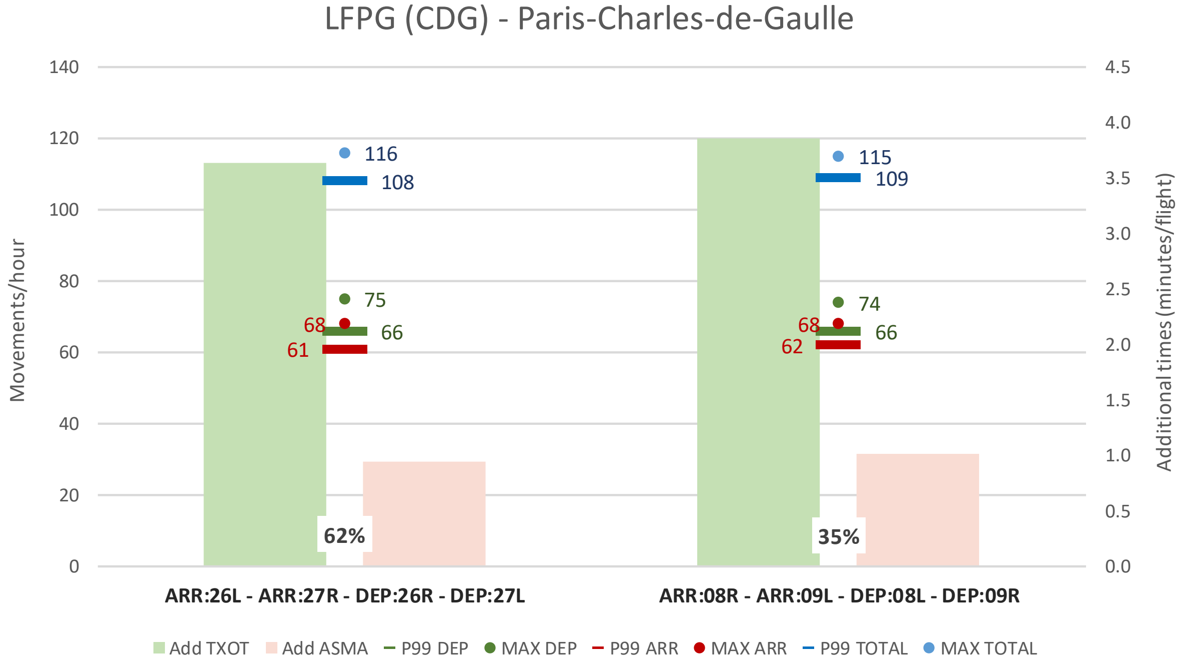


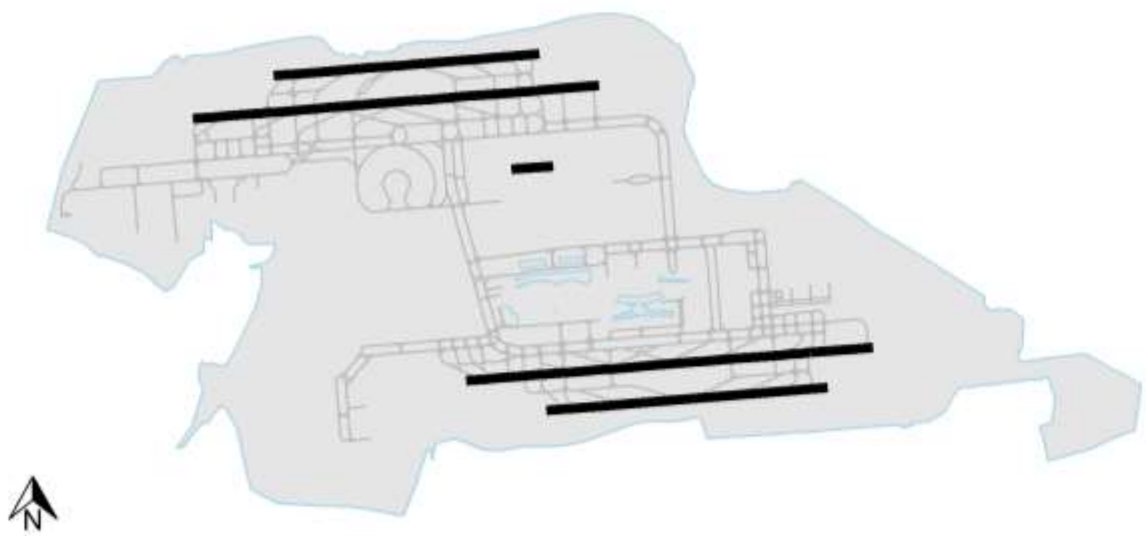



## 65.LFPG (CDG) - Paris-Charles-de-Gaulle

Paris Charles de Gaulle has 4 runways, almost parallel that are used as two independent sets of two runways operating in segregated mode. The longest runways are always used for departures and the shortest for arrivals. The capacity is nearly symmetric according to the results and the performance in terms of additional times is also very similar for both configurations.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFPG | Paris-Charles-de-Gaulle | 504887 | 2 | 0.08 | 0.03 | 0.62 | 99.43% |

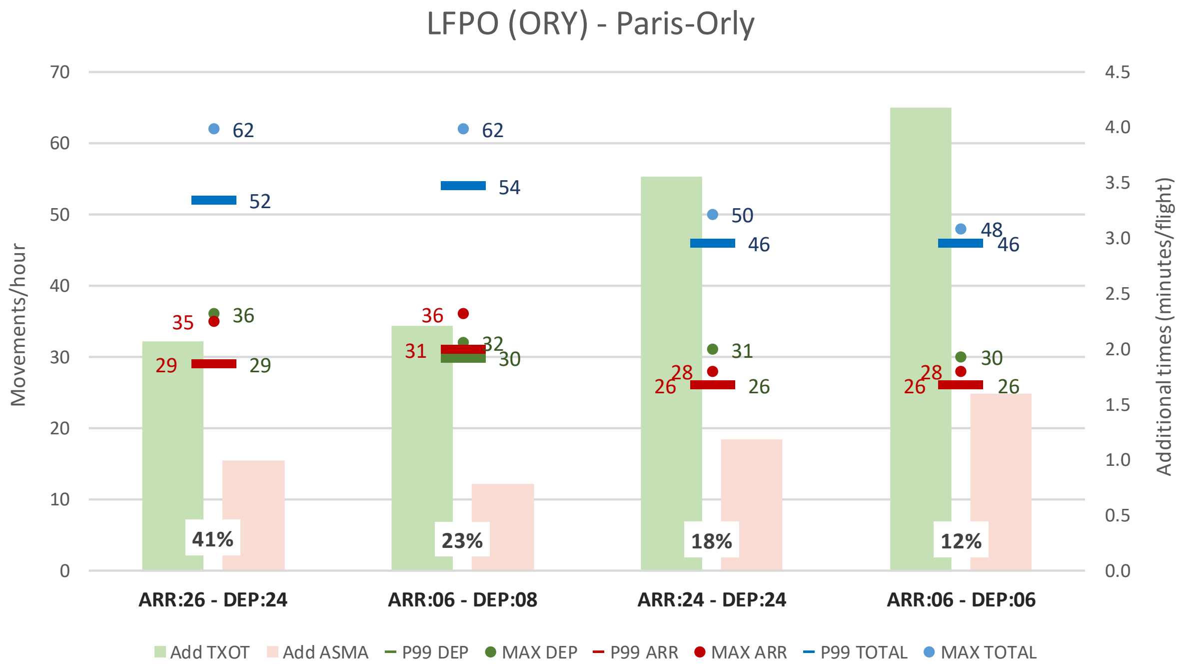


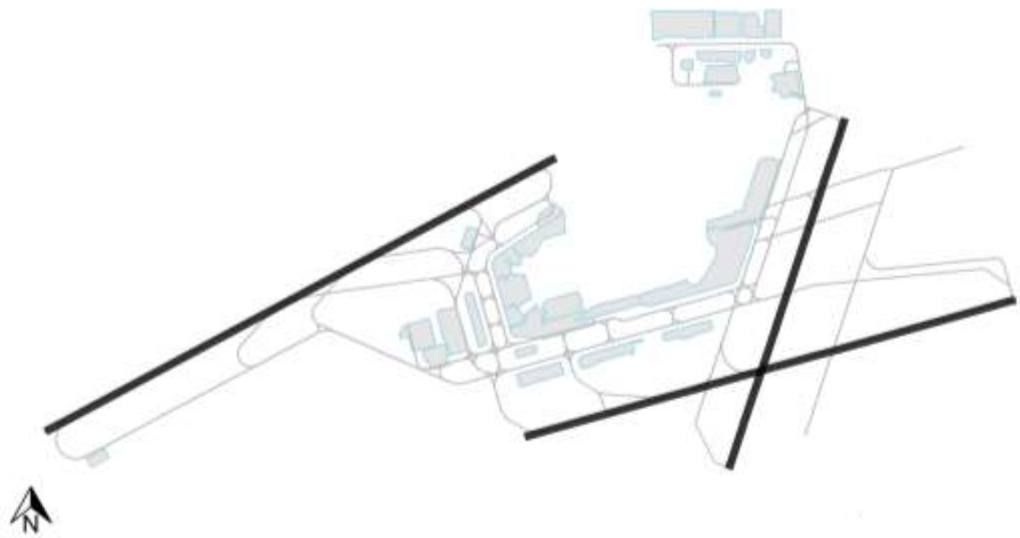



## 66.LFPO (ORY) - Paris-Orly

Paris Orly has three runways, from which RWY02/20 is operated only in exceptional circumstances. During the second part of the year the runway 08/26 was completely rebuilt, deeply affecting the normal operating conditions of the airport and consequently the results of this study. Taking the entire year into account, the most common use is the segregated modes ARR:26-DEP:24 (41% share) and ARR:06-DEP:08 (23% share), but of course due to the runway closure the single runway use in mixed mode also appears as representative. Although the schedule was adapted and reductions were coordinated during the period of the works, the impact of the single runway use and the works is clear in terms of additional taxi-out and ASMA times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFPO | Paris-Orly | 221602 | 4 | 0.54 | 0.25 | 3.18 | 97.41% |

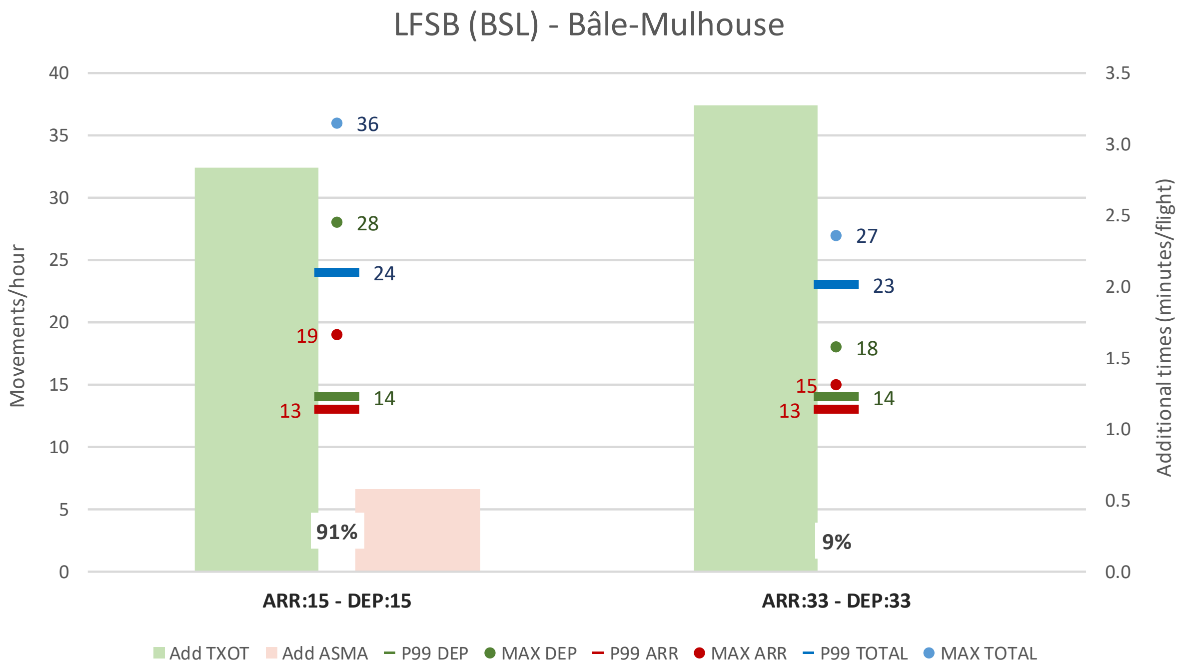


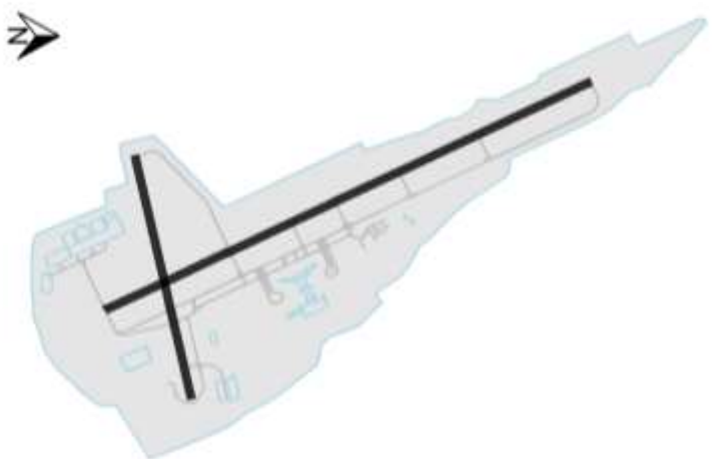



## 67.LFSB (BSL) - Bâle-Mulhouse

Bâle-Mulhouse has two crossing runways but one is too short so it normally uses only the longest one, operating it in mixed mode in both directions. RWY15 is used 91% of the time in 2019, showing a PSR 1 movement higher than the opposite direction, but this difference is minimized by the share and the resilience remains high. Nevertheless, the additional ASMA times are higher for this configuration, while additional taxi-out times are lower.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LFSB | Bâle-Mulhouse | 84560 | 2 | 0.04 | 0.52 | 0.09 | 99.63% |

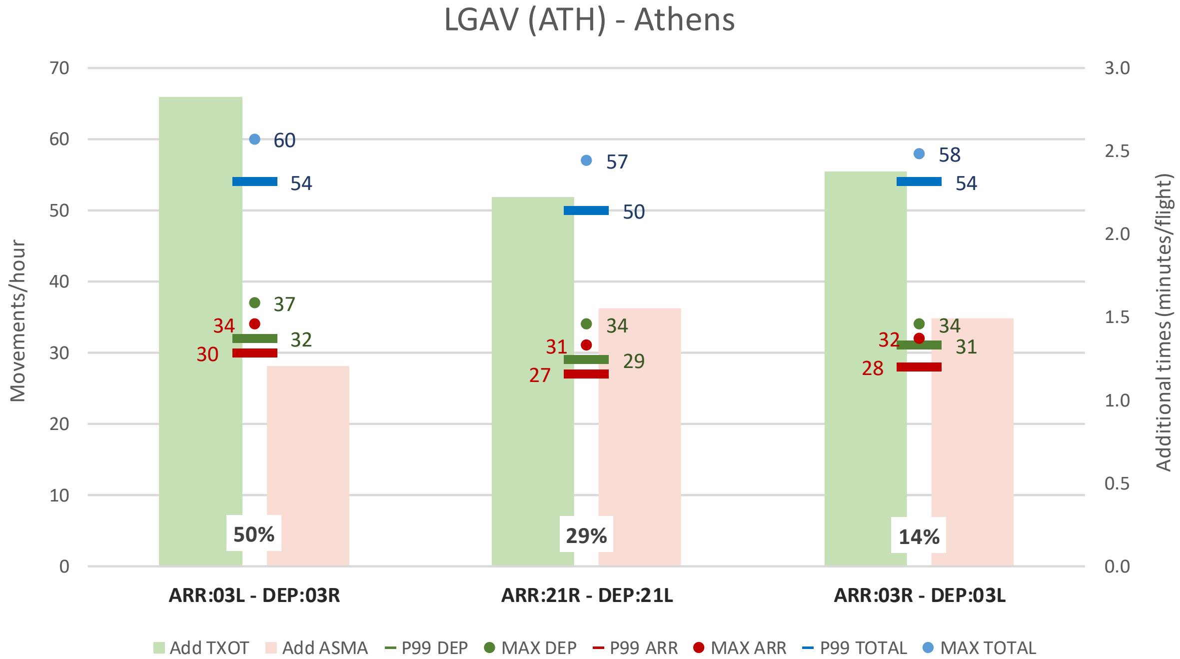


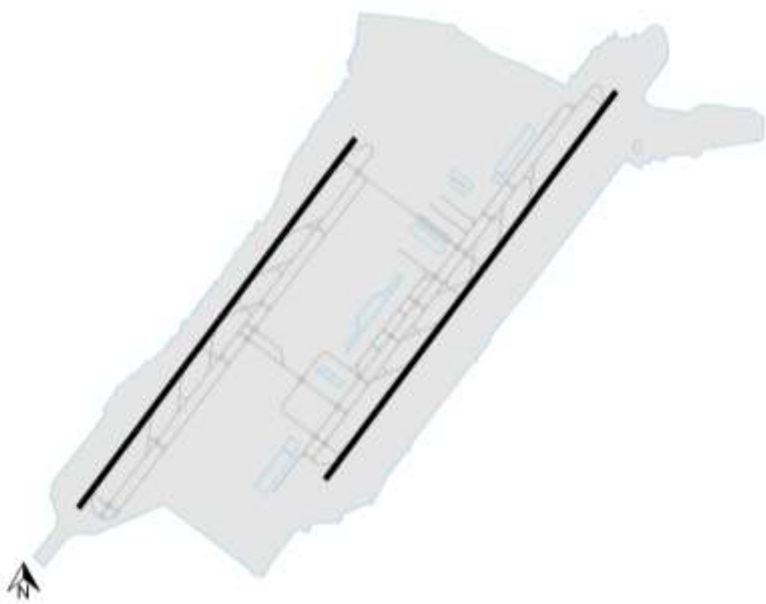



## 68.LGAV (ATH) - Athens

Athens has two parallel runways operated in segregated mode, with three representative runway configurations. The most common configuration ARR:03L-DEP:03R (50% share) shows the highest throughput (both in PSR and in maximum) but it also has the highest additional taxi-out times, while showing the best performance in the approach. There is a four movements difference between the two most common configurations, affecting the resilience and the impact on the PSR.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LGAV | Athens | 220639 | 3 | 0.33 | 0.14 | 1.15 | 97.87% |

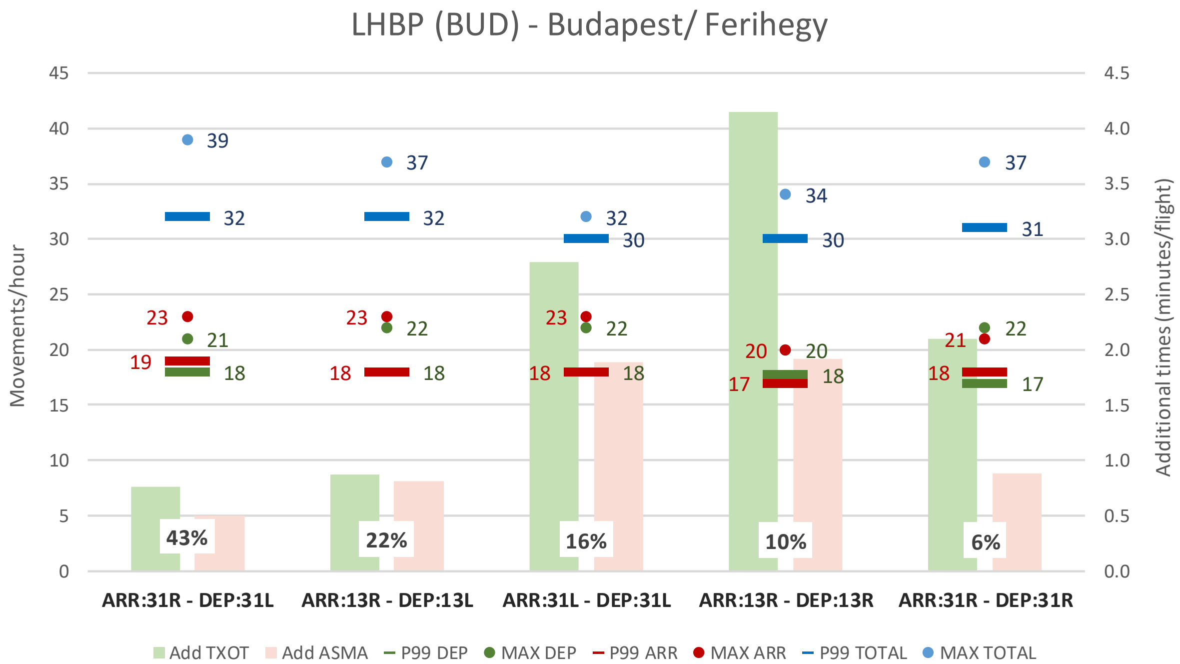


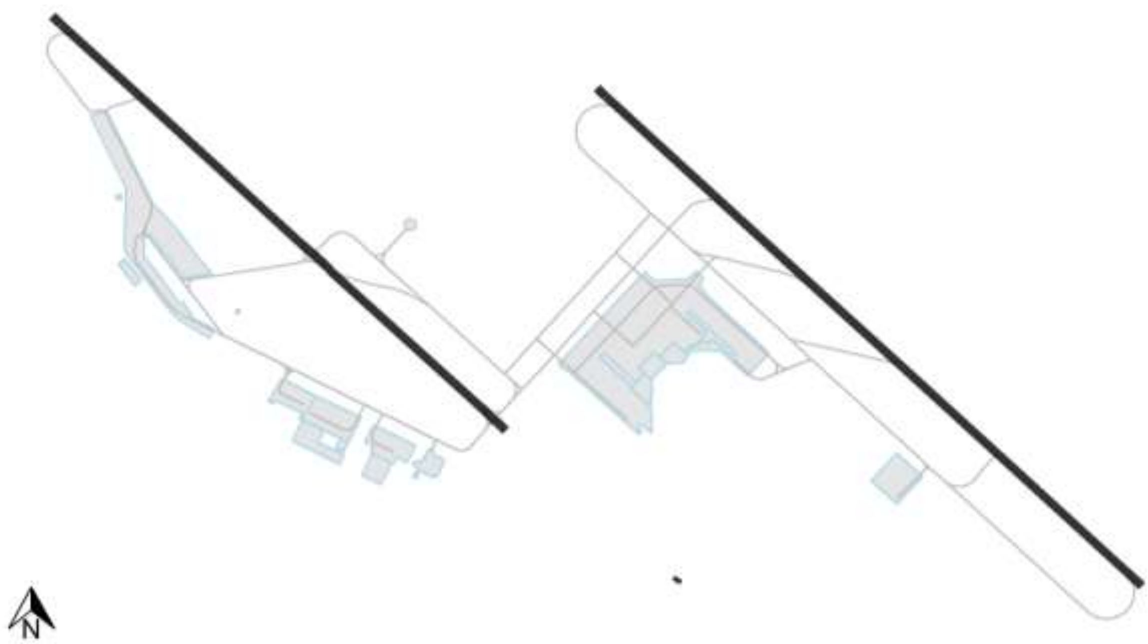



## 69.LHBP (BUD) - Budapest/ Ferihegy

Budapest airport has two parallel runways, only used simultaneously in segregated mode 65% of the time (the rest of the time only one runway in mixed mode is in use). The PSR is only two movements lower for the single runway configurations than for the segregated mode, but the performance in terms of additional times is much worse for both taxi-out and approach phase when only one runway is used for both arrivals and departures.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LHBP | Budapest/ Ferihegy | 122132 | 5 | 0.76 | 0.45 | 0.57 | 99.00% |

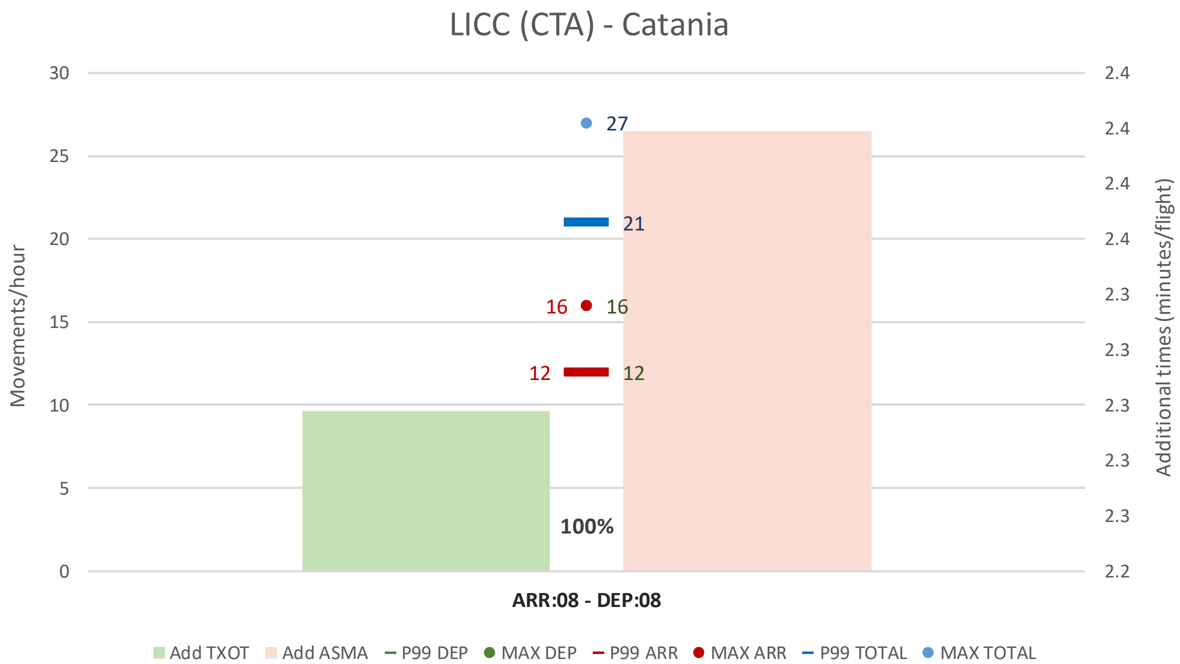


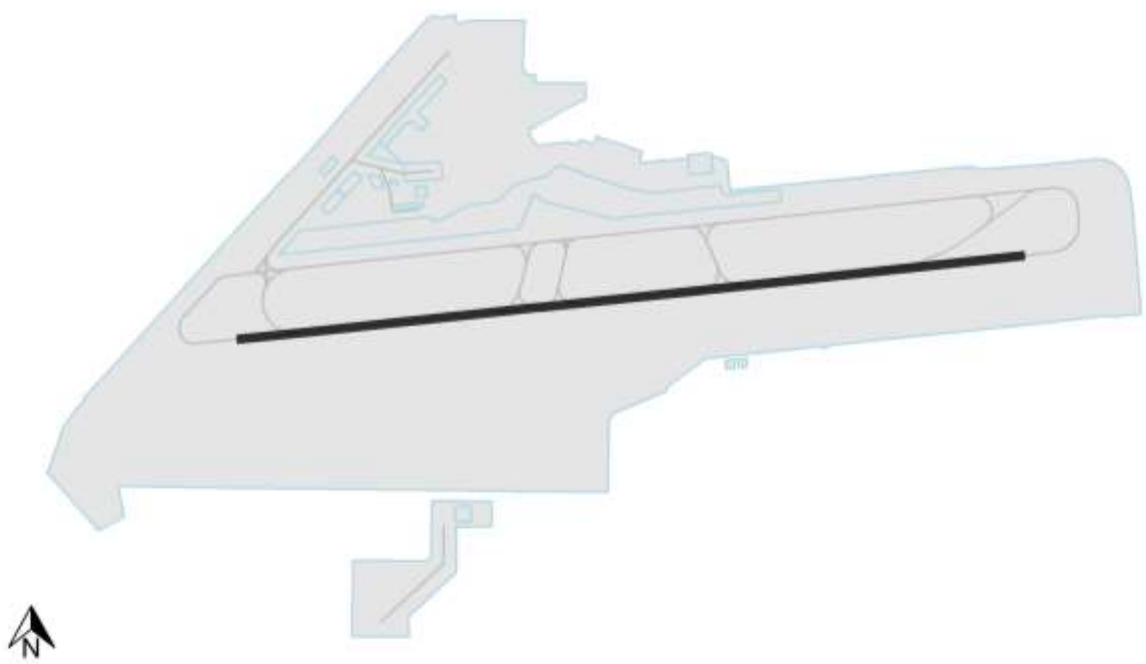



## 70.LICC (CTA) - Catania

Catania is a one runway airport with conditions that clearly favour one runway direction utilization. In fact, RWY01 is used (in mixed mode) 97% of the time in 2019. The other runway configuration is not used more than 3% of the time (with some time intervals being the transition between configurations or missing runway information) so it is not considerd representative and there is no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LICC | Catania | 75399 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

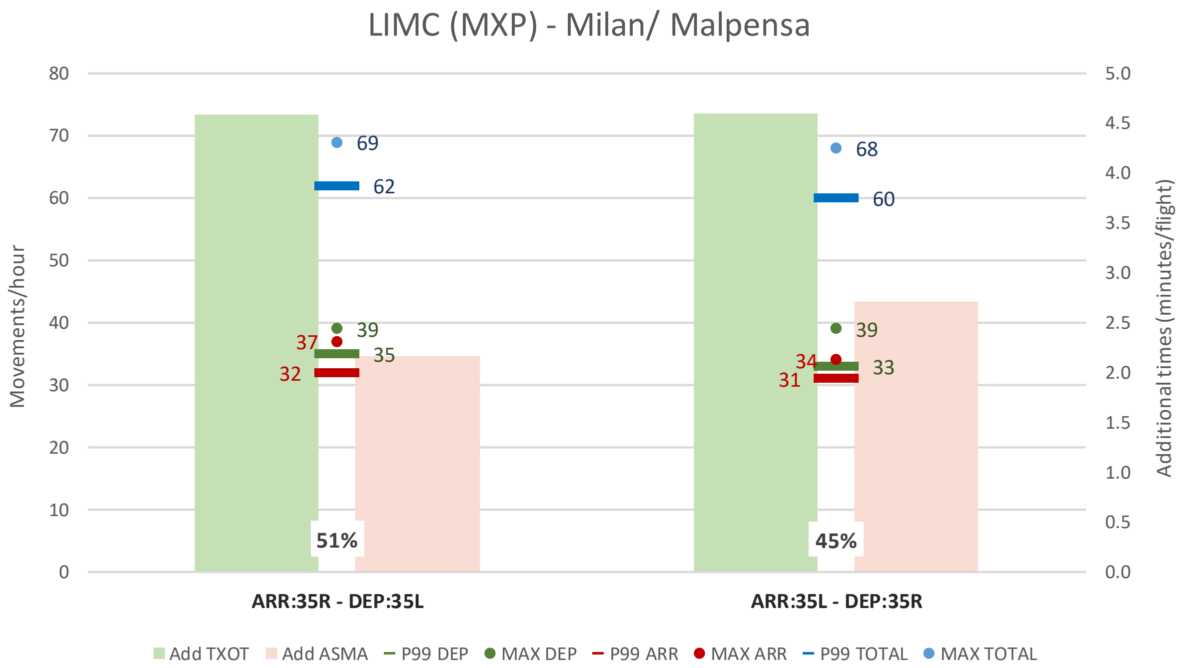


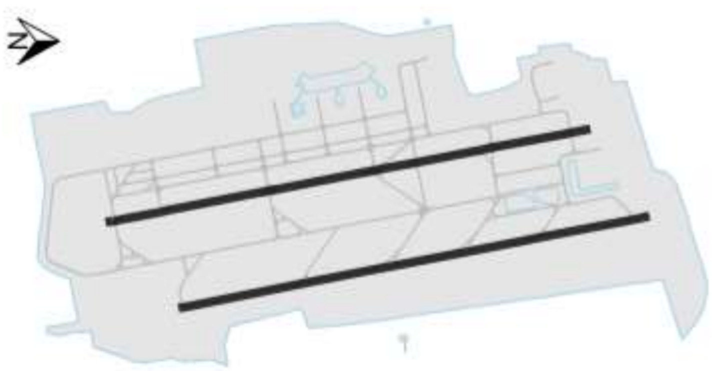



## 71.LIMC (MXP) - Milan/ Malpensa

Milan Malpensa has two parallel runways operated in segregated mode and almost equally used in both directions. The PSR is 2 movements higher for the more common configuration ARR:35R-DEP:35L; 51% share) and this configuration also shows slightly better performance in terms of additional times, especially in the approach.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIMC | Milan/ Malpensa | 233978 | 2 | 0.01 | 0.25 | 0.90 | 98.55% |

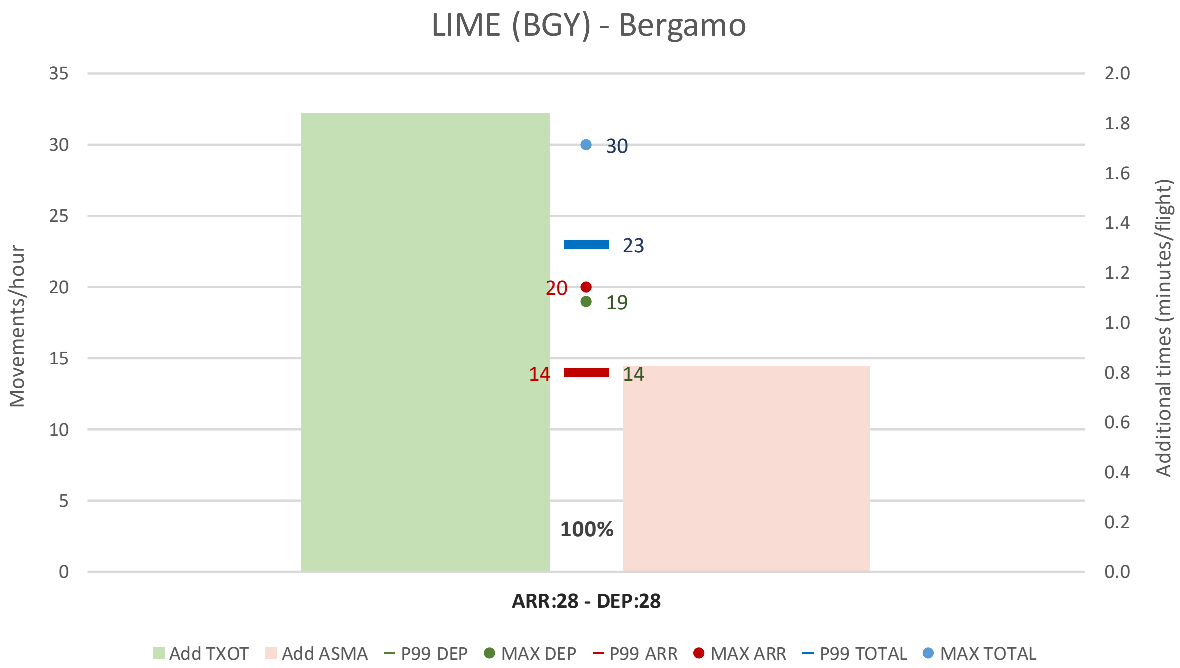


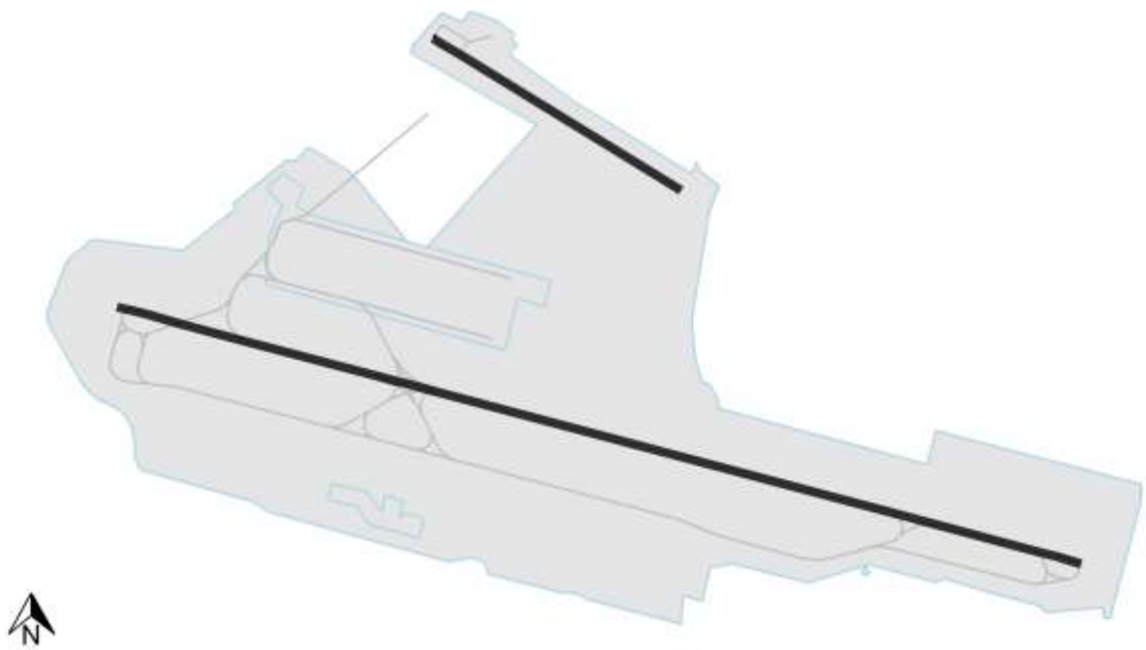



## 72.LIME (BGY) - Bergamo

Bergamo has two runways but one is a short landing strip, so basically it is operated as a one runway airport. Conditions at the airport clearly favour one runway direction utilization and in fact RWY28 is used (in mixed mode) a 100% of the time in 2019. There is therefore no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIME | Bergamo | 95147 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

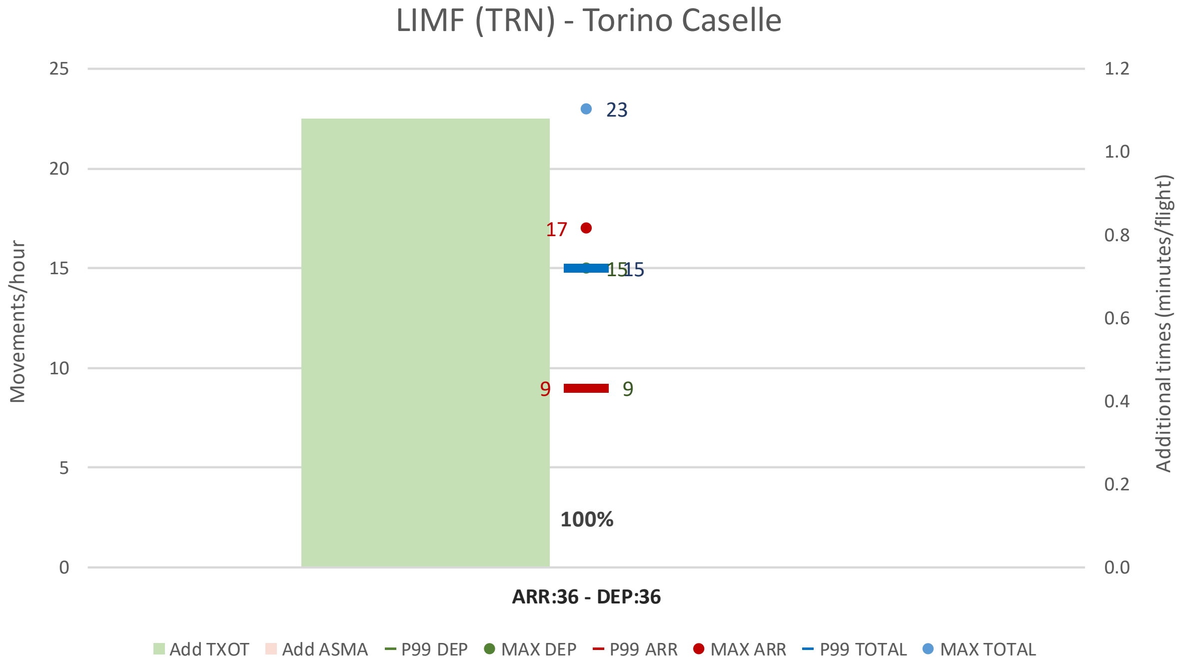


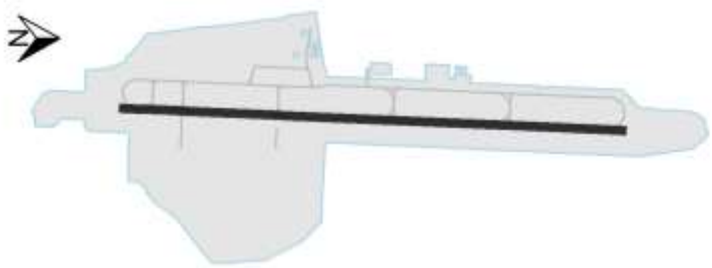



## 73.LIMF (TRN) - Torino Caselle

Torino is a one runway airport with conditions that clearly favour one runway direction utilization. In fact, RWY36 is used (in mixed mode) a 100% of the time in 2019. There is therefore no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIMF | Torino Caselle | 39229 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

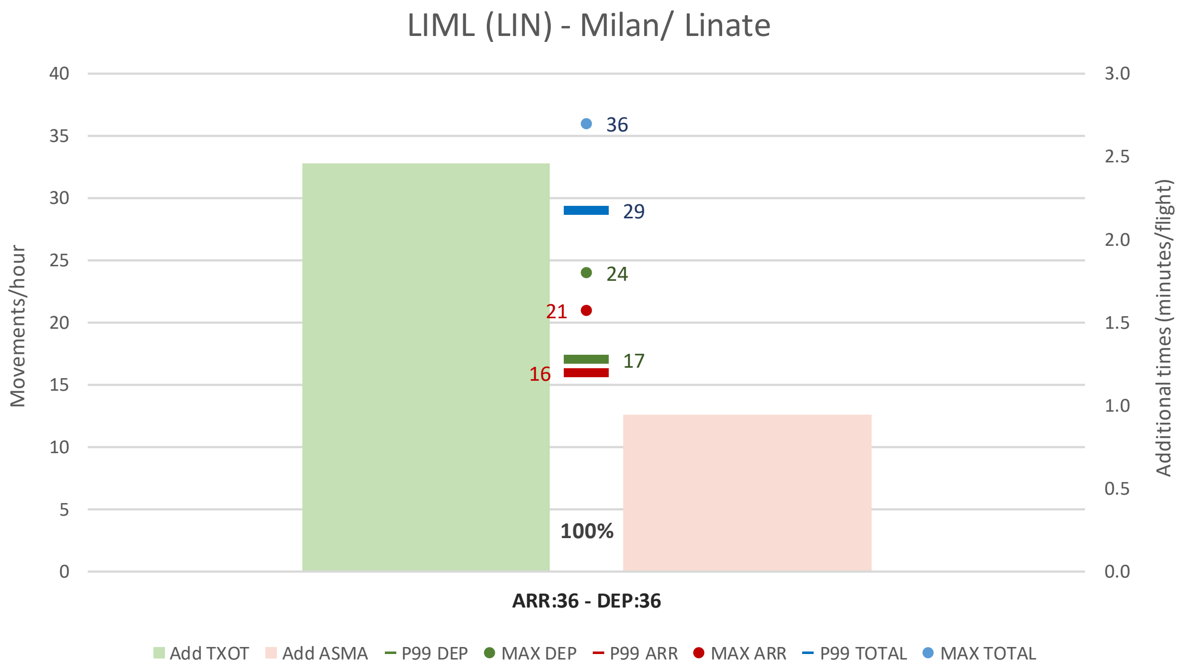


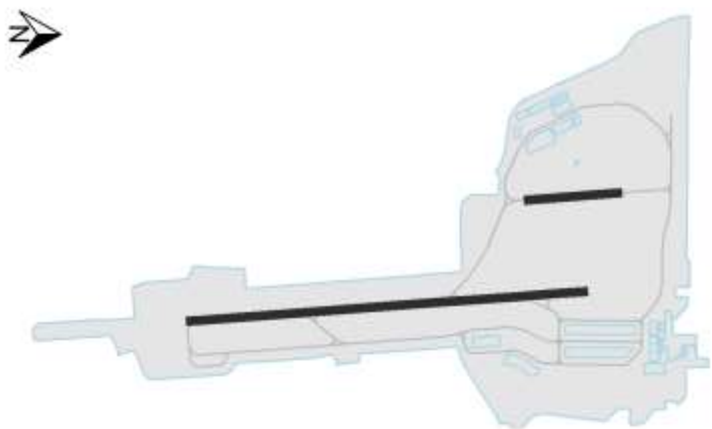



## 74.LIML (LIN) - Milan/ Linate

Milan Linate operates as a one runway airport and its conditions clearly favour one runway direction utilization. In fact, RWY36 is used (in mixed mode) a 100% of the time in 2019. There is therefore no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIML | Milan/ Linate | 84458 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

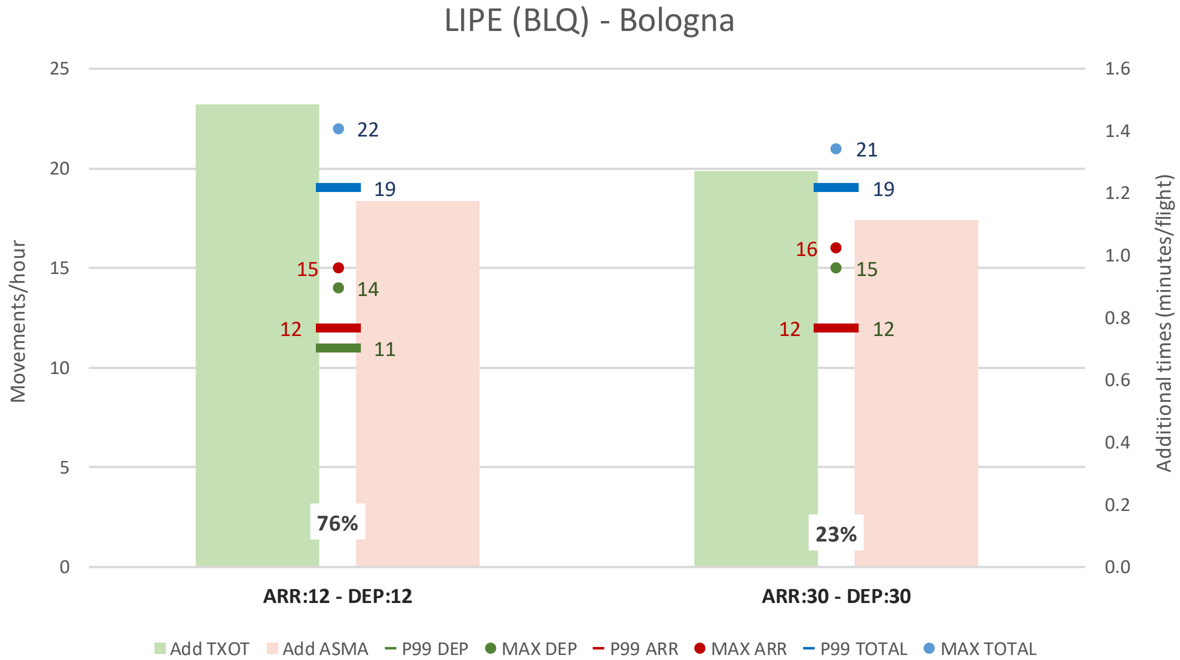


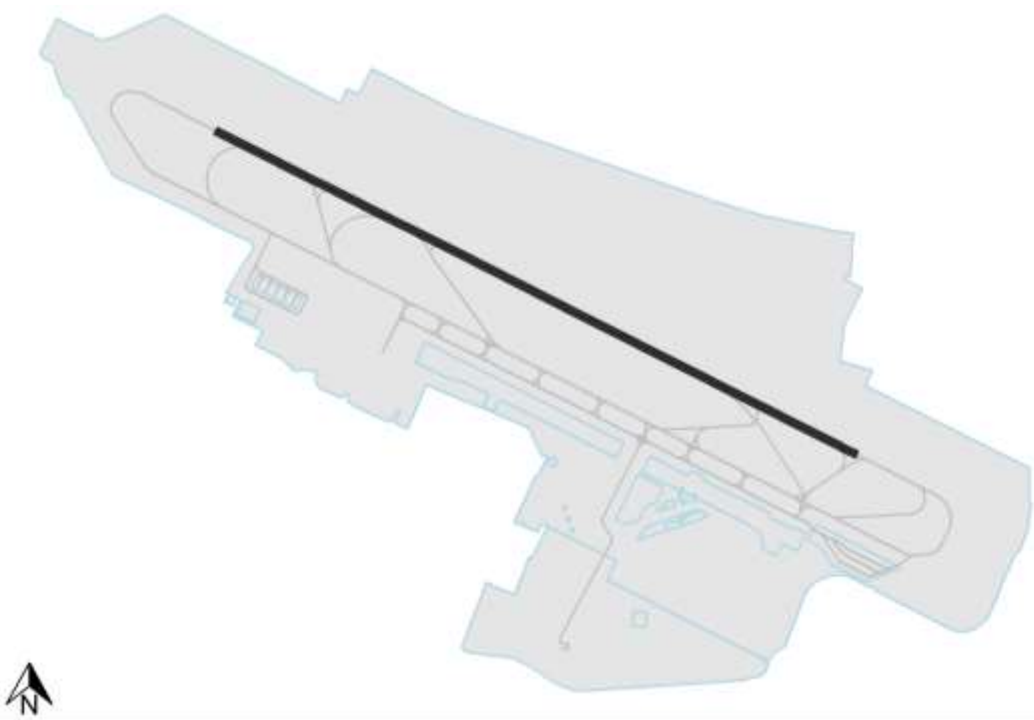



## 75.LIPE (BLQ) - Bologna

Bologna is a single runway airport operated in mixed mode in both directions, being RWY12 the most commonly used in 2019 (76% share). The PSR is almost identical for both configurations but additional times are slightly higher for the preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIPE | Bologna | 77090 | 2 | 0.16 | 0.05 | 0.00 | 100.00% |

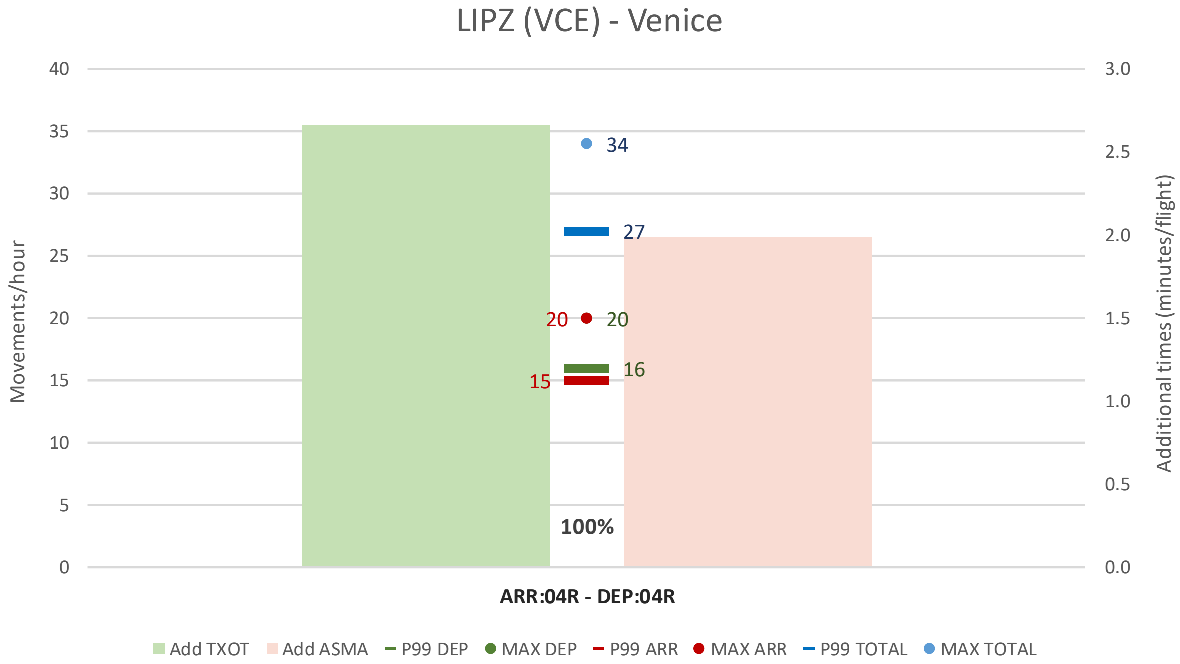


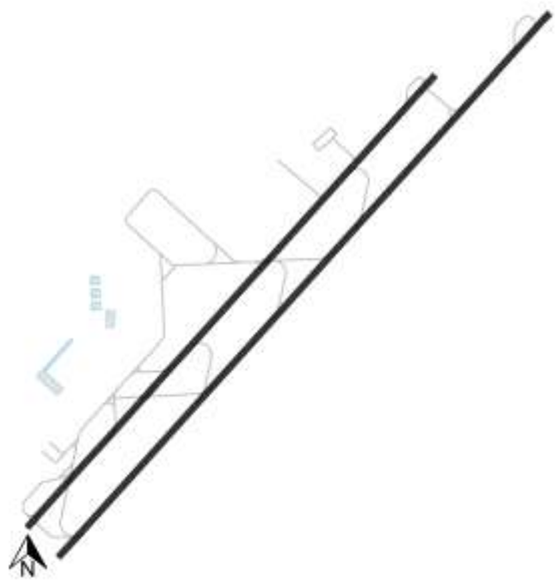



## 76.LIPZ (VCE) - Venice

Venice is has two runways but one is used mainly as taxiway. Conditions clearly favour one runway direction utilization, resulting in one configuration, where only RWY04R is used (in mixed mode) a 100% of the time in 2019. There is therefore no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIPZ | Venice | 95266 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

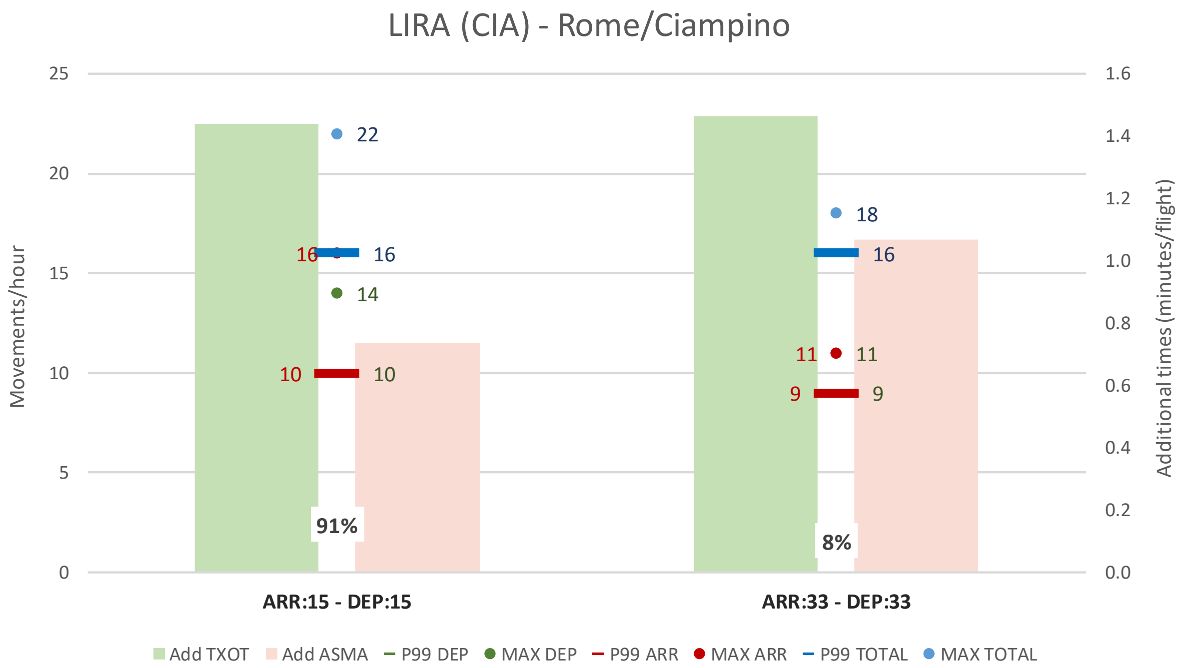


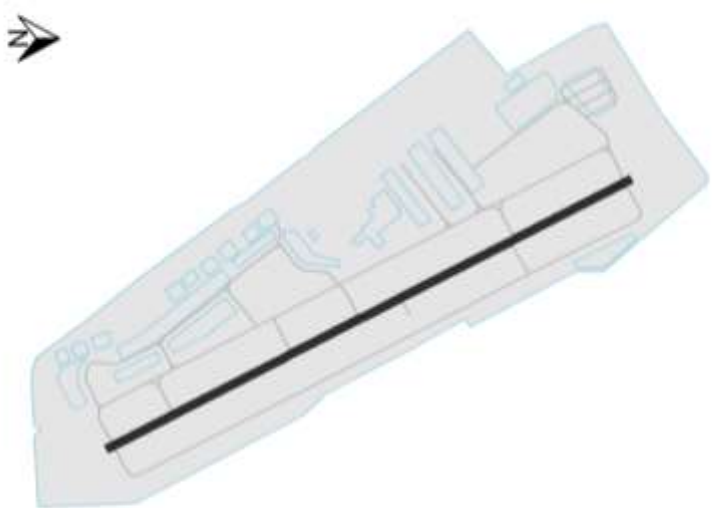



## 77.LIRA (CIA) - Rome/Ciampino

Rome Ciampino is a single runway airport operated in mixed mode in both directions, with RWY15 in use most of the time (91% share). The PSR is identical for both configurations but additional ASMA times are slightly higher for the non preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIRA | Rome/Ciampino | 51154 | 2 | 0.00 | 0.03 | 0.00 | 100.00% |

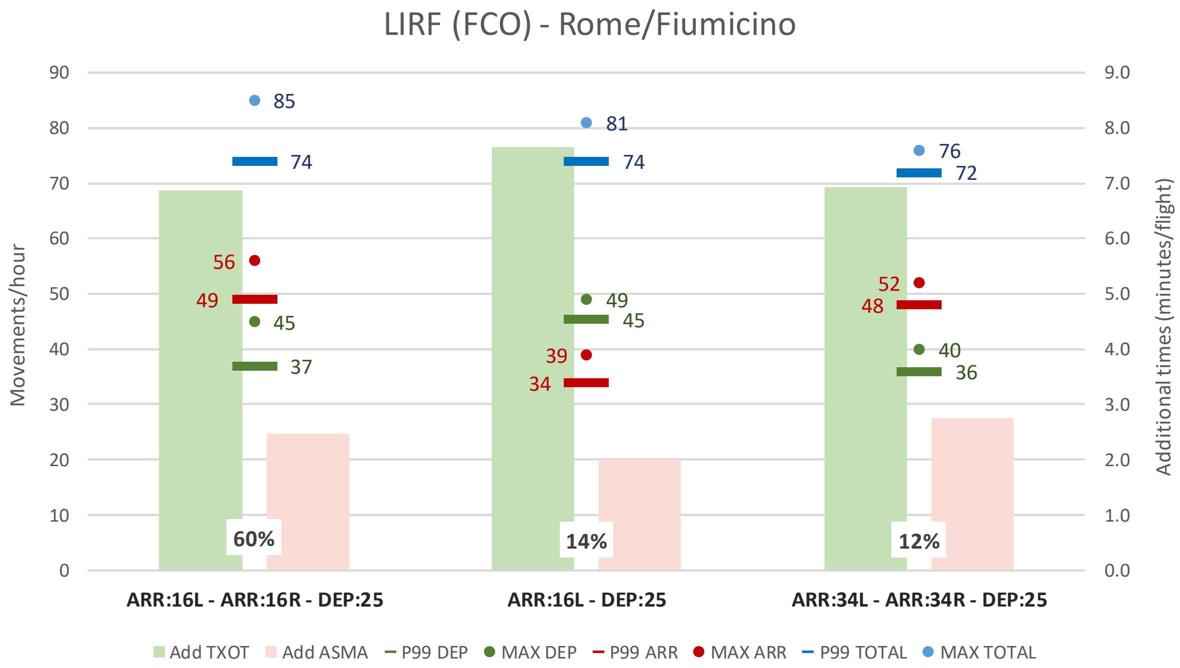


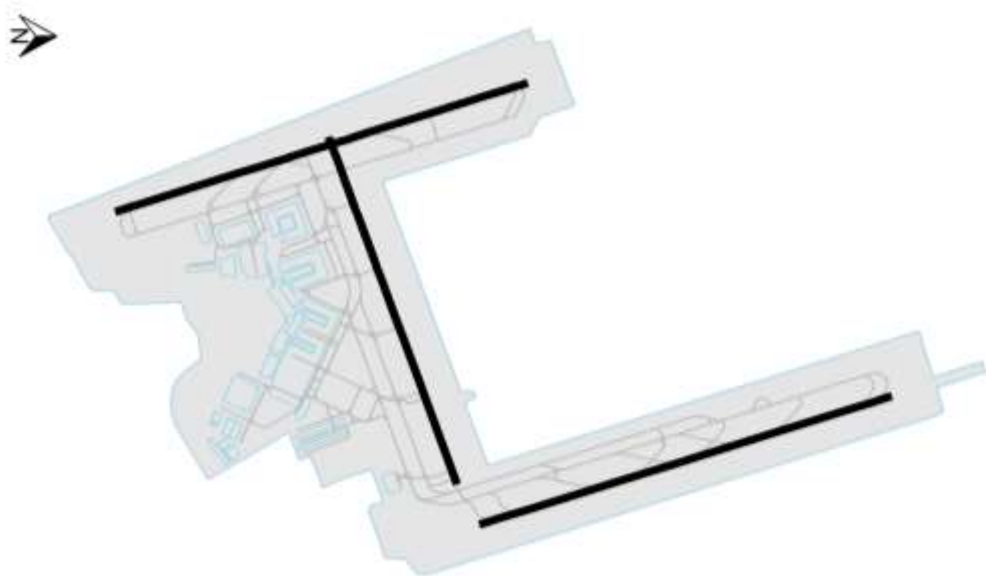



## 78.LIRF (FCO) - Rome/Fiumicino

Rome Fiumicino has three runways, two of them parallel, and from all operating possibilities the analysis identifies three representative configurations. The PSR is two movements lower for the least common configuration, with a low impact on resilience. The additional times at Rome, especially on the taxi-out phase are very high in general. There is no clear configuration that performs better than the others for both indicators, one being better for taxi and a different one being better for the approach.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIRF | Rome/Fiumicino | 309783 | 3 | 0.12 | 0.36 | 0.24 | 99.68% |

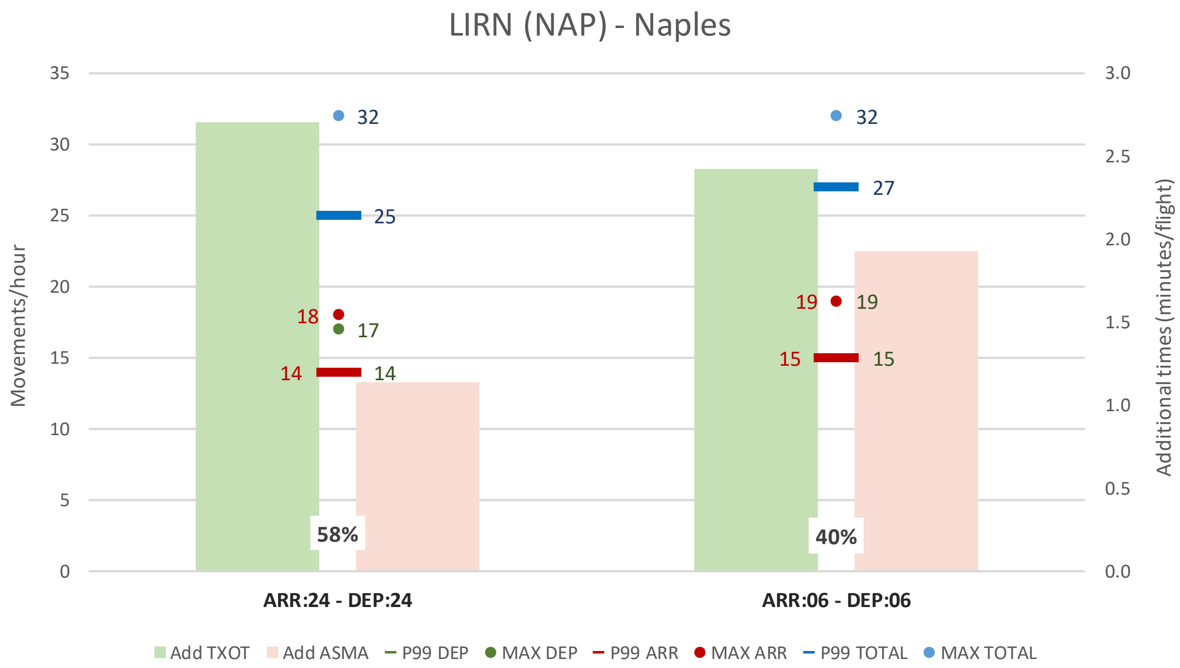


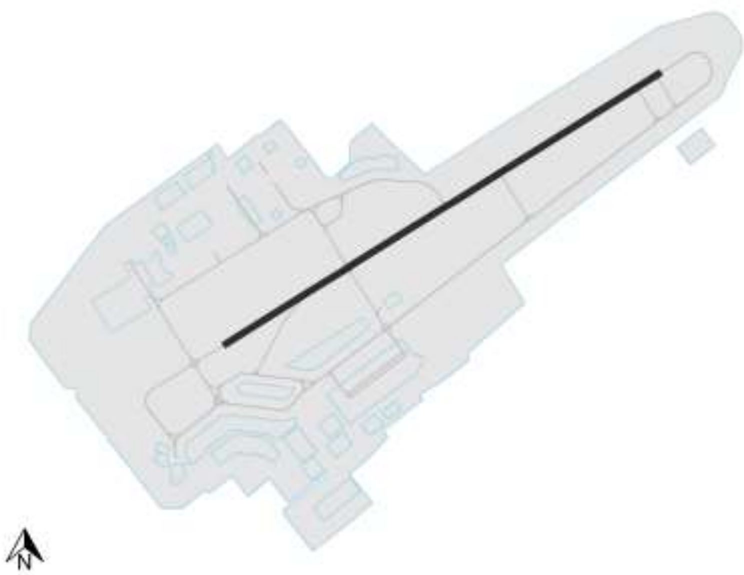



## 79.LIRN (NAP) - Naples

Naple has one runway operated in mixed mode operating it in mixed mode with quite even share of both directions (58%-40%). Performance in terms of peak service rate differs in two movements, and while RWY24 observed higher additional taxi-out times, RWY06 shows significantly higher additional ASMA times

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LIRN | Naples | 84387 | 2 | 0.16 | 0.32 | 1.15 | 95.73% |

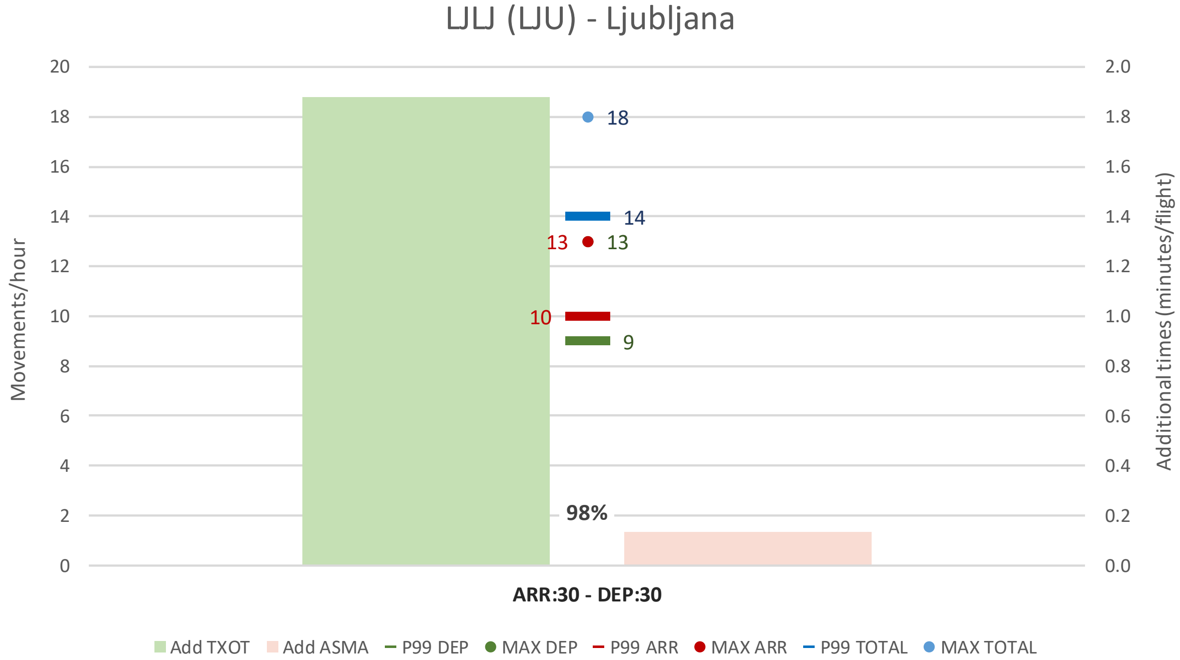


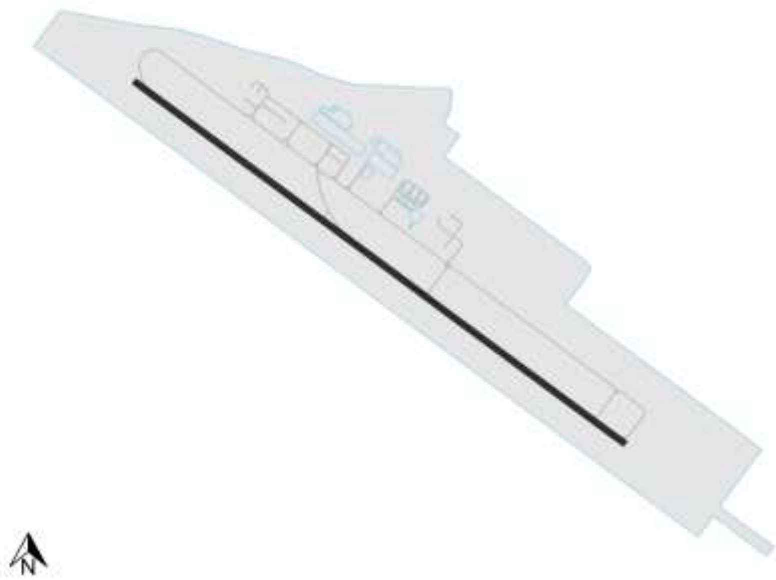



## 80. LJLJ (LJU) - Ljubljana

Ljubljana is a one runway airport with conditions that clearly favour one runway direction utilization. In fact, RWY30 is used (in mixed mode) 98% of the time in 2019. The other runway configuration is not considerd representative and there is no imbalance to be analysed.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LJLJ | Ljubljana | 27935 | 1 | 0.00 | 0.00 | 0.00 | 100.00% |

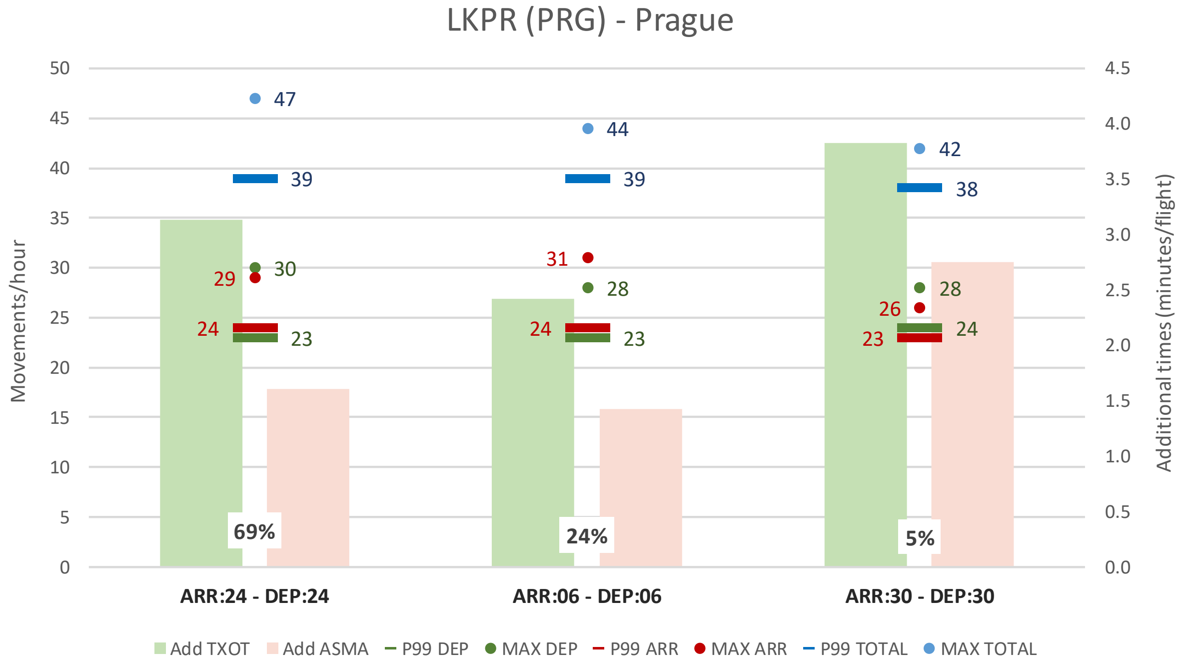


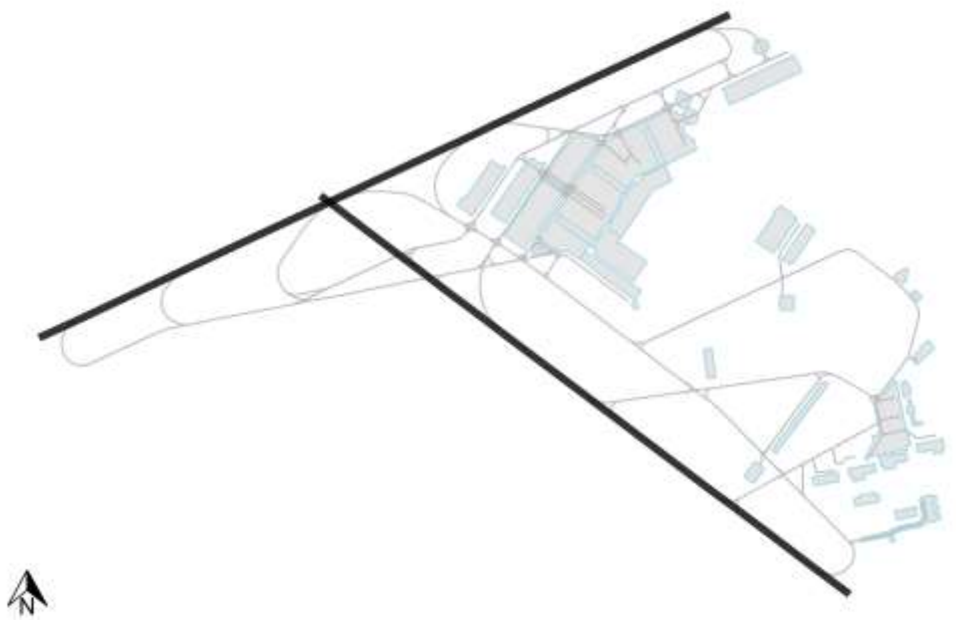



## 81.LKPR (PRG) - Prague

Prague has two crossing runways but it normally only operates one of them at a time, in mixed mode. The PSR only differs in one movement less for the least common runway (RWY30; 5% share), resulting in high resilience. Performance in terms of additional times is best for both approach and taxi-out phase for the RWY06 (24% share) and not for the preferred runway (RWY24; 69% share).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LKPR | Prague | 150434 | 3 | 0.56 | 0.18 | 0.05 | 99.87% |

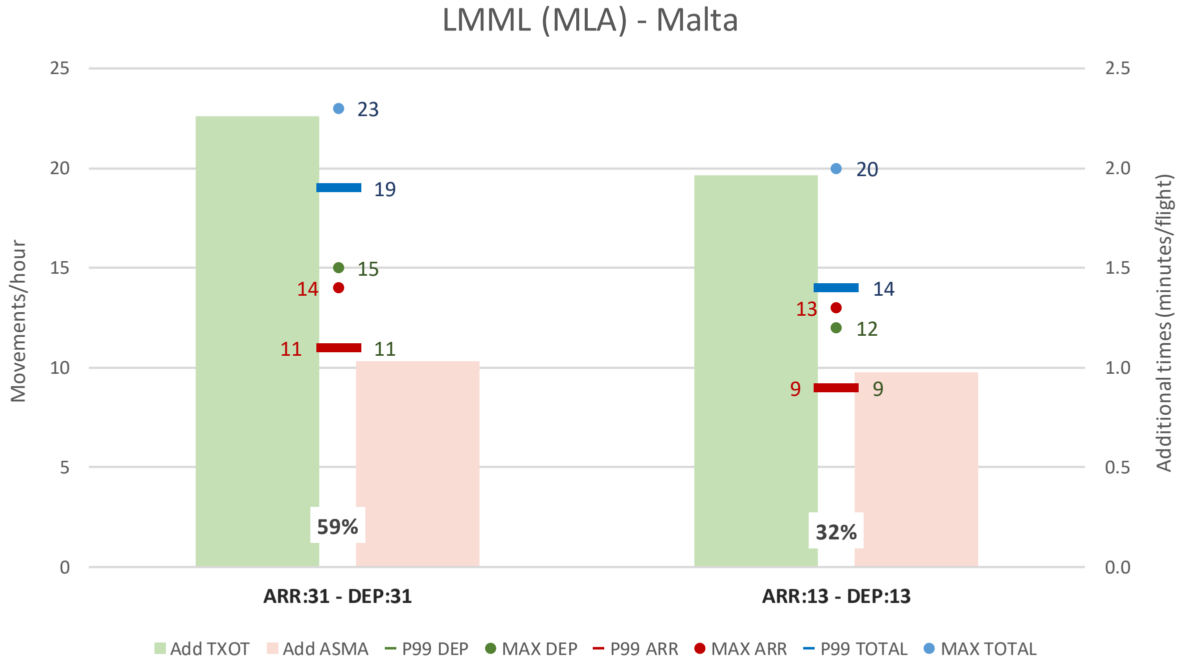


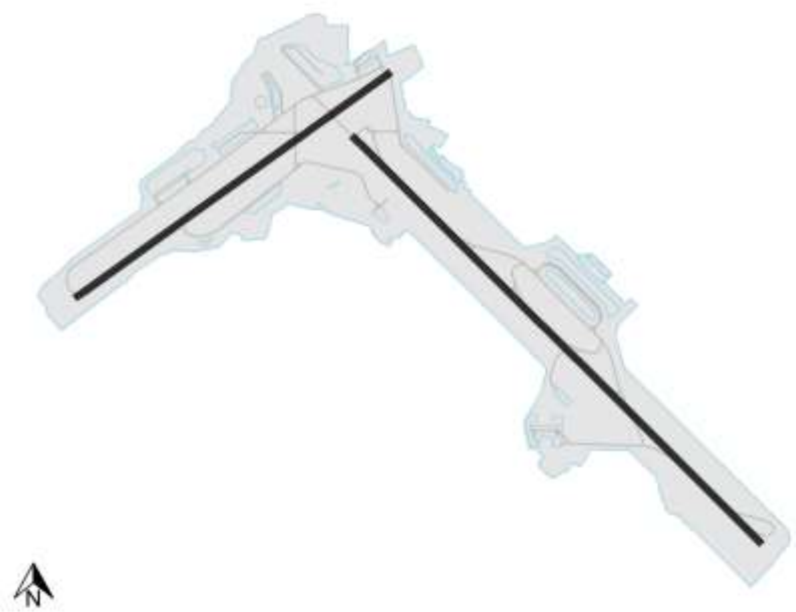



## 82.LMML (MLA) - Malta

Malta airport has two crossing runways but it normally uses only the longest one, operating it in mixed mode in both directions. The most commonly used (RWY31; 59%) shows a PSR significantly higher than the opposite direction, which results in a lower resilience value. Nevertheless, the additional taxi-out times are also higher for this configuration, while additional ASMA times are very similar.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LMML | Malta | 58181 | 2 | 0.17 | 0.03 | 1.59 | 91.63% |

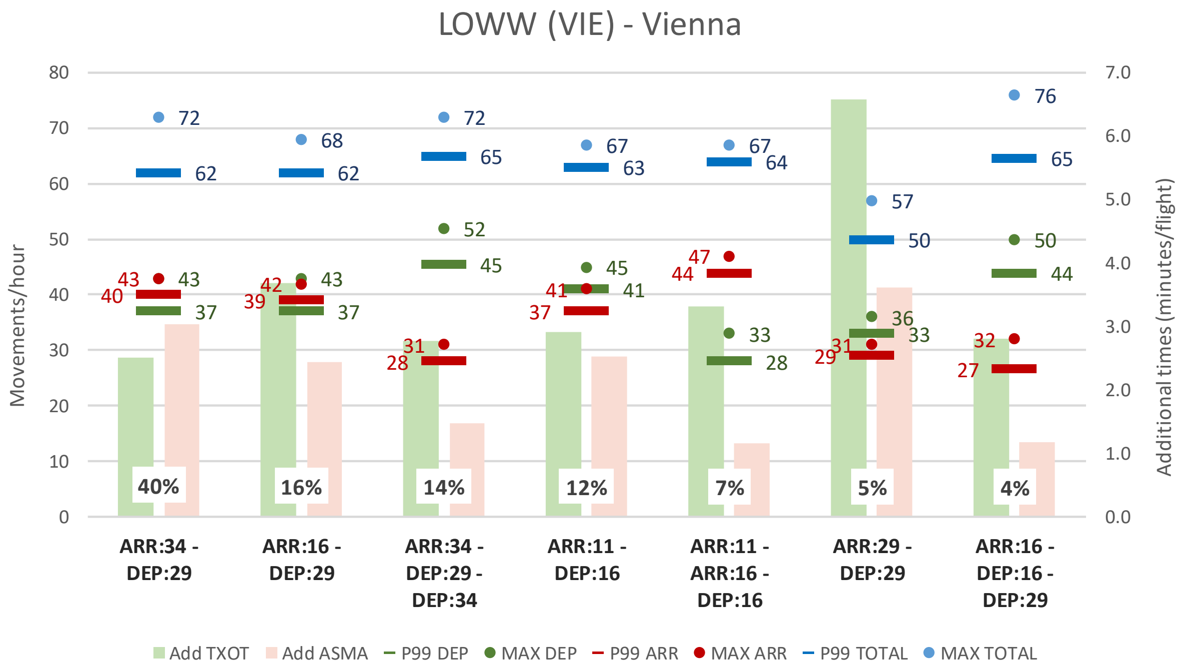


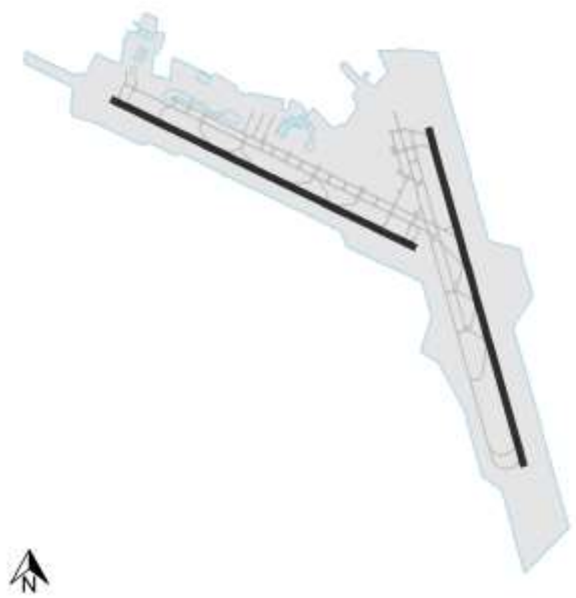



## 83.LOWW (VIE) - Vienna

Vienna airport has two runways that are operated in 7 representative configurations according to the data found in 2019. The PSR for all of the configurations that use the two runways differs in one or two movements, but in addition there is a configuration in which only RWY29 is in use (5% share) with a significant reduction of the PSR but most importantly, a drastic increase of the additional times both in the taxi-out and the approach phase. It is also noticeable the configurations used in departure or arrival peaks, which show the highest thoughputs.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LOWW | Vienna | 281716 | 7 | 0.53 | 1.29 | 2.71 | 98.14% |

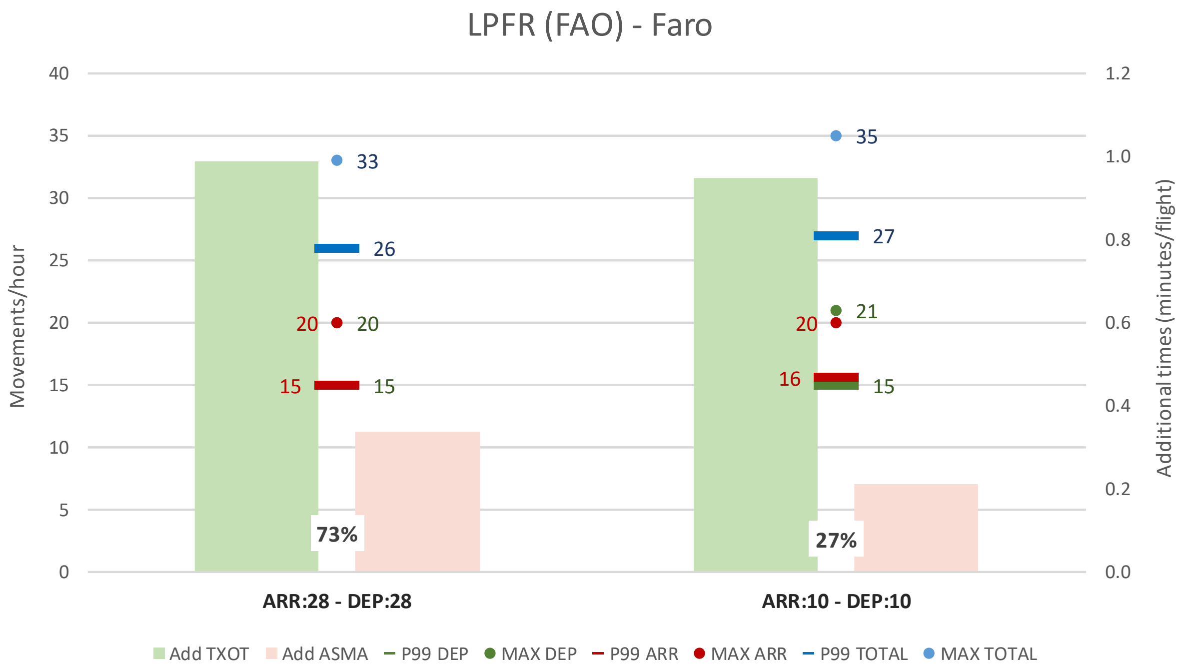


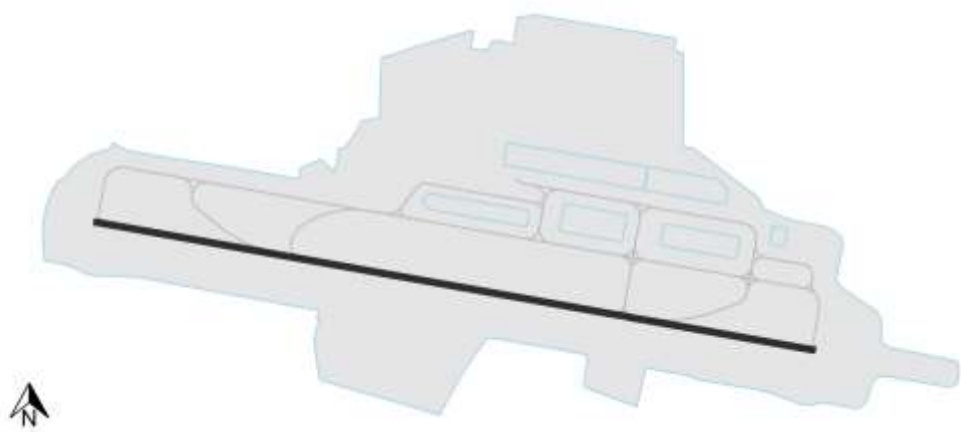



## 84.LPFR (FAO) - Faro

Faro is a single runway airport operated in mixed mode in both directions, being RWY28 the most commonly used in 2019 (73% share). The PSR for both configurations differs only in one movement and additional times are very similar, with additional ASMA time slightly higher for the preferential runway use.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LPFR | Faro | 60664 | 2 | 0.03 | 0.09 | 0.73 | 97.30% |

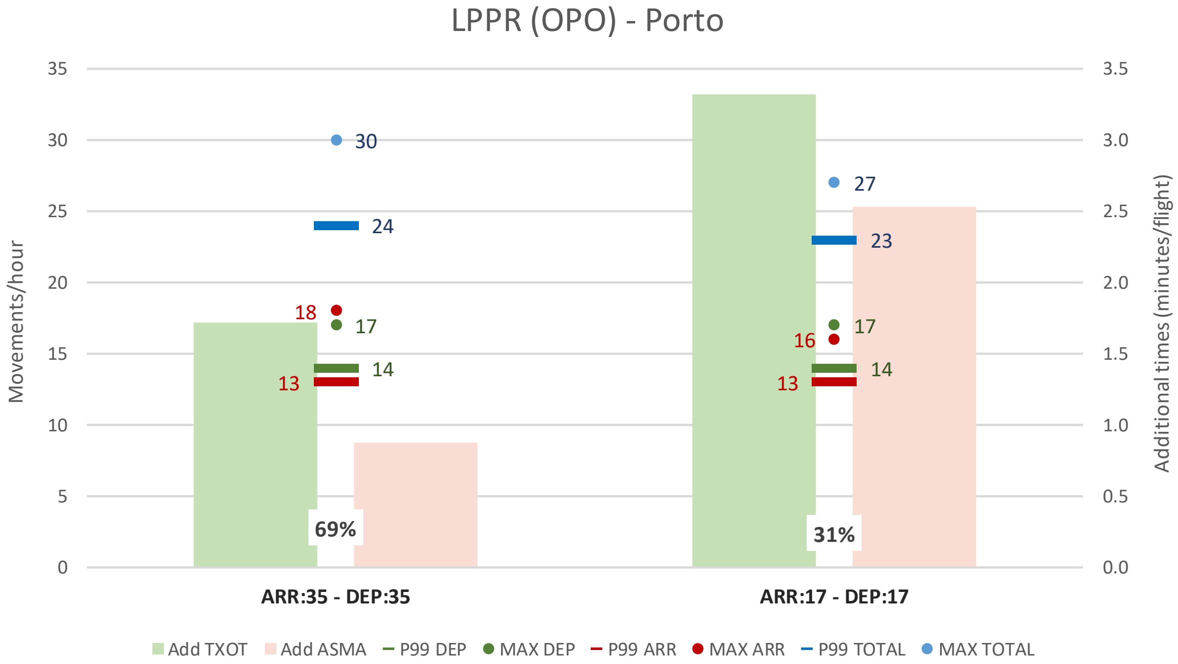


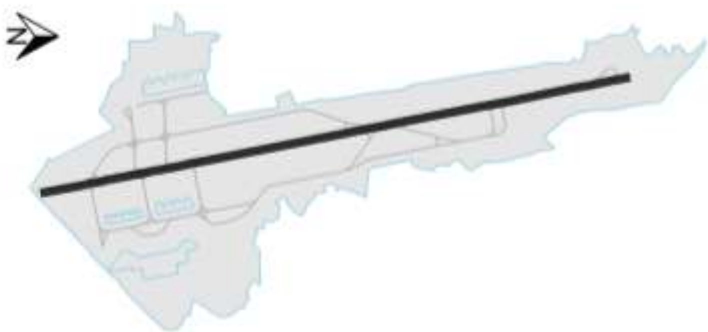



## 85.LPPR (OPO) - Porto

Porto in a single runway airport, used in mixed mode in both directions.RWY35, with a 69% share, shows the best performance both in throughput and in terms of additional times both in the taxi-out and approach phase, which are significantly worse for RWY17 (31% share).

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LPPR | Porto | 98816 | 2 | 0.50 | 0.52 | 0.31 | 98.70% |

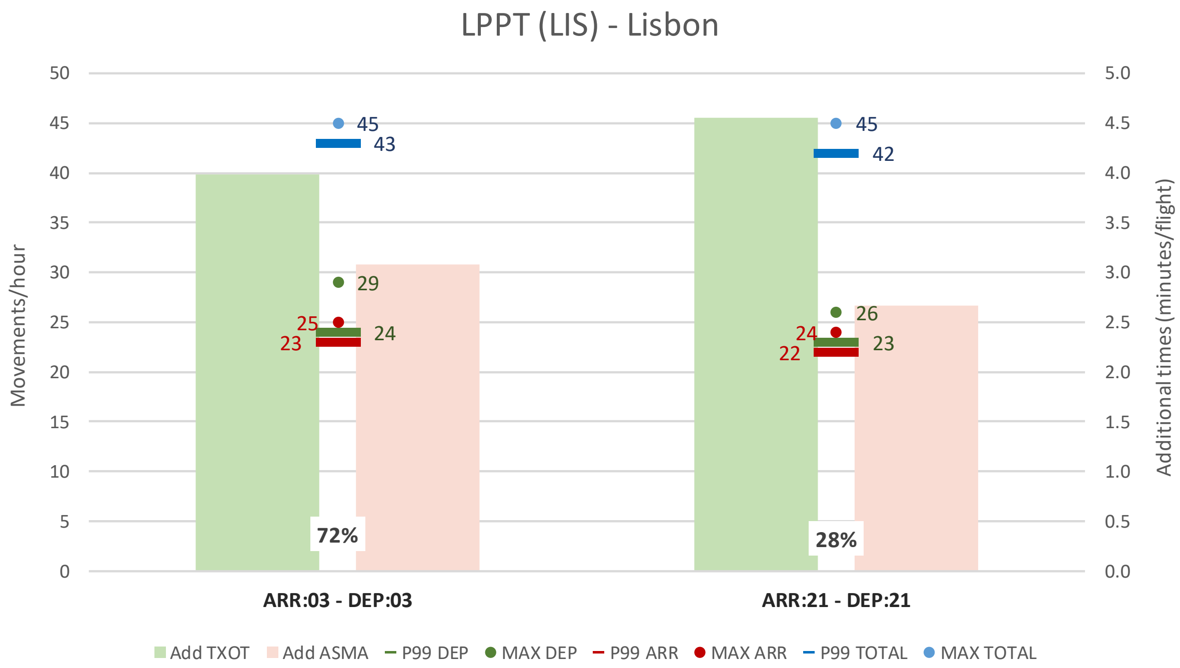


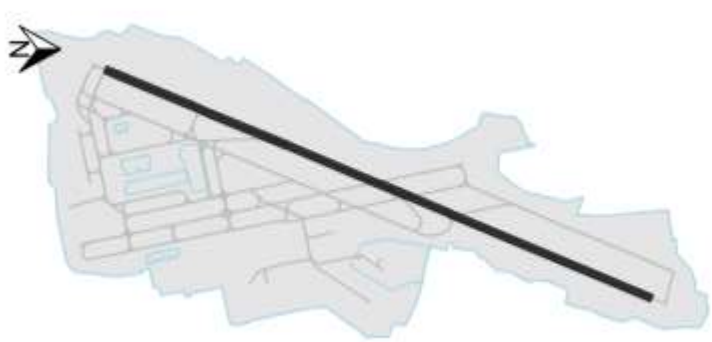



## 86.LPPT (LIS) - Lisbon

Lisbon airport has two crossing runways but normally only uses the longest one in mixed mode in both directions. The difference is PSR is only one movement less for RWY 21, and although this configuration shows higher additional taxi-out times, the most common runway (RWY03; 72% share) shows higher additional ASMA times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LPPT | Lisbon | 220938 | 2 | 0.16 | 0.30 | 0.28 | 99.35% |

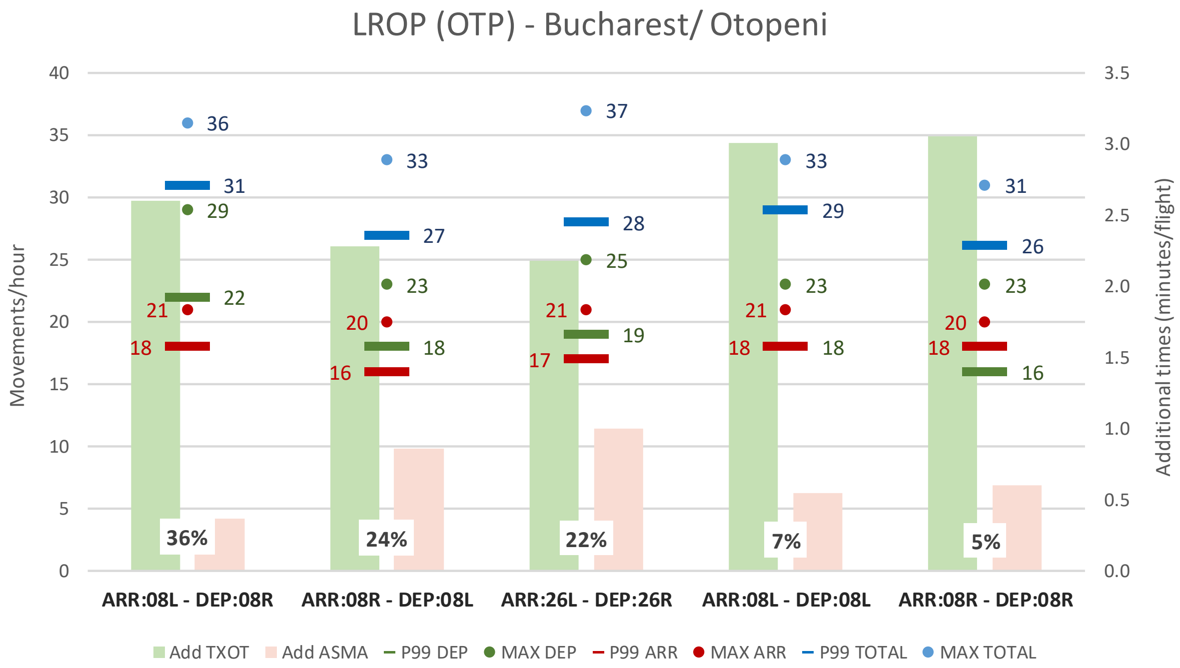


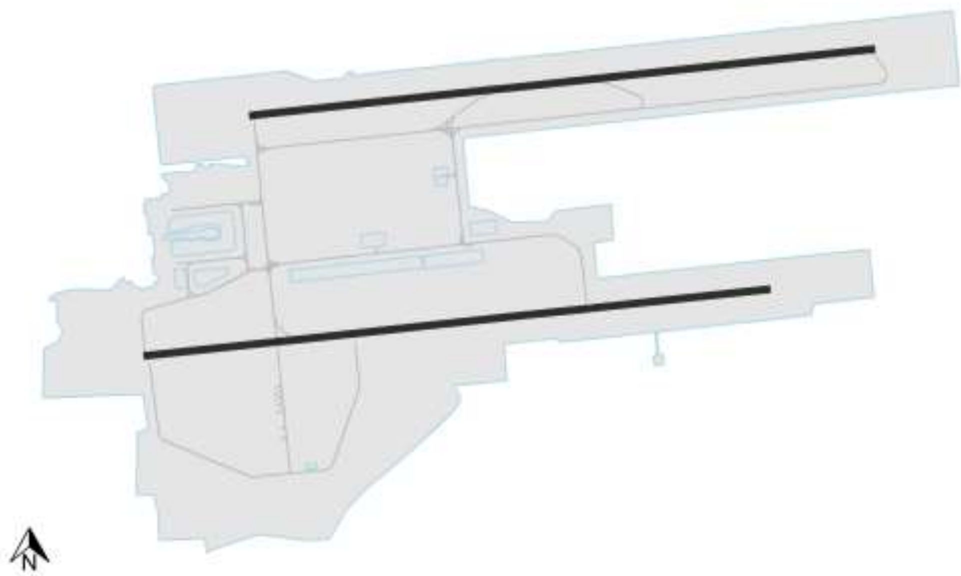



## 87.LROP (OTP) - Bucharest/ Otopeni

Bucharest Otopeni has two parallel runways used in segregated mode for 82% of the time. There is up to four movements difference in PSR between configurations, but it is interesting to observe that the use of only RWY08L in mixed mode is the second highest in terms of PSR. The single runway configurations (either RWY08L or RWY08R) show however the longest additional taxi-out times, while additional ASMA times are higher for two of the segregated configurations.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LROP | Bucharest/ Otopeni | 122831 | 5 | 0.28 | 0.28 | 1.98 | 96.91% |

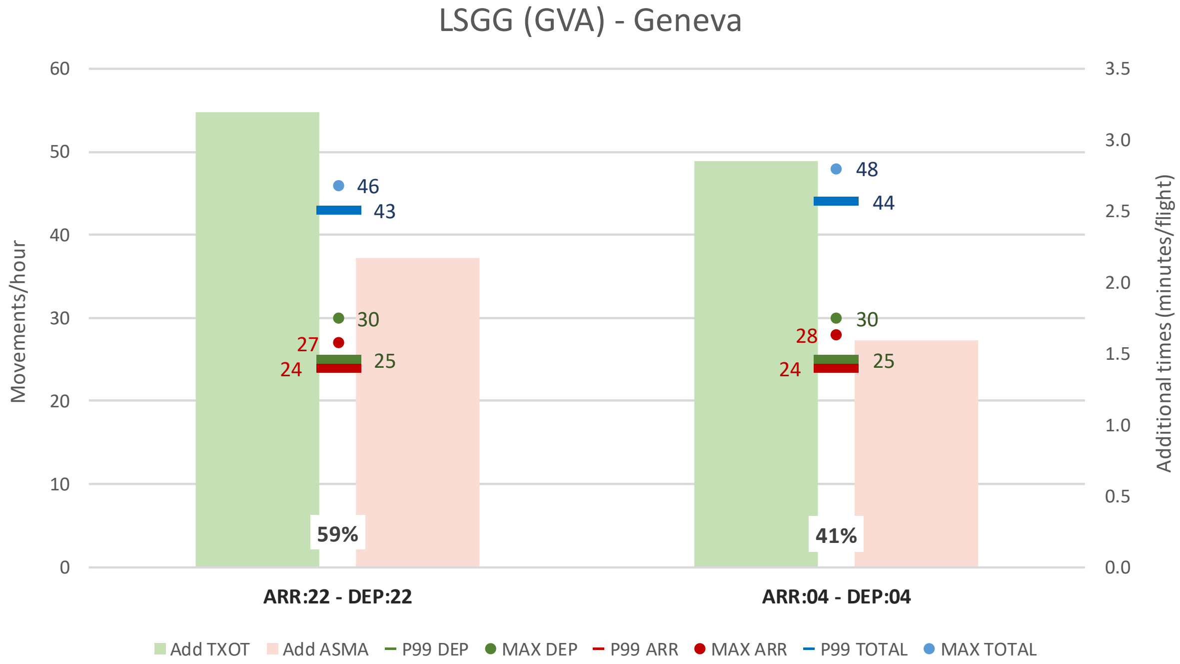


## 88.LSGG (GVA) - Geneva

Geneva is a single runway airport (plus a short grass runway) operated in mixed mode in both directions. RWY22, used 59% of the time, has a PSR 1 one movement lower than RWY04, and additional times are higher both in the approach and the taxi-out phase.

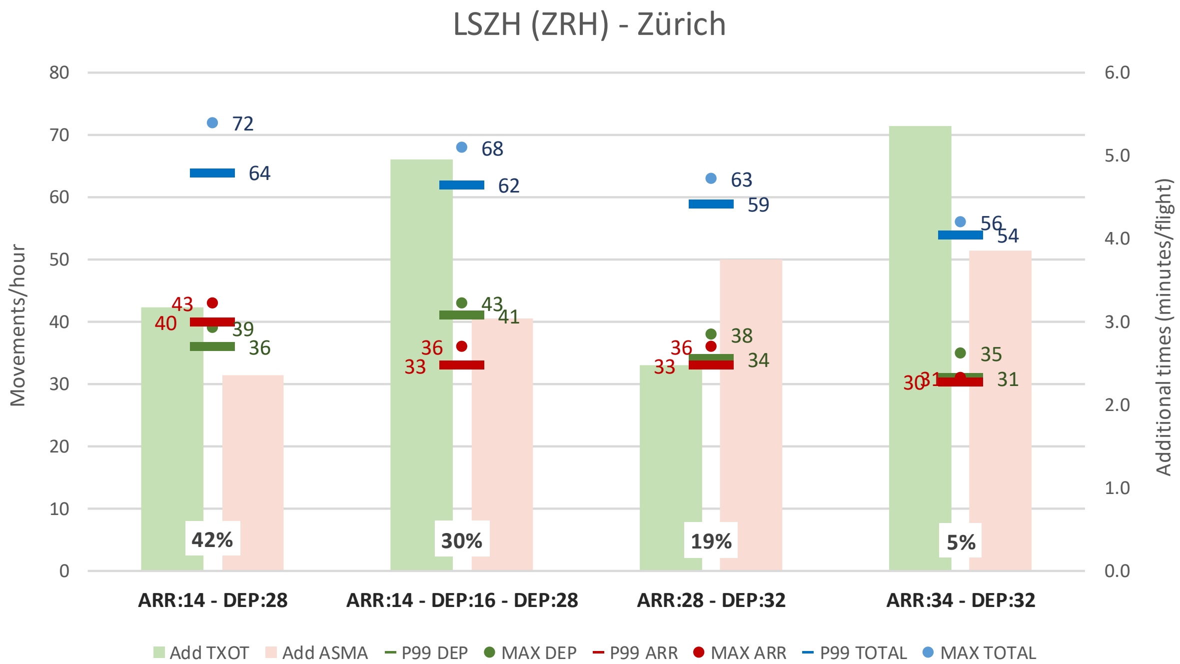
| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LSGG | Geneva | 179115 | 2 | 0.20 | 0.34 | 0.59 | 98.67% |

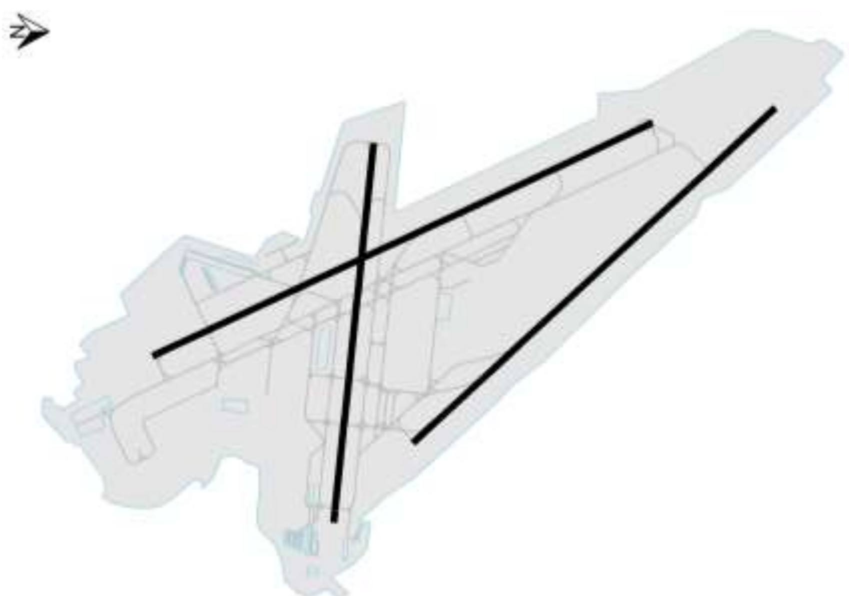



## 89.LSZH (ZRH) - Zürich

Zürich has three runways, operated most of the time in segregated mode. The most common configuration ARR:14-DEP:28 (42% share) has the highest throughput and the lowest combined delays. The least common configuration ARR:34-DEP:32 (5% share) shows a PSR 10 movements below the reference capacity, and the highest delays in the taxi-out and approach while configuration ARR:14-DEP:16;DEP:28 (30% share) seems to be used for departure peaks and has high additional taxi-out times.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LSZH | Zürich | 269223 | 4 | 1.19 | 0.54 | 2.06 | 98.50% |



## 90.LZIB (BTS) - Bratislava

Bratislava has two crossing runways operated in four representative configurations. The configuration that shows the highest throughput and the best performance in terms of delay in the taxi-out phase is used only 5% of the time (ARR:22-DEP:13). Although the demand is probably low to consider the PSR a good proxy for capacity, the two most common configurations, with a combined share of 89% show a low departure throughput with much higher additional taxi-out times, which might signal issues like bottlenecks in the taxi-out flows.

| Airport ICAO | Airport Name | Annual traffic 2019 | Number of configura-tions | Impact Add. Taxi-Out Time (min/dep) | Impact Add. ASMA Time (min/arr) | Impact Peak Service Rate (mov/h) | Airport Resilience |
|---|---|---|---|---|---|---|---|
| LZIB | Bratislava | 22593 | 4 | 0.51 | 0.07 | 6.22 | 72.60% |