EUROCONTROL

Impact assessment of COVID-19 measures on airport performance

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NETWORK MANAGER

STUDY CARRIED OUT BY
Airport Research Center GmbH (ARC)

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Abstract

Further to the EASA/ECDC guidelines for the management of air passengers in relation to the COVID-19 pandemic, EUROCONTROL commissioned an impact assessment of the COVID measures on airport performance. This work was performed by the Airport Research Center GmbH with the support of ACI EUROPE, IATA and four airports, Paris Charles-de-Gaulle, London Heathrow, Stuttgart and Swedavia airports. This document reports the major results and conclusions of this impact assessment.

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Edition History

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EXECUTIVE SUMMARY

COVID-19 is a worldwide pandemic that led to an unprecedented crisis. In this crisis, the aviation industry was affected like no other industrial sector. Airports need to be secured in order to, first, minimise the risk of spreading the virus and, second, maintain trust and confidence into air transportation that has always been considered as the safest mode of transport. In order to support a safe and smooth recovery from COVID-19 lockdown, EASA/ECDC, ICAO, ACI, and IATA issued guidelines and recommendations.

EUROCONTROL commissioned the Airport Research Center GmbH (ARC) to undertake a comprehensive study to assess the impact of the COVID-19 measures on airport performance, and terminal operations in particular, with the aim to support the European network to better prepare for COVID-19 traffic recovery. Six external partners largely contributed to the project: ACI EUROPE and IATA, and 4 airports, namely Paris Charles-de-Gaulle, London Heathrow, Stuttgart and Swedavia airports.

In this study, the airport performance was analysed with the implementation of the COVID-19 measures (including 1.5m physical distance), compared to the pre-COVID situation. Based on data collected from the project partners and the simulation of a generic airport, this study provided:

(i) an order of magnitude of the impact of these measures on the passengers' journey time throughout a terminal,

(ii) an assessment on the need for additional space for those facilities affected by the COVID measures, and

(iii) an estimate of when airports are likely to reach their saturation capacity when traffic will recover.

As far as departures are concerned, the compulsory COVID measures might add up to 10 minutes to the passengers' journey. One concern is the suitable provision of staff to support the COVID measures, especially to compensate a reduced security control throughput which, if not addressed, could lead to backing up passengers into the terminal areas.

In terms of space, the situation is more critical. Authoritative decisions about physical distance disrupt the airport's former queue and gate sizing. For the same passenger number in a queue in the pre-COVID period, much more space is required to manage COVID:

- 50% at check-in;
- 100% at security control; and
- 35-50% in boarding gates.

The additional time required for the arriving passengers’ journey, due to the implementation of COVID measures, is within a range of 5 to 20 minutes.

However, the provision of space is also quite critical. Immigration would need to double the space and baggage reclaim would require 30-50% more space for the same passenger number. New health checks measures on arrivals would have a considerable impact, in particular in transfers.

For those airports already saturated before the COVID, the general saturation capacity with COVID measures is expected to be in the range of 60-75% of their pre-COVID traffic volume during peaks. Security control (in terms of throughput) and the boarding gates (in terms of space) are likely to be the limiting components at airports.

Last but not least, this study identified that significant harmonisation of the measures is required and will be beneficial for all the parties involved. Consultation revealed that there exists a disparity in the implementation of the measures. Health forms should be harmonised at the European level as well as the criteria for the colour-coding used by the Member States and their regions to report about the pandemic evolution. It is strongly believed that this harmonisation at European level will improve the efficiency of the crisis management.

1 Introduction

1.1 Objective of the Study

COVID-19 is a worldwide pandemic that led to an unprecedented crisis. In this crisis, the aviation industry has been affected like no other industrial sector, most likely because of its specific business model mainly based on aircraft load factor.

With the wearing of masks, the risk on airplanes is probably lower than in many confined spaces, because modern airplanes have cabin air filtration systems equipped with high-efficiency particulate air filters (HEPA)[1], with a total flow rate equivalent to 20 to 30 air changes per hour (composed of 50% outside air and 50% recirculated air).

Nevertheless, passengers have to transit via airports to travel, and these environments need to be secured in order to minimise the risk of spreading the virus and maintain trust and confidence into the mode of transport that has always been considered as the safest one. The focus is therefore on implementing risk based measures on layered and temporary approach through, amongst others, physical distancing and enhanced sanitation. Measures on isolation should not be observed but as combination with the rest in place. In order to support a safe and smooth recovery from COVID-19 lockdown, EASA/ECDC[2], ICAO[3], ACI[4], and IATA[5] issued guidelines and recommendations.

Protecting passengers and staff from COVID and applying these guidelines and recommendations requires a substantial change in how airports operate their terminal facilities, in particular under the rule of physical distancing and potential new health checks.

Two key concerns triggered the set-up of this project to analyze the impact of COVID measures:

1. Regarding **terminal operations**: How to quantify the impact of applying the COVID measures in terms of capacity loss? To which extent do the COVID measures reduce the saturation capacity considering that the pre-COVID traffic levels recover again? What is the impact on the overall passenger journey?
2. As far as the **link with airside operations** is concerned: What is the impact of these COVID-19 measures on aircraft turnaround and stand occupancy? In other words, to

[1] A known as high-efficiency particulate absorbing and high-efficiency particulate arrestance filters. European standards require that a HEPA air filter must remove—from the air that passes through—at least 99.95% of particles whose diameter is equal to 0.3 µm. These filters are similar to the ones used in hospitals as well as for the manufacturing of products where contamination risks needs to be avoided (e.g. medical devices, semiconductors, nuclear, food and pharmaceutical products). https://www.iata.org/contentassets/f1163430bba94512a583eb6d6b24aa56/cabin-air-quality.pdf.
[2] https://www.easa.europa.eu/document-library/general-publications/covid-19-aviation-health-safety-protocol
[3] https://www.icao.int/covid/cart/Pages/default.aspx
[4] https://www.aci-europe.org/industry-topics/covid-19.html
[5] https://www.iata.org/en/programs/covid-19-resources-guidelines/

which extent turnaround time is increased if boarding, deboarding and cleaning processes take longer, and which magnitude of delay might this possibly trigger?

In order to lead this project to a successful end, the following is required:

1. An in-depth understanding of the influencing parameters;
2. The identification of "best practices" at airports in terms of COVID-19 crisis management;
3. The quantification of the impact of COVID measures on airport operations and capacity, whilst considering a wide spectrum of situations; and
4. The development of "What-if" scenarios in support to the development of guidelines for COVID measures implementation with the aim of a smooth recovery of traffic at airports.

This report uses practical examples to quantify and visualize the impact, and gives a summary on factors that reduce capacity. It shows the impact of COVID measures on the passengers' journey, and gives recommendations on mitigation measures to react and handle the risk of disruption and capacity reduction.

This report is to be considered from an airport perspective.

1.2 Airports' activities required to apply Health Safety Measures

With the application of the new health safety measures, airports have to deal with conflicting and diverging objectives.

On the one hand, health safety measures have to be integrated into the passenger handling processes in a way that they effectively reduce infection risks. On the other hand, the cost of implementation of such measures should be minimised as the financial situation of airports is critical due to the traffic lockdown and reduced airport income. This study focusses on airport capacity with the objective of ensuring handling capacity, on which physical distance has a major impact.

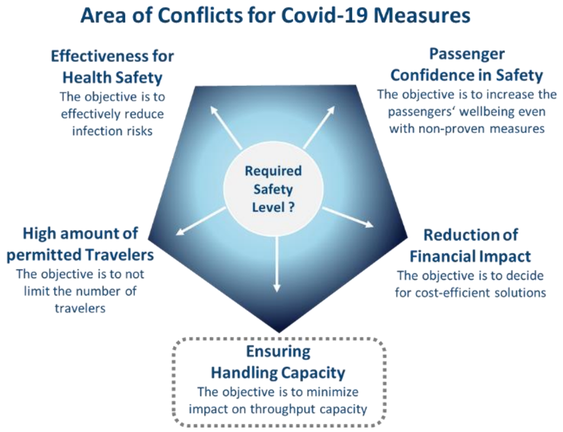


Figure 1: Areas of conflict for COVID measures

The management of COVID crisis brings new challenges. In addition to the increased sanitation and disinfection measures, one major challenge is to enable passengers and airport staff to **keep physical distance**. In this context, airports should plan, coordinate and conduct the following activities shown on Figure 2 here below.

Figure 2: Required activities by airports to align with health safety requirements and measures

In order to maintain physical distances, airport should focus on the following issues:

- **Expand Queuing Areas:** with physical distancing, less passengers can fit into dedicated queuing areas where they are expected to hold. In order to accommodate the passengers volume, the queue space needs to be expanded to some extent that will be analysed.
- **Realign Staffing / Allocation:** if no sufficient queue space is available or processing of passengers takes longer (e.g. due to additional health questions), staffing could be increased to reduce waiting times. Furthermore, a change of resource allocation can allow an improved “capacity-demand balancing”, releasing local peaks and distributing the traffic to reduce the local accumulation of passengers in space and time.
- **Elaborate Concepts for Local Health Authorities:** airports might proof and justify their concepts how they follow the recommendations to reduce health risks to the local health and national aviation authorities. They have to coordinate with the authorities the actions they take to implement the recommendations, in order to achieve optimal risk mitigation. Furthermore, airports have to develop alternative measures to mitigate the risks in case a recommendation cannot be implemented due to specific constraints. Thus, workarounds might need to be elaborated in order to get acceptance and agreement from the local authorities.
- **Know about Saturation Capacity:** it is obvious that the new health measures lead to a reduction of available capacity, primarily in space, but also in terms of throughput capacity of terminal processors. This might occur as soon as any process takes longer and might impact the availability of resources (e.g. use only every second reclaim belt).

  Depending on how an airport implements a measure and how the capacity situation was in pre-COVID situation, the capacity drop varies by individual airports. This also depends on terminal layout characteristics, e.g. if there is space to be used as additional overflow queue space or if a closed dedicated gate area cannot be used anymore as soon as it does not allow sufficient space to accommodate a flight with a typical load factor.

  A fundamental question is to know if health safety measures will end soon enough, before traffic gets closer to pre-COVID volumes. If not, in particular airport that were capacity limited before COVID will face a new saturation capacity; in that case, the closer traffic volumes get to this saturation level, the more problems are to be expected for terminal operations. Then airports need to be prepared with concepts how to respond to those constraints, for instance with concepts for holding passengers in overflow areas or with an increased level of staffing required to handle the risk of congested situations.

- **Prepare for Ad-Hoc Changes:** since the beginning of the crisis, the way national governments put new measures in place regarding travel restrictions and new health safety measures is quite dynamic. This was experienced with the requested implementation of passenger locator cards (PLC) and polymerase chain reaction (PCR) tests for passengers before travelling or at the destination. Airports might have less time to put required measures into place, if local governments asked for. Thus, in particular, if new processes or changed processes need to be implemented at an airport, it is recommended that airports plan for certain new requirements and new checkpoints, even before they are discussed to be implemented. Whilst anticipating and analyzing the need in place (equipment and staff), an airport can propose what would be the most feasible approach/compromise to realize a specific measure.

1.3 Project Description

1.3.1 Project Scope

Beyond project management, the project includes several work packages, as shown on Figure 3 here below.

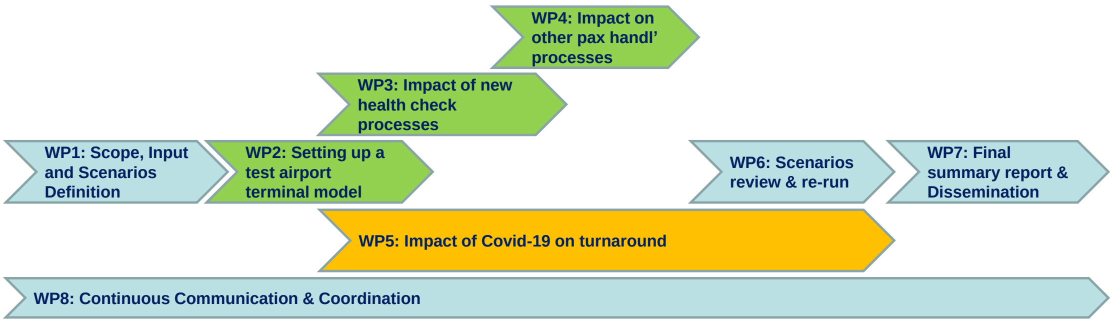


Figure 3: Work Breakdown Structure

This work breakdown structure includes the following work packages:

- WP1 aims at setting up and reaching a common and agreed consensus about the scope and the scenarios definition, with the aim that the results can be quickly used by airports in their crisis management. It also defines the performance indicators to be measured or simulated, i.e. the performance framework relevant for airports during this crisis. This WP also aims at collecting the input data required for the study.
- The objective of WP2 is to define the generic model to be used in the simulation. In this WP2, the analysis strategy is defined in order to be able to compare the terminal operations during a pre-COVID era against the impact of post-COVID measures.
- EASA/ECDC recommendations refer to required passengers' health check, what might range from simple check of any 'health certificate' to active medical checks through temperature control and medical consultations. WP3 aims at analyzing the impact of possible health checks on passengers' flow and global performance.

- WP4 will analyse the impact of COVID measures on other and conventional terminal operations processes, namely check-in, security control, and immigration.
- Since the beginning of the lockdown in February 2020, it is observed that the COVID crisis has an impact on stand occupancy. It is also expected that the COVID measures applied in terminal operations will have a certain impact on aircraft turnaround. For instance, boarding/deboarding delay and additional aircraft cleaning and disinfection might generate additional turnaround delay. WP5 aims at analyzing how the sum of all effects of COVID measures in terminal operations can impact the turnaround critical path and stand allocation.
- Preliminary results will be presented and discussed at this stage, in order to the full study can be reassessed and the simulation re-run in WP6, if needed.
- This consultation will be ensured all along the project in WP8, and as described in Section 1.3.2 hereafter.

In this work breakdown structure, WP2, 3 and 4 are passenger-centric, and will address terminal performance, whilst WP5 will be aircraft-centric. The area where these two perspectives meets is stand allocation and turnaround critical path. Beyond stand allocation and turnaround, the impact of COVID measures on air traffic movements in general was beyond the scope of this project, and was addressed through additional data analysis by EUROCONTROL.

EUROCONTROL contracted this study to the Airport Research Center GmbH (ARC) company.

1.3.2 Involvement of External Stakeholders & Timescale

In crises, the continuous exchange of information and discussion with stakeholders is key, and all the more important than the crisis is severe, dynamic and persists over time. Communication and dissemination of information was an important aspect of this project that brought added value. This enabled to collect latest insights, input and feedback on the simulation scenarios and results.

Six external partners largely contributed to the project: ACI EUROPE and IATA, and 4 airports, namely Paris Charles-de-Gaulle, London Heathrow, Stuttgart and Swedavia airports.

Figure 4: External contributors to the project

One key and challenging constraint for this project was its very tight timescale. Due to the crisis dynamics and severity, the results were to be reported and debated within a few weeks, in order to release directly consumable information to airports as soon as possible, before air traffic is expected to recover and airports reach saturation.

As shown on the timescale on Figure 5, 4 workshops were organised with the external contributors in order to

- Identify the factors to be analysed;
- Define, review and agree on the scenarios to be modelled;
- Define, review and agree on the input to be used; and
- Review and discuss about the preliminary and final results.

During these workshops, the contributors explained which measures were implemented at their airport and they shared their observations and knowledge about the initial restart phase and the challenges they were meeting. The contributors' insight was supplemented by, on one side, a survey set up by ACI EUROPE and, on the other side, ad-hoc interviews undertaken by ARC with airports even outside the ECAC area in order to collect wider trends on the international scene. These survey and interviews enabled to gain additional experience, and further refine the scenarios analysed in this project.

In addition to this airport perspective, IATA conducted several interviews with airline partners to support the study with latest insights on how airlines changed their passenger processes. Their input was valuable for check-in, boarding and deboarding procedures in particular.

DISCLAIMER

The input used in the scope of this project was defined from the best knowledge at the time of setting up and discussing scenarios with the project's contributors, including the 4 airports, ACI EUROPE and IATA.

The results of the study were presented to the ad-hoc EUROCONTROL Airport Operations Team (AOT) on 17th July, and to a well-attended webinar on 6th August.

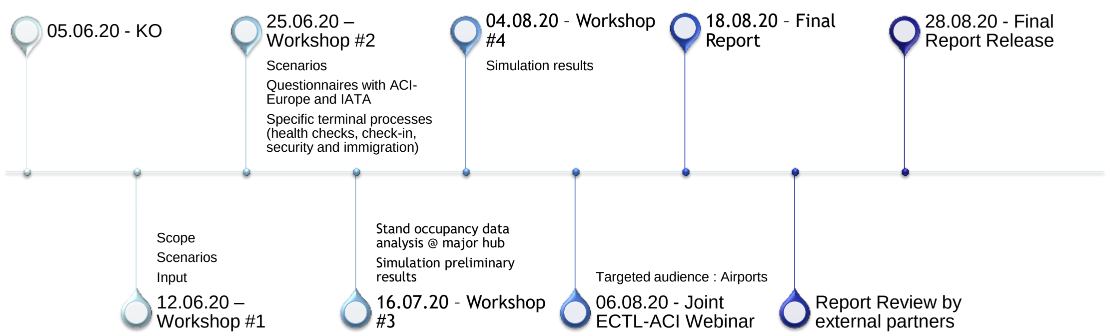


Figure 5: Project timeline with milestones for stakeholder exchange

1.4 General Analysis Framework

The objective of this Section is to describe, in a very concise way, the environment in which the study is performed.

1.4.1.1 Physical Distance Application

As shown on Figure 6, there are different recommendations and guidelines regarding physical distance rules used by various countries over the world. The 1.5m guideline seems to be most widely used within Europe, although some member states refer to the "two-arm-lengths" / "6 feet" or 2m guideline. The 1m guideline would be regarded as the absolute minimum, assuming that everybody wears a face mask.

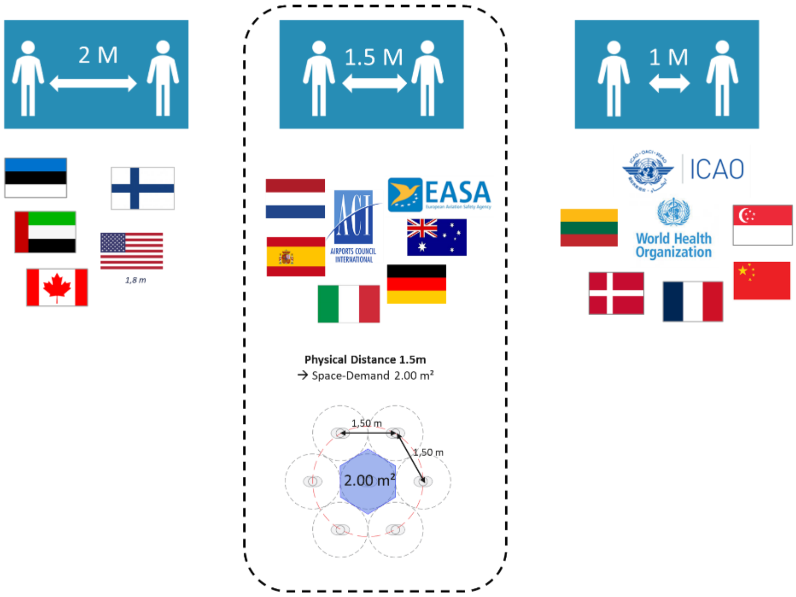


Figure 6: Recommendations for physical distance by country, with a focus on the 1.5m in this study

According to EASA, physical distancing should be 1.5m minimum and ideally 2m. Airport should ensure that 1.5m physical distancing is maintained wherever this is operationally feasible. As per the EASA guidelines, the 1.5m physical distance rule is used in this study for most of the analyzes, if not mentioned otherwise.

It is to be noted that, the application of the 1.5m physical distance rule to different terminal areas leads to an increase of the usual comfort level requirement per passenger as recommended by IATA.

For the purpose of this study, the 1.5m physical distance recommendation was converted into the following space requirement per passenger:

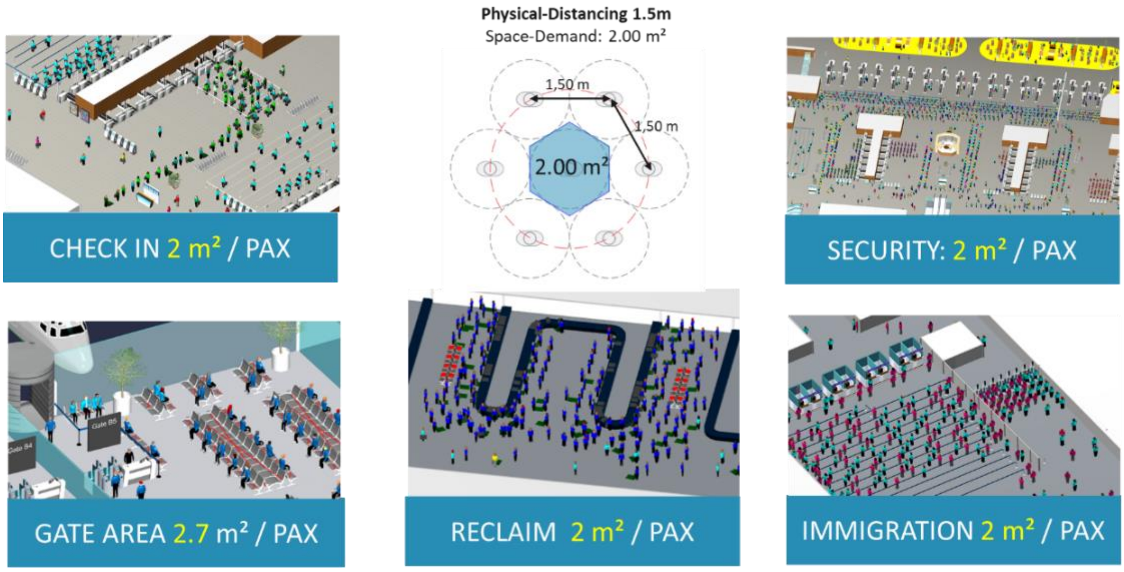


Figure 7: Space requirements in m²/PAX for different terminal areas when applying the 1.5m physical distance rule.

1.4.1.2 Use of a Generic Simulation Model

It is commonly recognized that each airport is specific in terms of layout, traffic mix, environment, staff expertise and operational procedures; there is no two similar airports even if similarities can sometimes be identified between airports on some aspects.

The model used in this study must be generic enough in order to get rid of local specificities that might bias the COVID-related results. Nevertheless, this generic model must be representative enough so that it can be customised to local airports with minimum effort if an airport wants to.

As shown on Figure 8, the generic model used in the scope of this study includes a central main terminal building with check-in, security control, central retail area, border control, transfer facilities, immigration and baggage reclaim hall.

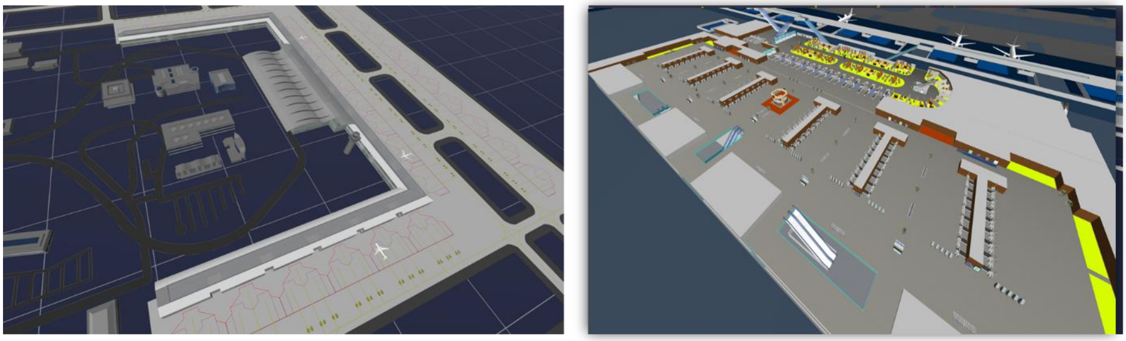


Figure 8: CAST model of a generic airport terminal

The main flight schedule used in this study represents a pre-COVID situation with around 8,000 PAX/h during total peak, and around 4,000 to 5,000 PAX/h arrival/departure peaks.

With this flight schedule, the terminal, as shown on Figure 8, was operated close to its saturation capacity.

In order to consider a set of traffic characteristics as large as possible, the flight schedule includes a variety of typical European traffic: a main full-service carrier, low-cost carriers, typical holiday carriers and a selection of other full-service carriers.

In the scope of this study, the flight schedule was decreased in the main peaks by removing flights and reducing the number of passengers per flight, whilst assuming the use of smaller aircraft and/or reduced load factors.

By doing so, different situations could be modelled to test the terminal operations with reduced traffic but increased spatial requirements due to COVID measures.

As a consequence, the results of this study shall not be interpreted as representing one airport in particular but should be considered in a general way. For this reason, the results of this study will be produced in relative terms (percentage) rather than absolute.

1.4.1.3 Scenarios and KPIs

With the aim to be generic, this study analyses possible tactics and options to implement the COVID measures. For instance, the study looks at various configuration options for boarding gate operations and assesses the impact of physical distance for the different choices of implementation. Furthermore, it looks at influencing factors and parameters that change gate utilisation.

The study analyses the fluctuation of the following parameters for the various scenarios of implementation at the terminal processors that are affected: demand and throughput capacity, waiting time, queue length and space occupancy. As far as aircraft turnaround is concerned, actual data from an airport was used and analysed, with a special focus on stand occupancy, boarding and connecting times.

Both quantitative and qualitative results are provided in this report, enriched by the insights from the involved airport stakeholders, ACI EUROPE and IATA.

1.5 Structure of the document

Sections 2 and 3 of this document are the technical report provided by ARC, on the impact of COVID-19 measures on, on one side, terminal operations and performance and, on the other side, on stand occupancy and turnaround critical path.

Section 4 provides the key conclusions of this study.

1.6 Terminology

The following terminology is used in the context of this document.

Term	Definition	Unit
Handling or throughput capacity	Actual capability of a processor or a complete checkpoint to handle a certain number of passengers within a given time interval.	Pax/h
Queueing or holding capacity	Maximum number of persons, which fit into the assigned queuing area.	Pax
Terminal Airside	Part of the terminal after security control for departing passengers and before customs control for arriving passengers.	
Terminal Landside	Public part of the terminal building, which is accessible to everybody without any further check.	
One Stop Security (OSS)	The EU's regulatory framework provides for the recognition of security standards applied in a non-EU country where those standards are equivalent to EU standards. Recognition permits One Stop Security whereby passengers, baggage and/or cargo arriving into the EU do not need to be subjected again to security controls when transferring at EU airports.	
Stand Occupancy	Actual time from on-block to off-block. It does not relate to any turnaround activities and also includes idle times.	
Aircraft Turnaround	All activities of an aircraft from arriving to leaving the aircraft stand. The (minimum) time needed to perform these activities is defined as (minimum) turnaround time.	

Table 1: Terminology

2 Impact Analysis by Terminal Process and Area

2.1 Health Check

2.1.1 Introduction

Air transportation could be one of the vectors for COVID transmission. It is recognized that the risk on airplanes is probably lower than in many confined spaces, because modern airplanes have cabin air filtration systems equipped with HEPA filters. Nevertheless, passenger have to transit via airports to travel, and these environments need to be secured in order to minimise the risk of spreading the virus. The focus is therefore on implementing risk based measures on layered and temporary approach through, amongst others, physical distancing and enhanced sanitation. Measures on isolation should not be observed but as combination with the rest in place.

At the time of the study, the situation around health checks is still **unclear** and very **dynamic**. One concern is that current guidelines and recommendations given by aviation organisations seem not to be sufficient to identify all sick passengers and prevent them from flying. In consequence, there is no common approach from local authorities and it is very difficult for them to act in a predictive mode. When a local authority submit a new regulation, airlines and/or airports have to align with this on a short notice. This adds uncertainties in a smooth operation and increases the risk for disruptions.

In recent weeks, COVID tests gained an increasing importance, even if they are not mandatory from a guideline point of view. However, this study has been looking into scenarios assuming that a growing number of passengers might be subject to testing before or after travel.

This Section shall answer the following questions:

- What is the current status? Which health checks have been already introduced?
- Did those measures have any impact on passenger handling on arrival or departure?
- What would be facility requirements if COVID tests will be more commonly implemented for departure and arrival processes?
- How would a concept for a COVID test centre could look like? What's the best place to locate it. What are the challenges?

The approach of the study to tackle these questions comprises:

- Interview of airport stakeholders
- Research and observation of current approaches
- Simulation of initial scenarios for facility requirement for arrival and departure
- Simulation and visualisation of a COVID test checkpoint

2.1.1.1 Current Status of Health Checks

The difficulty to detect COVID infected persons without symptoms is challenging. In the following, health check and screening measures introduced at the time of the study are listed:

- **Thermal temperature screening:** has been implemented at several airports in the initial phase of the pandemic, but has been identified by EASA as a high-cost but low efficiency measure, because 75% of infected passengers are not detected (passengers without symptoms).
- **PLC/PLF (Passenger locator Card/Form) to enable contact tracing:** passengers are requested to fill in a hard copy in-flight and hand it in, either to the aircraft crew or at passport control. The purpose is to rapidly identify secondary cases and prevent further spreading of the virus.

  The collection of passenger self-declarative health data (including person's identity, health conditions, contact details for tracing purposes and travel history.….) should be treated in all cases under the principle of respond to a direct interaction between passenger and authorities with no airlines' involvement beyond informing passenger on the need to provide such data. This should be clearly differentiated from the pre-existing data sets that airlines are providing to authorities in the context of inmigration or security.

  There should be initiatives to standardize PLF information whilst establishing an approach how to share data.
- **Health self-declaration:** governments requested a health declaration statement from passengers. Airlines had to ask health questions related to COVID. That was initially performed during check-in by agents, but most airlines have now integrated this to the online check-in. Some governments request this information online before travel.
- **Local authorities of destination airports request information online from passengers before travelling and provide QR Code:** In order to ask self-declaration health questions as well as enable contact tracing in a more efficient way, some national authorities (e.g. Spain or Greece) request passengers to fill in online forms. Based on this, a QR code is generated that passengers have to show during the check-in and eventually on arrival to prove that they provided the required data before entering the country of destination. This made it easier for local health authorities to obtain the data electronically and make the process easier than processing paper forms.
- **Recent negative PCR test before departure:** some countries have implemented requirements for recent negative PCR test (e.g. 48-72 hours before departure). This can reduce the risk, but a negative test does not exclude the possibility that a passenger tested negative could become infectious during travel. Such kind of tests can be done off-airport before travelling or at the airport where test results can be provided 2 to 3h after the test.
- **COVID testing at destination:** some countries have implemented testing of passengers on arrival, in particular from defined "risk areas". National authorities put

rules into place but currently have difficulties to develop local testing capacities to ensure timely results.

Aviation Stakeholders applying health check measures

Airports:

- Most common: some airports do temperature screening with infrared cameras, what is not intrusive
- Some airports voluntary installed COVID PCR test centres close to the airport as a service (passengers pay for the test) (example: Frankfurt Airport, Istanbul Airport)
- Recently, some airports had to install COVID PCR test centres requested by their government to offer free tests for returning tourists from countries declared as “risk area” (e.g. Germany and France from beginning of Aug 2020).

Airlines:

- Aircraft cleaning and disinfection
- Management of passenger health related forms (when recommended government portals are not in place)
- Adjust boarding/deboarding processes, including running checks on passenger before boarding (e.g. medical certificates)
- Implementing necessary protocols on board to handle suspicious cases
- Adjusting communication channels before and during the flight to keep passenger properly informed about travel requirements

National autorities: the aviation industry currently lacks of standardisation regarding health checks among EU States within the Schengen borders. Each state acts on national level regarding travel restrictions and implements individual requirements with different approaches. For instance, some national authorities:

- do nothing (e.g. even no PLCs for contact tracing)
- ask for PAX Locator Form (PLF) for contact tracing on arrival
- ask for passengers’ online health self-declaration filled on arrival
- ask for negative COVID PCR test before travel or on arrival
- allow waiver of self-quarantine with recent negative PCR test

To this day, there is no satisfying test method for COVID for aviation. The following picture summarises the main problem with current possible test methods and related fallbacks:

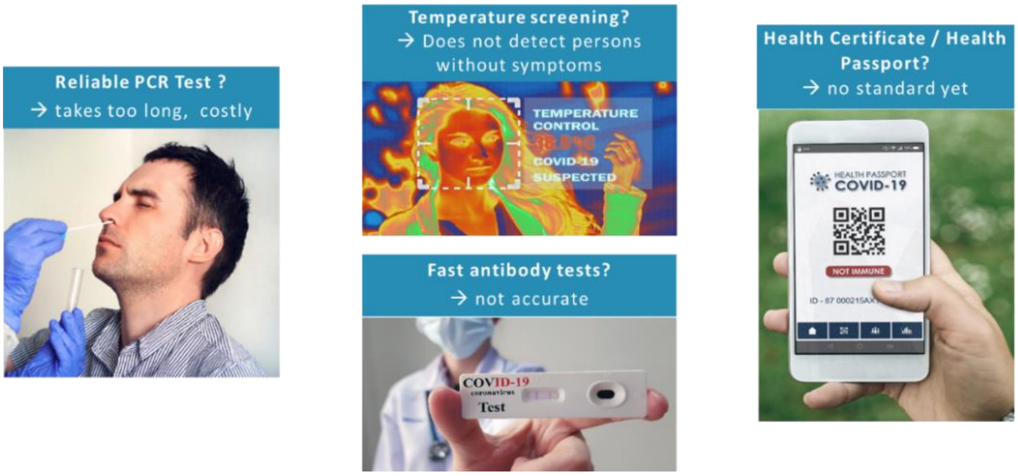


Figure 9: Problems with Health Checks: No fast, reliable test method available yet (status: Aug 2020)

IATA stated in a position paper dated June 30, 2020 regarding COVID testing that a test has to be scalable, quick, highly accurate and cost efficient. A test not meeting these criteria will cause more problems than it actually solves. If a test is required, it shall be upstream within 24h prior traveling and performed off-airport.

Currently, the PCR test method is most widely trusted. It however takes too long and remains costly. New test methods are currently under research and expected to be faster, more reliable and less costly test in future.

This analysis shows that the situation regarding health checks and how it will unfold in the coming weeks and months is quite uncertain.

2.1.1.2 Discussion with Airport Stakeholders

At the time of the study, health check measures were discussed with the airport stakeholders. It needs to be considered that the situation was very dynamic, and evolved during the short time of the study. At the beginning, health checks hardly being considered, whilst it now becomes more and more relevant.

1. **Health checks are not the responsibility of airports**

   In the workshops, airport stakeholders emphasized that health check is the responsibility of national authorities and not the responsibility of airports. As long local authorities do not commission any task to be the responsibility of airports, no mandatory action is required and any health-related check, e.g. temperature screening, is performed only on a voluntary basis with the focus to regain passenger confidence.

   As the situation has been unclear and different national authorities are acting quite differently, it could be observed that several airports still wait on governmental guidance in which way health checks shall be implemented.

2. **Proactive actions by airports observed**

   Nevertheless, several airports started to proactively test and implement certainmeasures, also demonstrating that they take the topic seriously. The objective is also to regain passengers' confidence in air travel.

   At the beginning of the pandemic, thermal cameras screening was popular to detect passengers with fever symptoms. However, as stated before, thermal screening is not effective to detect infected passengers without symptoms.

3. **COVID PCR testing**

   As reaction to some national authorities requesting negative PCR test before travelling, some airports early introduced test centres to offer tests on a commercial base as a service to passengers (examples: Frankfurt and Istanbul airport).

   COVID PCR testing became more relevant only towards the end of this study when some governments also requested mandatory COVID tests on arrival. During the discussion with the airports, it seemed likely that COVID testing might be implemented in terminal landside and in front of the immigration control for certain flights identified as risk area. Based on this, arrival scenarios were investigated in course of the study.

4. **Missing Standardisation**

   The concern about the lack of standardisation at the European level for tracing questionnaires and travelling forms has been raised by the airport and airline stakeholders. It was stated that ICAO and IATA are collaborating on standardisation and a guideline is planned for Sept 2020.

   Another key concern is the guidelines for connecting flights from risk areas to Schengen. Different countries use different criteria to classify a country or region as risk area adding confusion and uncertainty on travel restrictions for airlines and their passengers.

5. **Impact of health checks on passenger handling on arrival or departure**

   As long as temperature screening is done non-intrusively, it will not have an impact or interfere with the regular passenger processes.

   If health questions are asked before travelling (e.g. during online check-in by airlines or via online registration forms by governments) they will not change the passenger journey. Only if passengers do not check-in online and health questions might be asked during check-in, this can slightly prolong process times.

   If health questions and PLCs have to be collected during the arrival / immigration process and integrated into the process, this would impact the immigration process and would make it slower. However, if those questions and information can be shared online before travel, the impact can be reduced to a minimum.

   COVID tests become more prominent for departure and arrival. If only a smaller group of passengers use these test facilities, the testing facilities can co-exist as a landside service. However, current trends show a wider usage and tests might even become mandatory. In case COVID tests are integrated on the airside of the terminal, this would have a major impact on passenger handling and on the overall passenger journey. Although this scenario seems unlikely, this study analyzes the implications of such measures in simulation scenarios.

2.1.2 Scenario Setup

During the first workshop with the airport stakeholders, the only health checks applied were temperature checks to identify sick passengers with high temperature. Other health tests were regarded rather as unlikely at that time. As the temperature check is implemented preferably as non-intrusive thermal camera scan, there is no impact on the actual passenger flow. Therefore, temperature checks were not considered with simulation in this project.

During the time of the study, news channels continue to report on research and case studies at airports trying innovative COVID tests that better meet the requirements for a scalable, accurate, quick and affordable test. But still, currently the only accepted test is based on the PCR test method that is, however, not scalable (slow, costly, accuracy of only 95%). Nevertheless, COVID testing based on PCR are increasingly requested recently due to the lack of other reliable tests.

It is to be noted that the scenarios specified focus on measures that would have an impact on airport operations and capacity and would change the passenger journey by adding additional processing time. In particular, this refers to checking passenger's self-declaration and PLC on arrival and related to COVID testing for arrival and departure. When health checks are integrated as part of existing processes, such as checks during the check-in or immigration process, the reader can refer to the respective chapter of this report.

2.1.2.1 Specification of General Scenarios for Facility Requirements on Health Checks

Since no standard process for health checks at airports has been defined yet, several "Future Scenarios" have been considered in order to gain some insight in facility requirements for a possible heath checkpoint at airports.

In this context, a set of scenarios assuming possible fast tests in future (e.g. test results within 1 minute) are investigated. Scenarios for departing and arriving passenger flows has been considered as snap-shot scenarios:

- Health Checks on Departure:
  - Check of facility requirements for a set of processing times (1, 2 or 5 min) for a health test applied to different peak hour volumes (1,000, 1,500 and 2,600 PAX/h).
  - It is assumed that the departure checks are performed in the terminal and that passengers will get their test results right after the test.
  - Other health checks, such as health questions and contact tracing data collected from passengers, were not considered because this kind of

information is expected to be collected by the airline at online or agent check-in and not part of a dedicated health check.

- Health checks on Arrival:
    - At the time of scenario definition, it was assumed that there are special health checks on a flight-by-flight basis based on their classification. Flights arriving from a "risk area" are subject to a health check on arrival when requested by local authorities.
    - The scenarios check facility requirements for a set of processing times (5, 20, 60, 120 sec) assuming that dedicated health checks/tests are applied to single arriving flights (full narrowbody 180 PAX and full widebody with 300 PAX)
    - For arrival it was assumed that the health checks are:
        a) Checking a QR code for contact tracing data entered before travelling (5 sec)
        b) Checking of a health certificate, such as a negative COVID test performed before travel or a passenger locator form (PLF, 20 sec)
        c) Performing a "new" effective COVID test with immediate results (60 sec)
        d) Performing a PCR test on-site with notification of results off-site (120 sec). In this case, it is assumed that registration of data provided before travelling or a PLF had been filled in during flight.

2.1.2.2 Specification of a Scenario for a COVID Test Centre

The initial scenarios were simulated based on rather general assumptions for "Future Scenarios". Since the topic of COVID testing gained considerable attention towards the final stage of this study, another scenario considering a test centre was simulated.

First implementations offered PCR tests on a commercial basis for departing passengers flying to a destination requesting a negative PCR test or for arriving passengers arriving from a risk area to avoid mandatory quarantine of 14 days (link in Vienna, Istanbul or Frankfurt). These test centres are located at or close to the airport terminal, but are not part of the mandatory passenger process.

When holiday traffic within the European Union raised again in July, tourists return from vacations with COVID infections. Beginning of August 2020, some countries (e.g. France and Germany) reacted and made the test mandatory for all passengers returning on flights from risk areas. Initially there was a discussion that the test center shall be located on the airside of the terminal in order to keep track of all passengers that shall be tested as well as to enforce contact tracing. With this open discussion in place, a "worst case" scenario assuming a test centre airside before immigration has been setup in the model as well as a sub-scenario with a test centre after immigration.

The process design was discussed with airport stakeholders who were in the process of designing and implementing the test centres on request of their government authorities.

2.1.3 Results

2.1.3.1 General Health Check Scenarios on Departure

At the time of this study, separate health checks for departing passengers were not mandatory. However, negative COVID tests before travel are requested by an increasing number of governments.

The number of departing passengers arriving in the terminal before their flight depends on the show-up profiles by traffic segment and passenger type. Passengers conducting a test are assumed to arrive at least 30-60 minutes earlier.

The peak hour volumes of 1,000, 1,500 and 2,600 PAX/h relate to scenarios of the test airport assuming 30%, 50% and 75% of pre-COVID peak hour traffic. The volumes can also be interpreted for a higher peak volume and then referring to a sub-set of departing passengers to be tested, e.g. when assuming part of the passengers have done a test off-airport.

The following table summarises the scenario assumptions. The scenarios shall give an indication on the order of magnitude in number of required health check units for the specified processing times and level of service (LoS) settings.

ID	Scenario on kind of Health Checks on Departure	Assumed Processing Time per PAX	LoS Queue per position	LoS Waiting Time
A	**„New“ effective quick test** Performing a “new” quick ,accurate, scalable COVID test with immediate results (Note: such a test is not available yet- but assumed to be in the future for this scenario)	60 sec	10 PAX	10 min
B	**PCR Test – with Pre-Registration** Performing a PCR test at the airport landside with notification of results within 1-2 hours (Note: assumption for registration of data considered to be provided before travelling entered online or via an App)	120 sec	10 PAX	20 min
C	**PCR Test – plus Registration** Performing a PCR test at the terminal with notification of results within 1-2 hours (Note: assumption that process takes longer per passengers considering also a registration process)	300 sec	4 PAX	20 min

Table 2: Parameter Settings on General Departure Scenarios for Health Check (Initial Scenarios)

Assuming different processing times for COVID tests and different demand levels, the following number test positions is required (see Table 3). Depending on processing time and desired waiting time, the result shows that the number of required positions for health checks can increase significantly.

ID	Process Time	Positions for 1,000 Pax/h	Positions for 1,500 PAX/h	Positions for 2,600 PAX/h
A	60 sec	15	21	37
B	120 sec	27	38	66
C	300 sec	67	94	166

Table 3: Results on General Departure Scenarios for Health Test (initial scenarios)

As expected, the result shows, that a check of departing passengers would be staff and space demanding (considering space consumption of 2m² per PAX). While a fast scan seems to be rather manageable (e.g. health certificate), a fast test of only one minute (Scenario A) would already require a larger space and considerable amount of staff to operate.

Layout considerations have not been tested in the scenarios, but can be derived based on the findings in the scenario of simulating a COVID test centre (see chapter 2.1.3.3).

When several minutes are required for a test, the space and staff required to perform those test reach a level that could be hardly manageable as temporary measure; it would require space comparable to a check-in hall – thus rather unrealistic to cope with.

2.1.3.2 General Health Check Scenarios on Arrival

As specified Section 2.1.2, the scenarios assume that only selected flights from risk areas need to be checked upon arrival. The assessment considers two flights categories:

- A narrowbody flight with 180 PAX on board (load factor close to 1)
- A widebody flight with 300 PAX on board.

In this scenario, the health check is considered as a separate process which is not integrated in other processes (e.g. immigration). Therefore, it is not conducted by immigration officers but by separated staff in a specific process. Health check questions integrated in the immigration process is reported in Section 2.6.

The following table summarises the scenario assumptions, and provides an indication on the order of magnitude in number of required health check units for the specified processing times and LoS settings. This is based on the input collected at a workshops in June.

ID	Scenario on kind of Health Checks on Arrival	Assumed Processing Time per PAX	LoS Queue per position	LoS Waiting Time
A	**Checking a QR code** for contact tracing data entered online by all passengers before travelling	5 sec	10 PAX	<1 min
B	**Health Certificate Check or PLF** Checking of a document, for instance a health certificate,	20 sec	10 PAX	3.3 min

	such as a negative COVID test performed before travel or a PLF (passenger locator form) for contact tracing			
C	**„New" effective quick test** Performing a "new" quick, accurate, scalable COVID test with immediate results. Such a test is not available yet- but assumed to be in the future for this scenario.	60 sec	15 PAX	15 min
D	**PCR Test** Performing a PCR test on-site with notification of results off-site (assumption for registration of data considered to be provided before travelling or a PLF filled out during flight)	120 sec	12 PAX	25 min

Table 4: Parameter Settings on General Arrival Scenarios for Health Check (initial scenarios)

Depending on processing time and desired maximum waiting time, the result shows that the number of required positions (staff) can significantly increase. To conduct a PCR test on every passenger would result in a lot of facilities for the processing of only one flight.

ID	Process Time	Positions for 180 Pax Flight	Positions for 300 Pax Flight
A	5 sec	2	2
B	20 sec	5	6
C	60 sec	7	9
D	120 sec	10	14

Table 5: Results on General Arrival Scenario for Health Check (initial scenarios)

It is to be noted that a quite fast processing time for a PCR test had been assumed in this case (120 sec). At a later stage of the study, it has been communicated by the stakeholders that the actual processing time could be around 4 minutes. This higher processing time is considered in the COVID test centre scenario, as reported in the next Section 2.1.3.3.

2.1.3.3 Simulation of a COVID Testing Centre

In order to evaluate the operating principle of a separate testing area and analyse the possible interdependencies and impacts on passenger flows, a testing centre has been simulated. Based on current information regarding testing as well as inputs from airport stakeholders, a concept was designed and further implemented in the generic airport model used for the study.

The minimum requirement for a testing facility, whether installed on the public terminal area (landside of the terminal) or the restricted area (airside of the terminal) comprises two kind of processors:

1. **Registration area**

   Passenger's information needs to be collected for contact tracing, and questions on medical conditions might be asked. Depending on the country, payment or health insurance information need to be provided by the passengers.

2. **Testing booths**

   After the registration process, the actual test is conducted in separated booths by medical staff. At the time of the study, the tests conducted are related to a PCR test with a processing time of around 3 to 4 minutes. Depending what kind of tests would be available in future, the booth layout and requirements might be different.

For both processors, adequate queueing space for waiting passengers as well as floor walkers to guide and manage the passenger flows need to be planned for.

Figure 10 shows a possible concept of a testing area designed and integrated into the layout of the airport simulation model used for this study. The area considered is using a space of about 1,000m². With a total of 32 testing booths and duration of 4 min per tests, the facility in this set-up achieves a theoretically capacity of approximately 500 PAX/h.

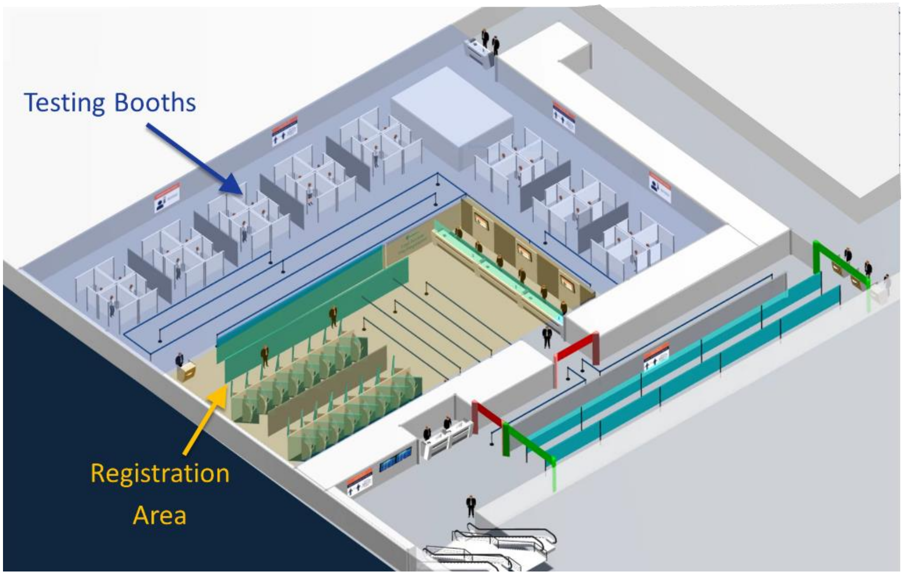


Figure 10: Example Concept of a COVID testing Area in simulation model

When placed inside the terminal, this facility needs to be elaborated carefully as a considerable high amount of space and operating staff is required.

When passengers from risk countries only are subject to a COVID test, the testing area should be established on arrival flow without further disrupting the flow of passengers which do not require a test. Since risk countries are identified currently at a national level, passengers need to be informed about the status of their originating flight in the country of their destination. The information could be provided by the airline before or during the flight but should also be displayed on information posters and screens as well as being communicated by airport staff in arrival corridors.

The testing area model includes different passageways in order to separate passenger flows. The red entrance on Figure 11 indicates the way into the PCR testing area for further registration and testing procedure. Passengers from non-risk countries or passengers with a valid PCR test (carried out before departure in originating country) shall select the green entrance. There is a requirement for a queue buffer zone for arriving passengers, since airport staff needs to check if passengers might require a PCR test and eventually redirect passengers to the testing area.

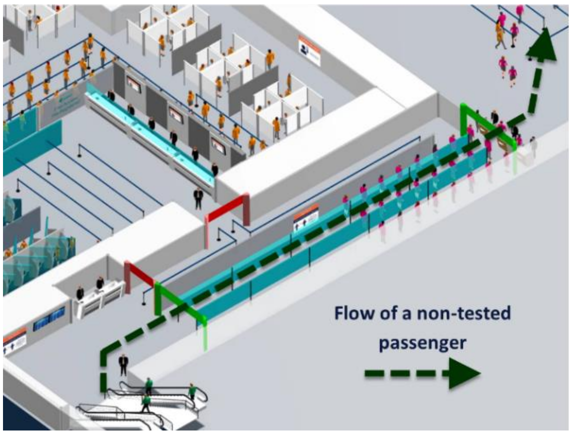


Figure 11: Passenger Flow of non-tested Passengers

The registration process can be carried out differently (e.g. questionnaire by staff, filling out paper form, pre-registration) and is country specific. In this testing area model, the registration can be performed:

(a) manually while staff retrieves information from the passenger as well as

(b) by using automatic kiosk or a mobile App where data is retrieved digitally.

(c) The third option would be a fast track for pre-registered passengers; since all information would be submitted earlier, either through web page or app, passengers have an identification number or QR code which allows them to pass the registration process and directly proceed to a testing booth. Pre-registration should be encouraged by airlines and airports since it saves time and space usually required for registration procedures on site.

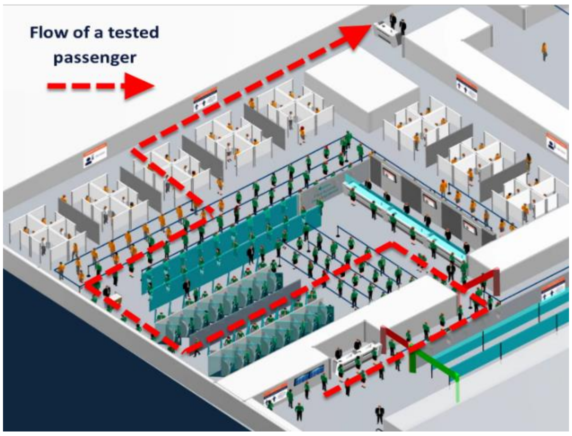


Figure 12: Passenger Flow of Passengers in Testing Area

After having fulfilled the registration process, passengers are directed to the queue area for testing booths. Due to the limitation of space and possible fluctuation of arriving passengers, floor walkers shall be planned in order to manage the queue systems. When the queue systems of the testing facilities are completely filled, the inflow from registration process or from other levels via stairs/ escalators shall be managed.

When the testing is complete, passengers need to show an indication of fulfilled test (e.g. sticker, paper form, QR code) in order to exit the testing area.

As mentioned before, it is assumed that the simulated test centre has an hourly capacity of 500 PAX/h. In the simulation scenario, a peak hour volume of around 1,000 passengers was simulated and 50% of these passengers needed to process through the testing centre. On the one hand, the simulation considered flights from risk countries, where every passenger needed to be checked. On the other hand, also flights with partly tested passengers are simulated (some passengers are assumed to have a valid PCR test conducted before travel and thus bypass testing on arrival).

The simulation showed that queues develop quite dynamically, because of fluctuation of traffic and short peaks triggered by flight arrival patterns and the proportion of passengers that need to be tested. Therefore, to handle contingency, it is important to plan for sufficient overflow areas and think about mitigation measures if overflow area comes to saturation. A possible mitigation measure to saturation is to postpone deboarding of a flight from a risk region as a measure to balance and release the available queue space and capacities of the testing area.

The visualisation of the simulation scenario for the COVID testing centre is provided in the video link (https://youtu.be/O9a-bScTnoE)

Test centre before or after immigration control / airside or landside?

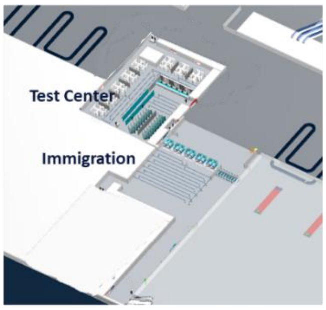
The scenario initially simulated assumed a “worst case” scenario, where the test centre is located airside and part of a mandatory process for passengers arriving from a risk country as classified by the local government.

The first scenario assumed the test centre **before immigration** control: from a capacity point of view, this is a “worst case” scenario as incoming passengers appear shortly after flights arrival. Due to fluctuation and variation of the actual arrival time and punctuality (fights can arrive early or late), local congestion can happen with an inherent volatility. The organisation and operations of such an area on arrival is challenging due to the nature of high peak demand of arriving passengers. In case several flights that need to be tested arrive at a same time, passenger queues can grow quite fast.

Another scenario considered that the test centre is located **after immigration** control. Usually the immigration slows down the throughput of passengers towards the downstream process to the baggage reclaim. Thus, arrival peaks are flattened after immigration process. The consequence is that also the number of required registration facilities and test booths are lower.

The simulation scenario, considering waiting time at immigration control and also allowing a waiting time of 15 minutes at the test centre, resulted in almost 30% lower required number of test booths.

Test Center **Pre-Immigration**



Test Center **Post-Immigration**

Scenario	LoS Waiting Time	Number of Test Booths
Test Pre-Immigration	15 min	32
Test Post-Immigration		23

Figure 13: Comparison test booth requirements on arrival depending of test is before or after immigration

There is an important insight regarding the aspect of using the immigration “by intention” in order to control the inflow to a testing area by capacity-demand balancing. If the test centre would get too crowded but immigration still offers queue space to hold passengers, closing an immigration control can increase the number of waiting passengers at immigration, but also reduces the inflow of passengers to the test centre.

It is also to be borne in mind that, if the test centre is in front of immigration and flights from Schengen countries would need to be tested because they are categorized as a risk flight, they would be handled as Non-Schengen to guide passengers towards the test centre. If the test centre is located after immigration, the passenger flow can be organised in a way that Schengen and Non-Schengen passengers can use the test centre without Schengen passengers unnecessarily using the immigration.

After having investigated the scenario of a COVID test centre, the evolved situation changed dynamically again. Some national authorities had to acknowledge that test on the airside will result in too many issues not solvable on a short notice. Test capacities cannot be setup in the required order of magnitude. For instance, German government allows testing within 3 days after arrival and offers on-airport and also off-airport testing options. Test is free of charge, but test results are only available several hours or days after testing and passengers need to keep in quarantine until receiving a negative test result. Controlling if passengers are behaving according to the guidelines of self-quarantine currently is done based on random checks.

At this point in time, there is still lots of uncertainty. It is not known how effective the process is, if really all passengers needed to be test are really tested, and if there will be an enforced testing airside again in future.

2.1.4 Conclusion

At the time this report is written, the situation around health checks remains unclear. The standardisation and coordination at European would certainly decrease uncertainty for travelers.

The simulation scenarios considered a potential COVID test integrated in the passenger flow of arriving and departing passengers. So far this had not happened on a large scale, but the study intended to share insight with "What-if" scenarios in case a COVID test centre will be a mandatory process on departure and/or arrival.

COVID testing on departure

The currently accepted test (PCR) is costly for passengers and receiving results takes too long. Therefore, passengers would only do such a test if the country of destination and/or the airline requesting a negative PCR test before travel.

Consequently, the only setup currently observed for testing on departure is the test before travelling at an off-airport test centre shortly before travelling. To date tests for departing passengers require organisation and payment by the passengers themselves.

Depending on the number of passengers to be tested and the time a test requires, different scenarios were investigated. With current processing times for a test of 2 to 5 minutes, a quite high number of test facilities and associated space would be required. Even a short test of only 1 minute would require a significant number of processors.

In any case, it can be said that such a test centre for a high number of departure passengers would have highest impact for both, the passenger and the airport. Passengers might need to get to the airport much earlier and the airport would need to assign lots of space for such a new process. Since both aspects are not of the interest of the travel industry, current development indicates that health checks shall rather be done off-airport. What remains at the airport could be a quick and less intrusive health certificate check.

COVID testing on arrival

According to the current situation of the study, the topic of a COVID test on arrival has been considered by several countries in order to identify and limit infections brought in from potential risk areas. However, there is no standardized process yet. As triggered by the discussion and quite dynamic evolution of the topic, "mandatory testing on arrival" was evaluated in different scenarios.

Impact of a mandatory test centre on arrival:

- **Location**: currently most test centres are installed at the landside of terminal, and passengers might decide to be tested after arrival at the airport or off-airport to shorten self-quarantine. However, it has been discussed to include mandatory testing also on the airside of the terminal. Establishing a test centre on the airside is very challenging because of high moment peaks and volatility of flight arrivals. The simulation shows that less test facilities would be needed if a test centre is arranged after immigration because the immigration slows down the passenger flow towards a downstream test centre. Furthermore, Schengen flights from risk areas would not use and block immigration facilities unnecessarily.
- **Baggage reclaim process**: if passengers would get stuck not only at immigration but in addition at a new health checkpoint with additional waiting and processing time, the pickup of baggage might be delayed considerably. Baggage reclaim capacity would be reduced or baggage need to be picked up manually by floor walkers and arranged for later pickup.

- **Transfer passengers**: arriving from a risk region, passengers transferring at and to a final destination without travel restrictions would need to be tested as well. In case a Schengen-to-Schengen transfer is impacted and has to run through a health check on arrival, this could mean a suspension of simplified flows (OSS), a change of passenger flows, a higher demand at transfer facilities and would also have a negative impact on MCT (minimum connecting time). This topic is further elaborated under the chapter of transfer passenger handling (see chapter 2.8).

In brief, testing a high number of passengers on arrival or departure requires a lot of facilities, space and staff even with short processing times of potential tests in the future.

A test prior to departure could reduce the risk of virus transmission by up to 90%, enabling air travel to be opened up between a large number of countries without a quarantine requirement. However, and as requested by IATA, testing for COVID-19 should not be a necessary condition for reopening borders and/or resuming air service operations where infection rates between two countries are similar and stable or decreasing. Risk-based, or risk-differentiated, testing offers a flexible solution with testing requirements and other public health risk mitigation measures adapted to suit the specific circumstances of the country pair or regional grouping under consideration[6].

[6] https://www.iata.org/contentassets/5c8786230ff34e2da406c72a52030e95/iata-position-covid19-testing.pdf

2.2 Check-In

2.2.1 Introduction

As first area in the passengers' process chain the departure hall including check-in is considered to be one major element regarding the potential requirement for any additional COVID related early checks of the passengers. In addition, any changes regarding passenger characteristics due to COVID, e.g. different show-up behavior at the airport or number of checked luggage, will immediately have an influence on the check-in process. Next to these process related impacts, the need for physical distance while queuing for the actual check-in transaction has to be considered.

As consequence of these thinkable process and passenger behavior related changes during COVID it has to be expected that the throughput and holding capacity of the check-in area is reduced. In case the check-in represents the bottleneck processor at an airport, this may even have a negative impact on the saturation capacity of the airport.

This chapter shall answer the following question:

- What does physical distancing mean for queues at check-in?
- Which changes have to be expected for the check-in process regarding
  - changed passenger behavior
  - new operational requirements?
- How does COVID impact various traffic clusters / airline types?
- Which mitigation measures are thinkable?
- How does the capacity of the check-in hall change in terms of
  - Throughput capacity / number of flights to be allocated
  - Holding capacity in queueing areas

At the time of the study, the airport stakeholders described the following key changes compared to Pre-COVID:

1. **Passengers tend to arrive at the airport earlier**

   There are different factors that trigger passengers to show-up at the airport earlier before the flight compared to Pre-COVID. In the beginning, it started with the expectation that passengers might accumulate at the entrance before being granted access to the building. All the time throughout the study there were frequent changes related to the necessity of health checks prior departure, which would require more time and lead to uncertainty of passengers since it is a completely new process. For the recovery phase it might happen that ground handlers or security personnel are not able to open sufficient facilities, which can result in long waiting times. When passengers are aware of this before travelling (e.g. when mentioned in news), the past has shown that passengers anticipate this delay again and try to compensate it by earlier show-up.

2. **Passengers check-in more luggage**

   As one measure to decrease the interaction between passengers in the aisle, and therefore reduce the risk of infection as well as to compensate the increased time for boarding, many airlines have reduced the allowed amount of hand luggage. In consequence, the number of checked luggage has increased, which means higher demand at check-in.

3. **The check-in process takes longer due to health questions and more paperwork**

   In response to (local) government requirements, airlines need to ensure that passengers declare their health status. Short-term this was done in a manual way by check-in agents, including the need for everybody to see a check-in agent (no self-service check-in possible). Meanwhile this process has been integrated in the online check-in system for many airlines.

4. **Passengers keep a physical distance in queues**

   As one of the first measures keeping distance while queuing was enforced. Depending on local regulations the distance between passengers varies but 1.5m distance between queue positions can be considered as typical. In the beginning of the COVID outbreak one common initial measure was to leave every other check-in counter not allocated. This even intensified physical distancing. However, this measure has now been substituted by plexiglass shields between the counters.

2.2.2 Scenario Setup

On the one hand, the study shall give an order of magnitude of the changed capacities for the check-in process in general, e.g. to quantify a new saturation capacity. On the other hand, it is important to understand cause and effect of potential check-in issues. Only then, suitable mitigation measures can be recommended. Due to the complexity and differences of check-in processes, the study includes an in-depth analysis of various flight types (namely full-service carrier, low-cost carrier, touristic flight).

With the intention to cover a wide range of traffic, the following parameters have been agreed to be used as typical representatives for the relevant traffic clusters for the baseline situation. pre-COVID:

Type	Hub Airline	Full-Service	Holiday	Low-Cost
Show-up behavior	Early / well distributed	Early / well distributed	Early / bunched 2-3h prior STD	rather late
Check-in opening	Common check-in, always open	- 2.5h prior STD	- 2.5h prior STD	Partly common check-in, other LCC does flight check-in - 2h prior STD
No bag share, skipping check-in	25%	25%	10%	50%
Check-In type	Online: 50% Counter: 20% Kiosk: 30%	Online: 50% Counter: 20% Kiosk: 30%	Counter: 100%	No, but 90% online check-in
Processing time	Full service: 120 sec/Pax Bagdrop: 90 sec/ Pax	Full service: 120 sec/Pax Bagdrop: 90 sec/ Pax	90 sec/Pax	Full service: 90 sec/Pax Bag Drop: 75 sec/Pax
Desired service level	10 min	10 min	30 min	20 min
Transfer share	Approx. 20%	no	no	no

Table 6: Check-In Traffic Clusters (Pre-COVID)

After considering the Post-COVID expectations by stakeholders, these characteristics are amended in the following way to represent the various COVID impacts:

Type	Hub Airline	Full-Service	Holiday	Low-Cost
Passenger show-up change	approx. 30 min earlier			
Opening time adjustment	no change	some airlines of each cluster open 30 min earlier		
Check-in process change	no change	some airlines of each cluster make agent check-in mandatory to ask health questions		
Reduction of “no bag” pax	25% → 20%	25% → 20%	10% → 5%	50% → 30%
Changed processing time	no change	+15 sec/Pax for those airlines, asking health questions (low, e.g. 20% of flights)		
Pax number change	0 | -25% | -50%			

Staffing adjustment	Partly proportional to traffic volume decrease	Proportional to traffic volume decrease	Proportional to traffic volume decrease	Proportional to traffic volume decrease
KPIs	Level of Service Assessment before and after COVID (flight based) Capacity loss for an optimized opening and allocation concept (one peak of example schedule)			

Table 7: Parameter Adjustments for Check-In Traffic Clusters (Post-COVID)

It is very likely that these changes will lead to prolonged waiting times and queues in a do-nothing scenario. Thus, the following optimisation measures are tested for the different traffic clusters, to check, how effective they can be and how a "mitigated" situation could look like:

1. **Adjustment of opening times**

   While for common check-in airlines handling many flights (e.g. hub carrier) the opening schedule of counters is dynamically balanced to the demand anyway, single flight check-in typically follows more strict rules and (all) counters only open at a certain time before the flight (e.g. 2.5h prior STD). In the latter case, a change in passenger show-up puts the Pre-COVID usual counter opening times in question. In order to consider the ground handlers' objective for an efficient use of manpower, only a part of the allocated counters move to an earlier opening time in this "What-if" scenario:

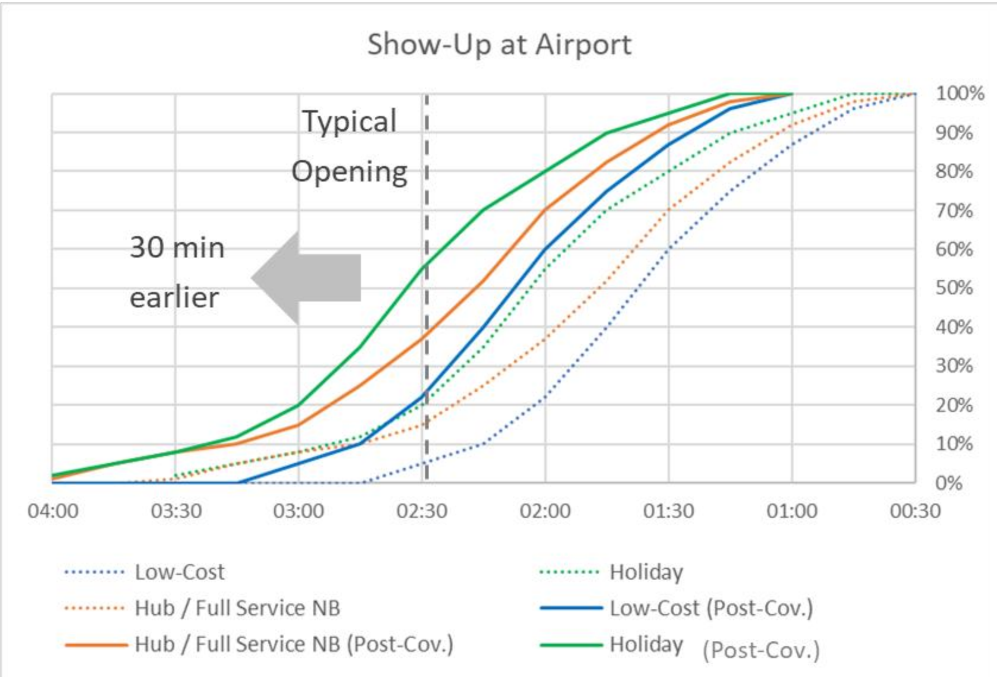


Figure 14: Show-Up at Airport pre- and post-COVID

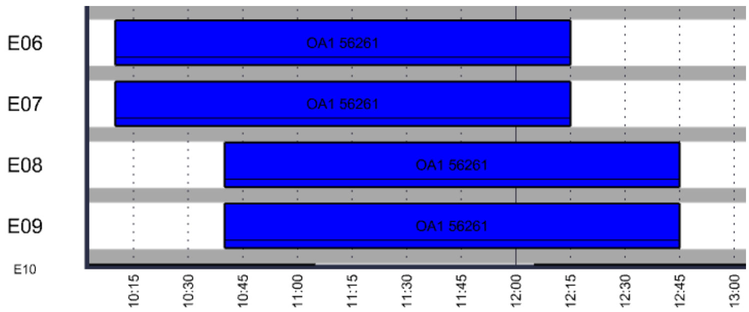


Figure 15: Check-In Opening Time Adjustment

2. **Including health questions in online check-in**

   Since a mandatory agent check-in even for passengers without checked luggage would make the passenger journey more bothersome and require additional resources (infrastructure, manpower), self-declaration could happen off airport, e.g. via the airlines' online check-in system.

3. **Combination of both measures**

   After an analysis of each measure individually, the combination of both mitigations is analyzed as a "best case" for optimisation.

The overall assessment is done in a 2-step approach. After an analysis of a single flight (narrowbody with 180 PAX) an allocation exercise is done for an entire flight schedule. This flight schedule and the applied airport infrastructure are balanced, so that the check-in area can be considered "saturated" in the baseline pre-COVID.

2.2.3 Results

2.2.3.1 Impact of physical distancing at check-in

As for every other processor, physical distance shall be kept while queuing for check-in. Following a frequently used guideline to keep 1.5m to other passengers, this would mean a space requirement of around 2m²/PAX.

Comparing this to pre-COVID space requirements (1.3 - 1.7m²/PAX as defined by IATA's ADRM 11 Edition) the loss of queue space capacity at check-in is less than for other processors such as security control or immigration (with 1-1.2m²/PAX). The reason for this is that the regular IATA recommendation for check-in already includes a supplement for luggage and trolley usage. Anyway, the capacity loss at check-in still accounts for 25%.

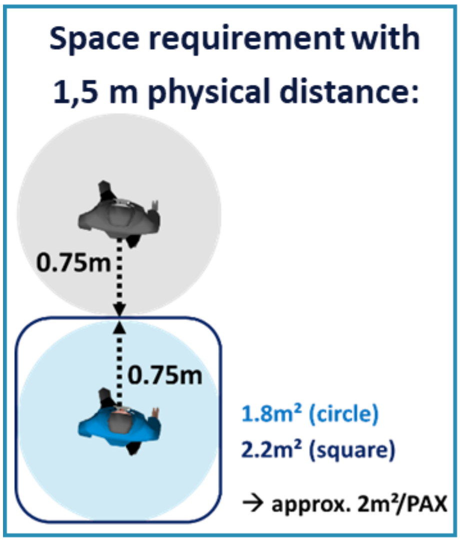


Figure 16: Space Requirement with 1.5m Physical Distance

In order to make this reduced queuing capacity better comparable for operations, the new queue capacity can be transformed into a waiting time equivalent:

Assuming that a "full queue" meant a waiting time of 20 minutes Pre-COVID, the same space can now be used to accommodate a queue representing e.g. 15 min only (with 1.5m physical distance). This means, if queue space cannot be expanded, airlines must offer their passengers a better time Level of Service (LoS) than before COVID. This should be considered in the ground handlers staffing calculation.

Available Queue Space	Physical Distance Rule	Space Requirement per Pax	Max. Pax per Counter	Waiting Time Equivalent	
				Full Service 120 sec/PAX	Bagdrop 90 sec/PAX
210m²	1m	1.5m²/PAX (IATA Standard)	10 PAX	20 min	15 min
	1.5m	2m²/PAX	7 PAX	15 min	11 min
	2m	3.5m²/PAX	4 PAX	9 min	6 min

Table 8: Waiting Time Equivalents for Check-In Queue

Looking at the same issue from another perspective: A "20 minutes queue", which fitted in the check-in counter's queueing system Pre-COVID would spill out due to physical distance Post-COVID.

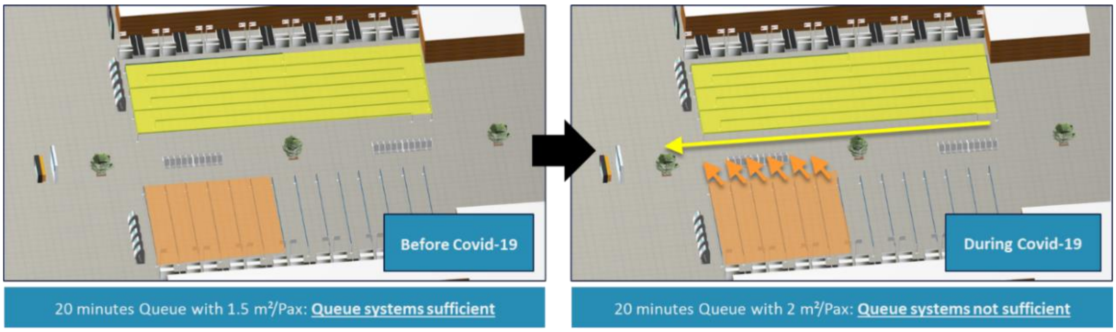


Figure 17: Visualisation of "20 min Check-In Queue"

This principle intensifies, the longer the queue respectively waiting time gets. A "30 minutes queue", which already used a bit of the overflow area, now might need much more overflow space of adjacent areas / corridors.

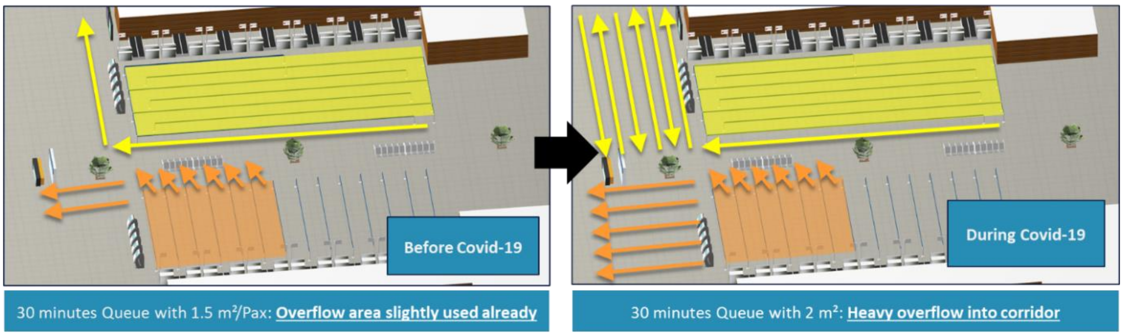


Figure 18: Visualisation of "30 min Check-In Queue"

Next to the general need for more space or the reduction of queuing passengers (see next sub-chapter), there are some advantages and disadvantages regarding the different queuing types in general. Some are COVID related but some are also valid under regular conditions:

Queue Configuration	Single Queue	Common Queue
General Capacity	Often quite similar. Unused space between lines if pax strictly queue one after the other	Often quite similar. Slightly better space utilisation, when less exit options from counters
Flexibility of Capacity	Only direct space in front of counter can be used	Space of adjacent idle counters could be used
Preparation	No special preparation needed	Adjustment to allocation needed
Changing staffing	More difficult to redirect passengers to other counter when closing	Opening and closing of counters does not affect the queue
Organisation in Overflow Situation	Unorganised as several queues might reach back into departure hall	Single entry is better to organise
Health Safety	Keeping distance to adjacent lines is easier but backflow in close proximity	Proximity to adjacent lines but no interference with backflow

Table 9: Comparison of Queuing Concepts

For understanding cause and effect of further COVID related changes and best suited mitigation options, the following bottom-up approach assessed the COVID impact on single flights for different traffic segments first and afterwards supplement the analysis by a holistic view on an airport's allocation:

2.2.3.2 Impact on full-service carrier (single flight assessment)

- Pre-COVID:

  A full-service carrier is typically characterized by a suitable balance of demand and capacity: a reasonable percentage of passengers uses online check-in and thus does not use check-in counters at all. In terms of show-up behavior just a few passengers turn up before check-in opens. Once check-in counters are open, demand is usually balanced with the throughput.

  In consequence the Level of Service can be regarded as good for a full-service carrier Pre-COVID.

- Post-COVID “Do Nothing”:

  In case the ground handlers do not react to the changed demand, the impact of earlier show-up, mandatory agent check-in for everybody and increased processing time show the full negative effect. In the analyzed example this resulted in the following key demand figures:

  - No use of self-service technology could increase the overall number of counter users by approximately 25%.
  - A shifted show-up could mean that the number of passengers lining up at check-in before it opens goes up from 15% to 35%.

  In terms of Level of Service (LoS) these changes can turn a previously very comfortable situation into a critical one. Not only that the waiting time and number of queuing passengers goes up; the increased space per passenger ratio leads to the effect that queues are disproportionately longer.

- Post-COVID “Optimisation”:

  For a typical full-service carrier both analyzed mitigation measures “adjust opening times” and “health questions online” have a good potential to reduce the check-in queues. Each measure applied alone leads only to a moderate improvement compared to the “Do Nothing” case but both measures in combination could lead to a situation only a slightly worse compared to Pre-COVID.

  Note: The optimized case does not necessarily involve *more* manpower but rather the same amount at a shifted (= earlier) time.

Figure 19: Visualisation of Check-In Scenarios (Full-Service Carrier)

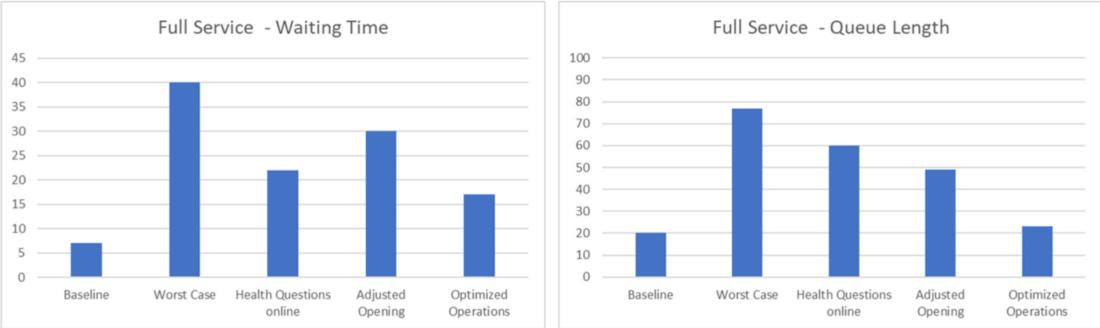


Figure 20: Numeric Results of Check-In Scenarios (Full-Service Carrier)

Situation	Demand	Waiting Time	Queue Length
Baseline	Only 80% use counter (144 of 180 PAX), Only a few (15%) arrive before opening	Short (7 min)	Short (20 Pax at 4 counters → 30m²)
Worst Case	All pax use counter (180 PAX), Several (37%) arrive before opening	Very high (40 min)	High (75 Pax at 4 Counters → 150m²)
Optimisation A: Health Questions online	Total number almost reduces to pre-COVID, just slightly higher because of more pax checking-in bags, Several pax still show up earlier than opening	High reduction potential (20 min)	Moderate reduction potential (60 Pax at 4 Counters → 120m²)
Optimisation B: Adjusted Opening (some Counters)	No mitigation potential reg. total user number, Earlier show-up is partly mitigated	Moderate reduction potential (30 min)	High reduction potential as early pax are immediately handled (50 Pax at 4 counters → 100m²)
Optimisation with both Measures	Total number almost reduces to pre-COVID, Earlier show-up is partly mitigated	Good reduction but waiting time still higher when not all counters open earlier (16 min)	High reduction potential almost as pre-COVID (25 Pax at 4 Counters → 50m²)

Table 10: Results of Check-In Scenarios (Full-Service Carrier)

2.2.3.3 Impact on touristic carrier (single flight assessment)

- Pre-COVID:

  A touristic carrier is typically characterized by an early show-up of passengers at the airport before the check-in opens in combination with almost every passenger checking in a bag. This behavior often leads to long queues around check-in opening even in a Pre-COVID situation. The available queue space is often used to full extent or an overflow area is used already.

- Post-COVID "Do Nothing":

  When the early check-in intensifies without opening times being adjusted, the number of passengers already queuing at opening could increase 20% to 55% in the simulated example situation. The required space grows excessively due to physical distancing. Interestingly, any thinkable need for agent check-in does not play any important role for holiday flights, as most passengers are expected to check a bag and will see an agent anyway.

- Post-COVID "Optimisation":

  The main measure for optimisation of touristic flights is the adjustment of opening times. Integrating health questions in the online check-in would only have the potential for a moderate waiting time reduction but there is no relevant effect on the queue. Thus, even when applying both measures the situation remains challenging, in particular related to space.

  Therefore, compared to the other traffic clusters, the touristic flights are regarded as most sensitive and challenging to handle.

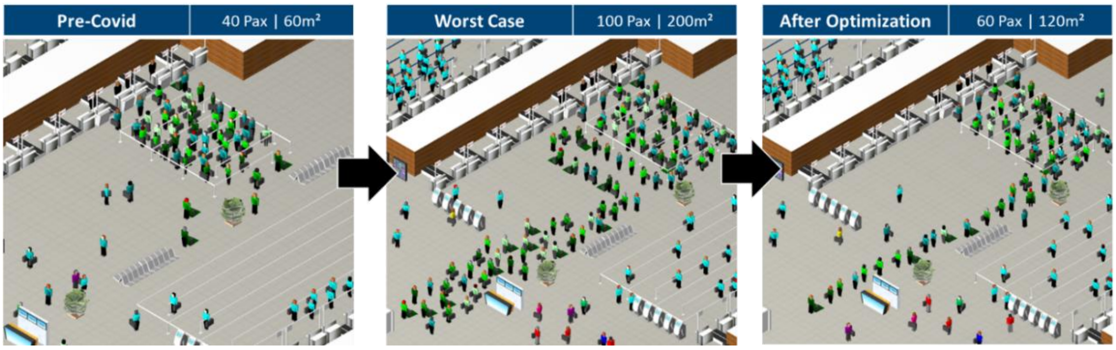


Figure 21: Visualisation of Check-In Scenarios (Touristic Carrier)

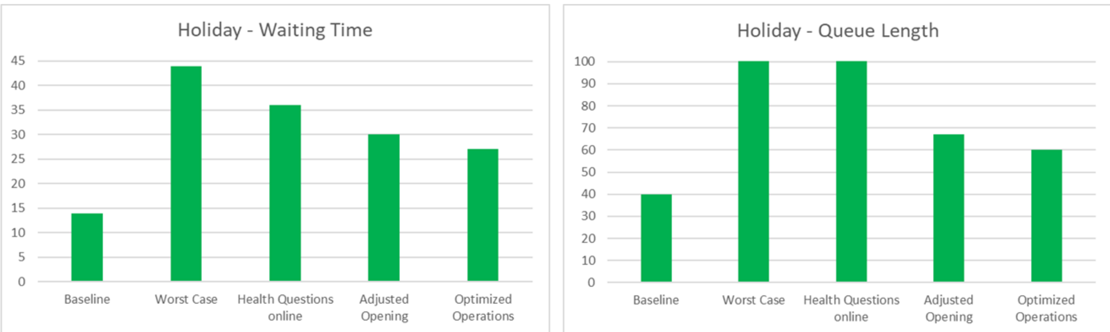


Figure 22: Numeric Results of Check-In Scenarios (Touristic)

Situation	Demand	Waiting Time	Queue Length
Baseline	All pax use counter (180 PAX), Some (20%) arrive before opening	Moderate (15 min)	Moderate to high (40 PAX at 4 counters → 60m²)

Worst Case	All pax use counter (180 PAX), The majority (55%) arrives before opening	Very high (45 min)	Very high (100 PAX at 4 counters → 200m²)
Optimisation A: Health Questions online	Same as in worst case situation	Moderate reduction potential (36 min) cause of return to regular processing time	No reduction potential (100 PAX at 4 counters → 200m²)
Optimisation B: Adjusted Opening (some Counters)	Same total user number, Earlier show-up is (partly) mitigated	**Good reduction** potential as early pax are immediately handled (30 min)	**High reduction** potential as early pax are immediately handled (65 Pax at 4 counters → 130m²)
Optimisation with both Measures	Same total user number, Earlier show-up is partly mitigated	Good reduction but waiting time still higher when not all counters open earlier (27 min)	High reduction potential but still high space requirements (60 Pax at 4 Counters → 120m²)

Table 11: Results of Check-In Scenarios (Touristic)

2.2.3.4 Impact on low-cost carrier (single flight assessment)

- Pre-COVID:

  A low-cost carrier is characterized by low percentage of passengers with checked luggage. It is not unusual that only half of the flight or less passengers actually check-in at an agent position. This even allows low-cost carriers to open their check-in rather late without losing an acceptable service level.

- Post-COVID "Do Nothing":

  The "worst case" situation for a low-cost carrier would consist of three elements:

  - Earlier show-up (similar to other traffic clusters)
  - Mandatory agent check-in due to health-related checks (especially a problem for low-cost airlines with high number of passengers skipping typical agent-based check-in while using online or kiosk check-in instead)
  - Increase of checked luggage due to limitation of hand luggage without the airline's staffing reaction to this higher demand.

  In particular, the growing overall number of passengers without online check-in would overburden the regular check-in allocation. The difference between Pre-COVID and Post-COVID would be the highest in this case.

- Post-COVID "Optimisation":

  However, such a worst case situation is regarded as unlikely. The business model of low-cost airlines relies on online check-in to reduce manpower at airports. Thus, the integration of health questions in the online system is most likely.

  Though, this would still not reduce the overall number of users because the checked luggage increases.

  Thus, even for the remaining situation after optimisation longer queues are expected.

Figure 23: Visualisation of Check-In Scenarios (Low-Cost Carrier)

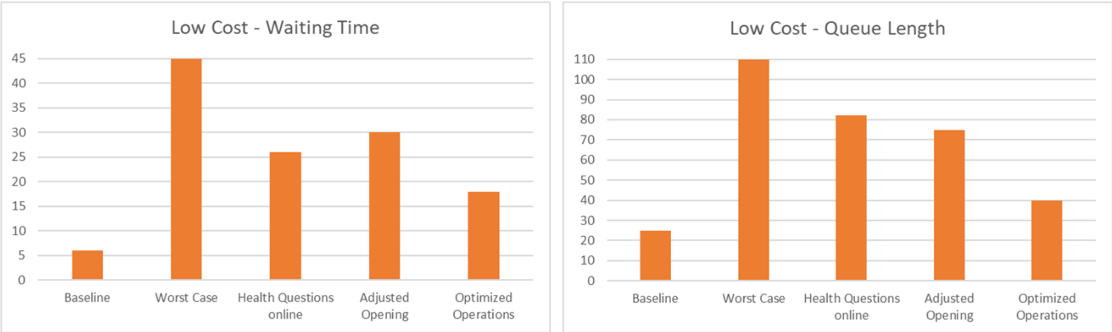


Figure 24: Numeric Results of Check-In Scenarios (Low-Cost Carrier)

Situation	Demand	Waiting Time	Queue Length
Baseline	Very low, only half of the flight uses bagdrop.	Short (7 min)	Short (24 Pax at 4 counters → 36m²)
Worst Case	Doubled pax numbers uses counter (180 PAX), The majority (60%) arrives before opening	Very high (45 min)	Very high (110 PAX at 4 counters → 220m²)
Optimisation A: Health Questions online	Total number of pax significantly reduced again but still higher compared to pre-COVID because of more passengers check-in luggage, earlier show-up	**Good reduction** potential (26 min)	Moderate reduction potential (80 PAX at 4 counters → 160m²)
Optimisation B: Adjusted Opening (some Counters)	Total number of pax same as worst case, opening time adjusted to show-up	Moderate reduction potential (30 min)	**Good reduction** potential (75 PAX at 4 counters → 150m²)
Optimisation with both Measures	Total number of pax significantly reduced again but still higher compared to pre-COVID because of more passengers check-in luggage,	Situation still worse than pre-COVID because of more passengers check-in and counter opening only partly optimized (17 min)	(40 PAX at 4 counters → 80m²)

Table 12: Results of Check-In Scenarios (Low-Cost Carrier)

2.2.3.5 Summary for single flight assessment

The analysis of three very different traffic clusters indicated, that COVID measure will likely affect them to a different degree. In addition to that the potential mitigation measures show different impact and therefore recommendations depend on traffic type:

Flights with low luggage (domestic full-service and low-cost) shall enable and motivate their passengers to use online and kiosk check-in as good as possible to reduce number of counter users and avoid passengers waiting in the departure hall prior check-in opening.

Holiday flights do not have this potential. They can best be mitigated by an adjusted opening of counters. Still, these flights would be most critical.

2.2.3.6 Impact on common check-in flights

The previous analyses demonstrated the sensitivity of single flight check-in. Common check-in is expected to better cope with COVID impacts as there is typically less accumulation of passengers before check-in is allowed but rather a "come and go".

Full-service carrier:

Assuming the same number of booked passengers, COVID could affect the check-in demand in this way:

- Minimum increase of total number of passengers at counter
- Earlier show-up (30 min)

As mitigation, opening earlier should almost be sufficient. It might be accompanied by a minimum increase of passenger to counter ratio because of more checked in luggage (<5% higher manpower for same booked passenger volume).

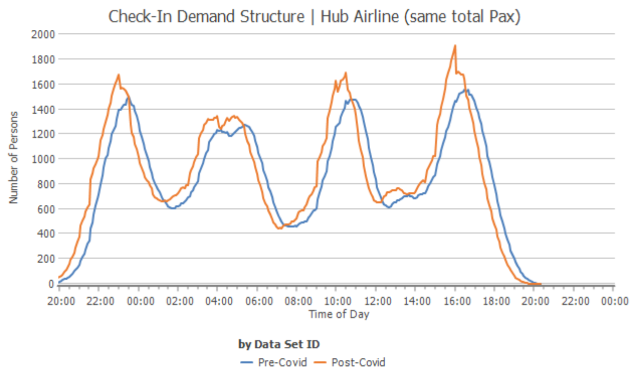


Figure 25: Common check-in demand profile (Full-service carrier)

Low-cost carrier:

A similar scenario for a low-cost carrier shows higher differences:

- Considerable total demand increase (50%) by many more passengers checking in bags
- Earlier show-up (30 min)

In this case mitigation must include a higher counter per booked passenger ratio (+35% higher manpower for same booked passenger volume).

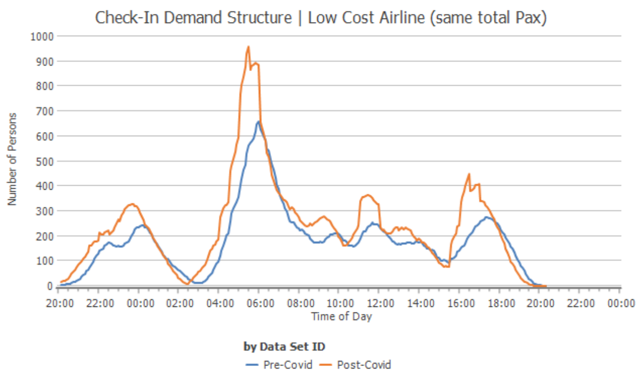


Figure 26: Common check-in demand profile (Low-cost carrier)

2.2.3.7 Impact on overall allocation

Assuming that the available queuing system at check-in counters was already used to good extent Pre-COVID, with the COVID outbreak two effects might come together:

- Longer queues
- Higher space requirements per passenger

Even after optimisation, at least holiday flights will need the queuing space of 2-3 adjacent counters. This needs to be considered in the overall allocation. In the shown example 4 counters would actually be used but 2-3 further counters next to this flight would be allocated for the purpose of queuing space.

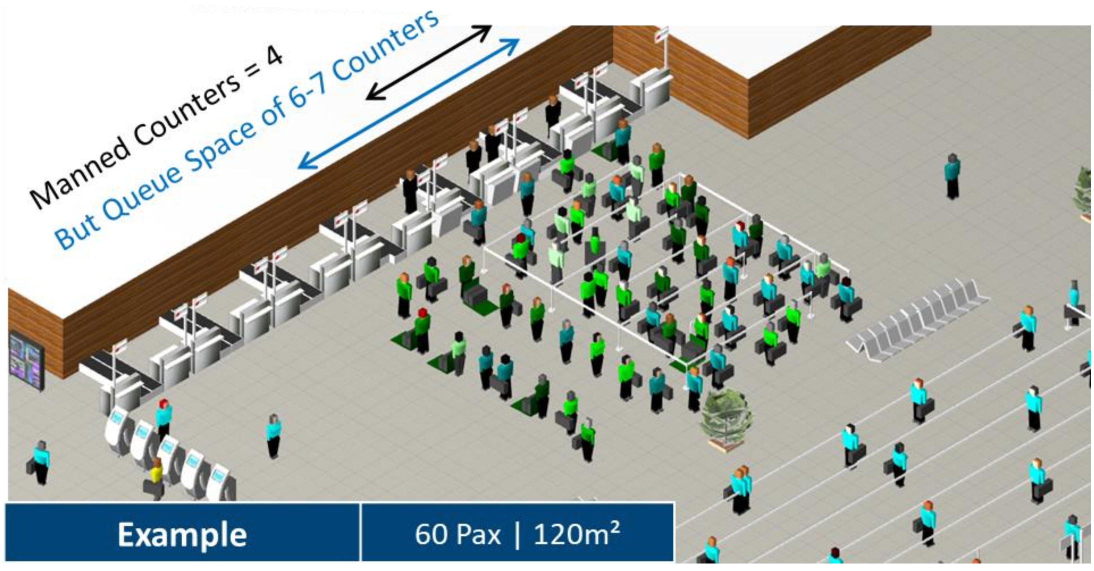


Figure 27: Check-in Allocation Based on Queue Space

With the purpose of ensuring physical distancing for all passengers at check-in, this principle would have to be followed for all flights where queue space of initial counters is insufficient and the allocation should be adjusted. Overall objective would be to spread the traffic as much as possible and leave gaps between single flight check-in to allow for an increase of the queuing system.

In the course of this project an allocation exercise with the above principles was done for a generic airport environment to understand the order of magnitude when the check-in area gets saturated.

Pre-COVID:

As mentioned earlier, the generic airport represents an airport which is already saturated to a good extent in the baseline. Figure 28 here below provides a visual representation of check-in counters allocation over time; each row represents a counter. The areas for the assumed main carriers use exclusive check-in areas. On Figure 28, the main carriers are represented in blue for the hub airline (on the top), and in orange for the low-cost airlines (at the bottom).

This leads to more or less all counters of other airlines being assigned in the peaks, whilst only a few counters remain unused in the areas of the two main carriers.

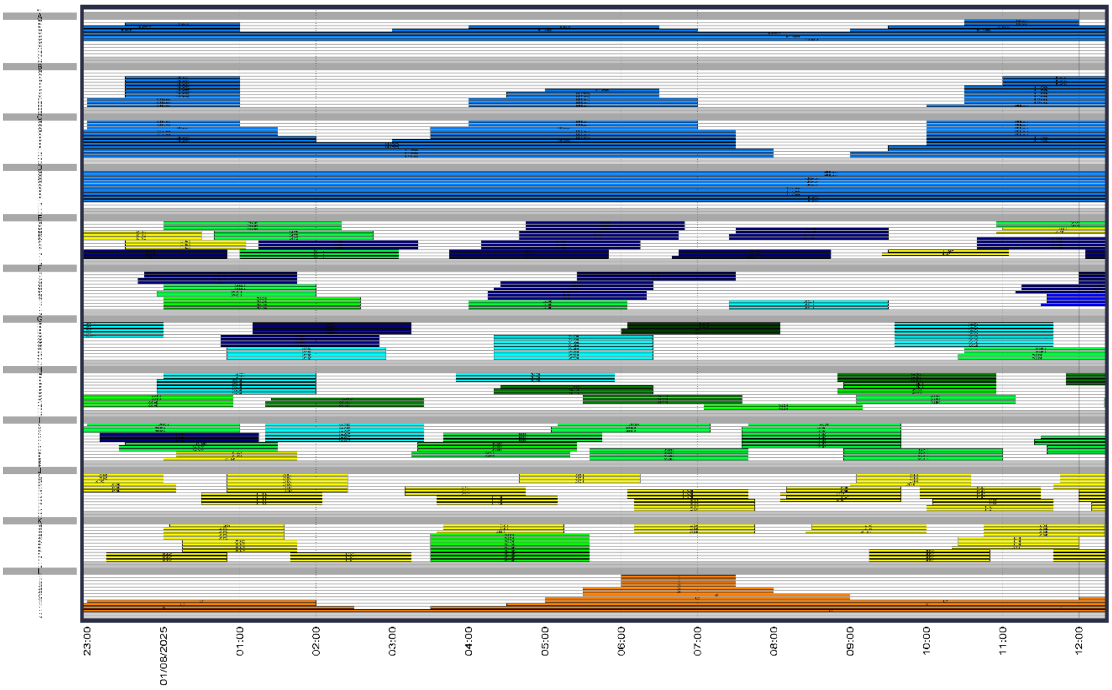


Figure 28: Check-In Allocation (Pre-COVID)

Post-COVID:

With higher space requirements and thus more counters being "blocked" per flight, the same infrastructure naturally cannot handle the same traffic volume anymore. During the recovery phase it gets essential to know how long the available infrastructure will be able to accommodate the recovering phase while ensuring the necessary COVID measures.

As a demonstration of the methodology, this study analyzed two recovery flight schedules, representing 50% and 75% of the regular Pre-COVID traffic volumes.

These results indicate that it should be possible to allocate a 50% schedule without constraints.

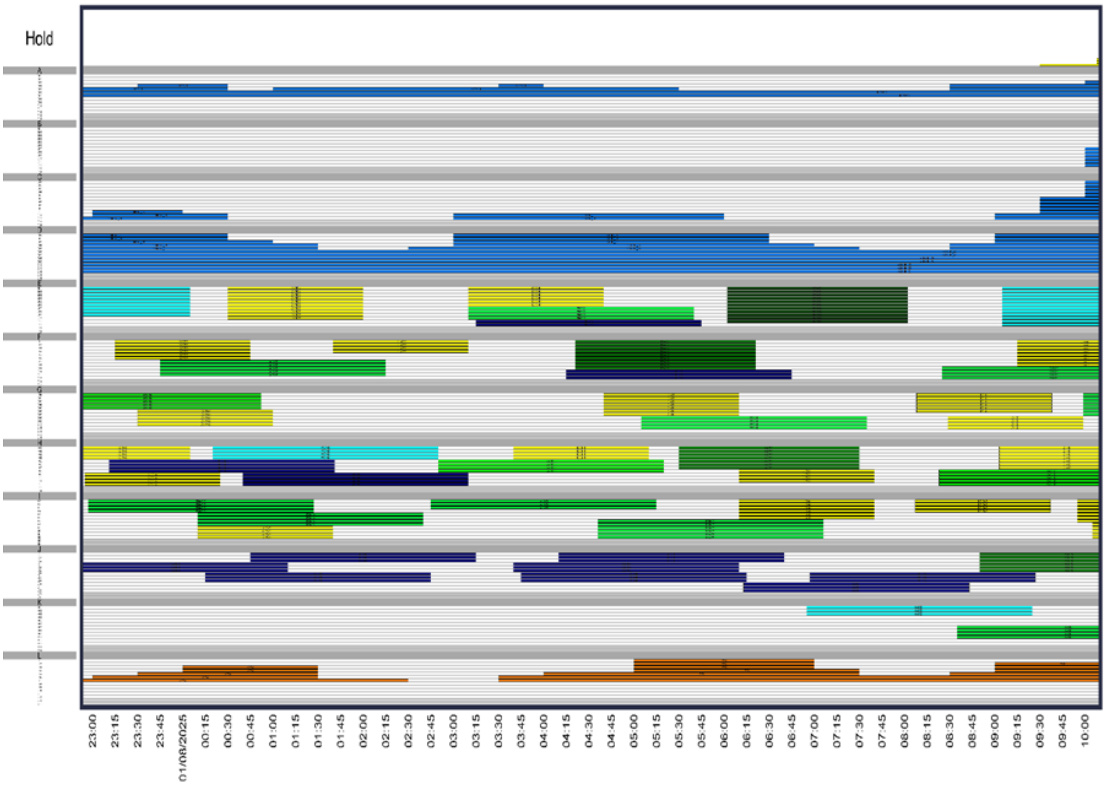


Figure 29: Check-In Allocation (Post-COVID 50%)

Trying to allocate the 75% scenario schedule shows that certain flights of Non-Home Carrier airlines cannot be allocated (they appear in the upper part of the chart on “Hold” in the following Gantt chart). However, it can also be seen from the chart that the main carrier does not require all resources anymore. Other airlines’ flights could be allocated, if the exclusive assignment of counters is reduced in line with the new traffic volumes of the main carrier.

In summary, this may lead to a re-design of established allocation principles.

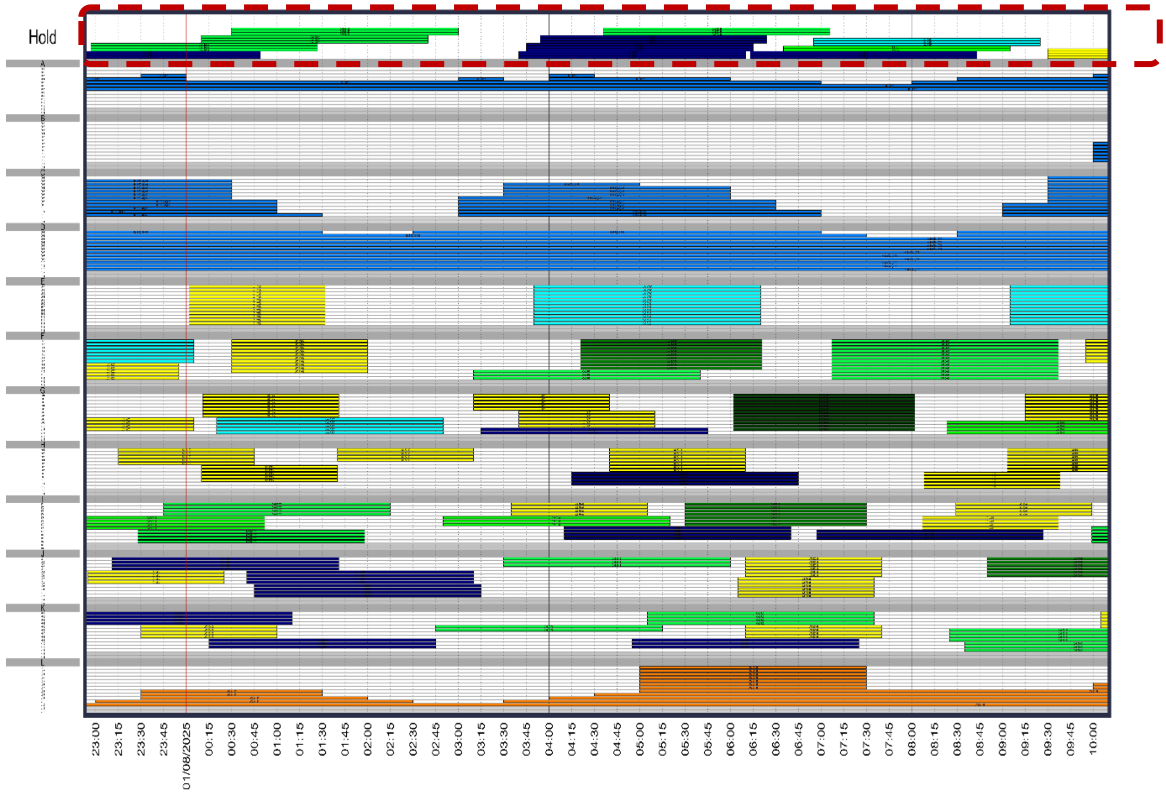


Figure 30: Check-In Allocation (Post-COVID 75%)

2.2.3.8 Impact on departure hall

As described in the previous chapters, a potentially earlier show-up and only partly reacting check-in opening times will lead to more passengers dwelling in the departure hall.

Simulation test runs have shown that e.g. a 75% schedule with Post-COVID characteristics can already lead to more passengers in the departure hall compared to 100% traffic Pre-COVID (see Figure 31).

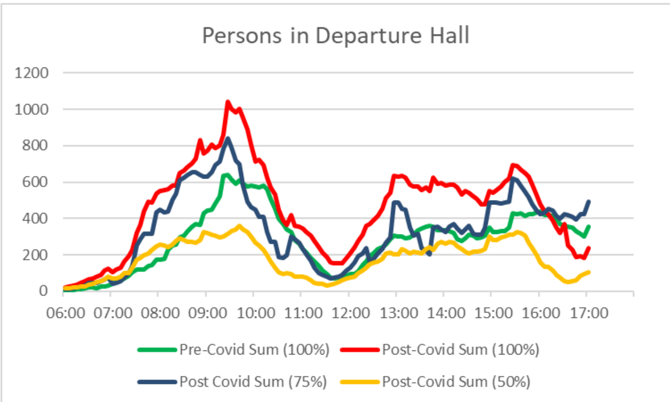


Figure 31: Occupancy Scenarios of Departure Hall

Not only that the same number of passengers in the departure hall is reached faster, in addition physical distancing and check-in queues reaching out of the dedicated areas and interfering with dwelling passengers lead to further challenges.

Another fact is worth to mention: while the pre-COVID passengers in the departure hall were a heterogenous group of passengers of many flights, which distributed quite well in the hall, post-COVID these passengers are rather passengers of the same flight. In consequence, the load concentrates on the same part of the departure hall.

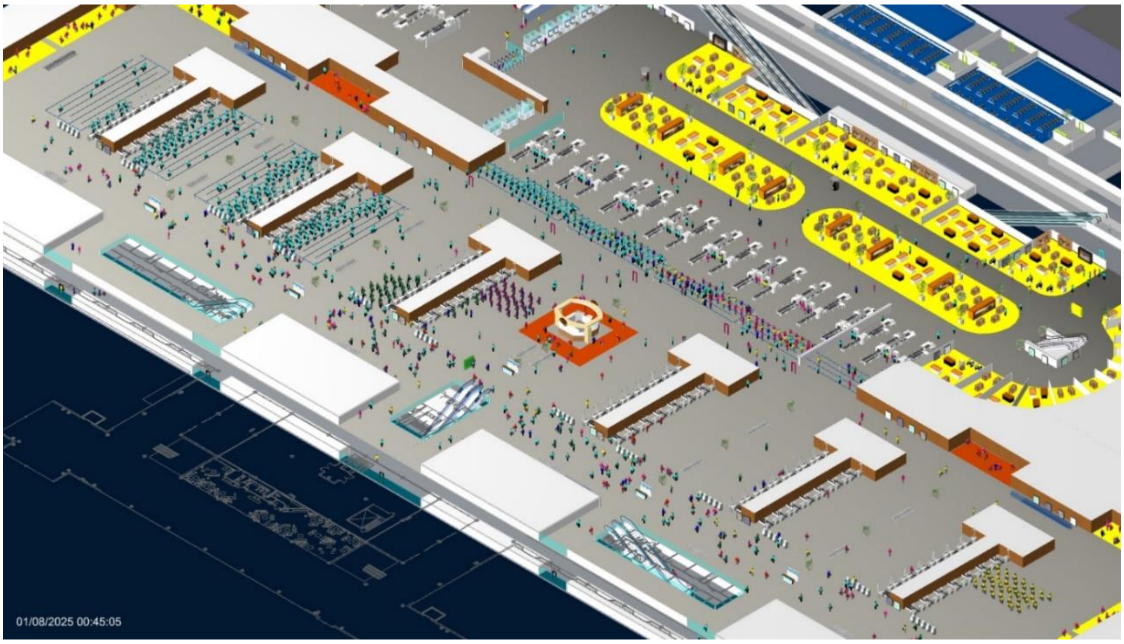


Figure 32: Occupancy of Departure Hall Pre-COVID (100% Traffic)

Figure 33: Occupancy of Departure Hall Post-COVID (75% Traffic)

Thus, airports should address this issue from both sides:

1. Limit the number of passengers by avoiding any unnecessary early show-up
2. Handle passengers as soon as possible to avoid congestion around check-in

2.2.4 Conclusion

2.2.4.1 Potential Issues for Check-In

The potential COVID related issues for check-in can be grouped into the following 3 categories:

1. Organisation of queues (to ensure physical distance)
2. Changed demand numbers
    - in general, e.g. because of more checked luggage or suspended online check-in
    - in time, e.g. because of earlier passenger reporting
3. Process related changes (e.g. health certificate / travel restrictions checks)

Next to these analyzed systematic impacts, the interviews have shown that airports and ground handlers are still confronted with a high unpredictability of booking numbers and quickly changing principles and regulations. This means, that any planning should also consider a contingency factor.

2.2.4.2 Most affected Traffic

Based on the previous analyses the following traffic segments can be considered as most impacted:

1. Flights with single flight check-in and rather late opening before flight

   (always open common check-in can better compensate changed passenger show-up)
2. Holiday flights with high agent check-in ratio (much luggage, no self-service)
3. Flights with significantly growing baggage numbers due to COVID (e.g. low-cost carriers)
4. Any flight, where additional health / travel restriction checks must be done at counter, in particular when this flight had many self-service users before

2.2.4.3 Mitigation Measures

The following Figure 34 summarises the recommended mitigation measures.

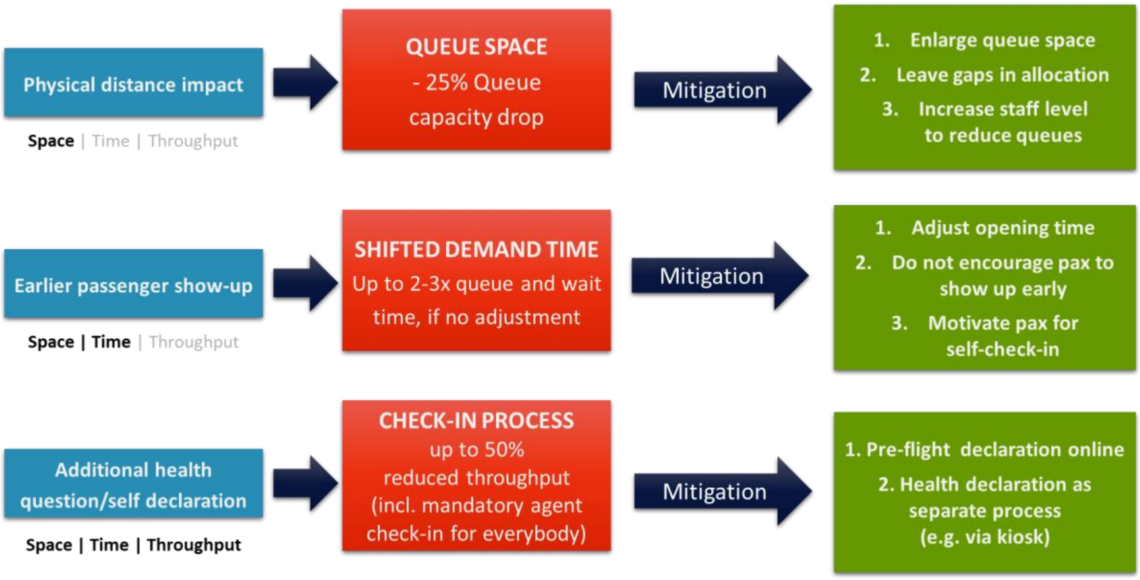


Figure 34: Mitigation Measures for Check-In

2.3 Security Control

2.3.1 Introduction

The security checkpoint is one of the main processes of a passenger's journey throughout the terminal which every passenger and members of staff need to undergo. During busy days, the security checkpoint is often close to capacity limit and there is a high demand for closely coordinated staffing and queue management. Constantly changing conditions in times of COVID put additional pressure on that sensitive system and new factors need to be considered for ensuring both, fluent processes as well as the safety of passengers.

2.3.1.1 Topics of Interest

Due to physical distance and increased hygiene standards, processes in a security lane are affected and therefore change the throughput capacity of a security lane (usually indicated by a flow rate of passengers per hour). This study evaluates how and in which extent single COVID measures affect the throughput capacity of an example security lane and how do combinations of several measures affect the overall performance. Since it is expected that the measures have different magnitudes of impact on a lane's performance, this study also aims to evaluate main drivers for security lane throughput reduction for different lanes types. Another field of interest is the interaction of throughput reduction, service level and staffing requirement at a typical security checkpoint in times of COVID. The study also evaluates the requirement of space with higher space consumption per passenger due to physical distance and the necessity of adjusted staffing rules.

In sum, the following questions are answered in the following chapter:

- How does COVID influence the throughput capacity at a security lane?
- What are the main drivers for security lane throughput reduction?
- What is the impact of lower throughput in combination with staffing considering queue space and waiting times?

2.3.1.2 Qualitative Interviews with Airport Stakeholders

The interviews with airport stakeholders showed that the situation at security checkpoint changes since the COVID outbreak and that the security checkpoint is confronted with new challenges:

1. **COVID measures have a negative impact on security throughput**

   Interviews with airport stakeholders revealed a strong decline of security throughput performance after initial measures in response of the COVID outbreak took place. Even though the traffic broke down and only a small percentage of former traffic remained, it was expected that security processes would emerge as a bottleneck as soon as the traffic would recover.

2. **Less capacity of available queue space due to physical distance rules**

   Dependent on the respective country and federal rules, different physical distance rules are enforced in times of COVID (varying between 1m, 1.5m and up to 2m). Passengers are educated through media and are used to follow this rule in several areas of their daily life. Airports take their part and support the compliance with using information displays and floor markers. Therefore, passengers adhere to these rules, leading to less capacity in queue systems than before. Overspill situations can occur earlier than airports are normally used to. In addition, insufficient queues are also more critical than before since negative effects like cross flow situations should be highly avoided in times of an ongoing pandemic.

3. **Changing staffing requirements**

   In pre-COVID times airports used to apply lane staffing schedules which are balanced with daily peaks and allow to comply with waiting time targets and prevent critical situations of long waiting times and insufficient queues systems. However, since COVID outbreak, these former rules seem to be outdated due to changed throughput as well as queue space consumption because of physical distance regulations. Even with small percentage of remaining staffing, airports do open more lanes relatively to traffic than before in order to ensure a fluent process flow.

2.3.1.3 Computer-Aided Simulation

In order to being able to transfer results of the study to a broad spectrum of airports, a generic simulation model was selected and build in the simulator for both, a microscopic view of a security lane setup as well as a macroscopic evaluation of a generic security checkpoint with multiple lanes. For this analysis, different traffic recovery scenarios combined with various possible security checkpoint performance limitations were evaluated. Furthermore, concentrated experience regarding input data and processes from former projects of ARC in aviation field adds value to the study whenever applicable.

2.3.2 Scenario Setup

As mentioned before, two different simulation setups were used within the scope of this study. On the one hand, a microscopic simulation of a security lane considering all sub-processes of a single security lane (e.g. divesting carry-on luggage, passenger pat search, etc.) was established in order to assess the impact of several COVID measures on throughput. On the other hand, a more macroscopic model consisting of a generic security checkpoint area with several lanes was established in order to investigate the impact of different traffic scenarios as well as lane staffing. For both simulation models, different input data assumptions have been undertaken which are presented in the following.

2.3.2.1 Scenario Setup of detailed Security Process

The security lane layout selected for this study is a double lane with a throughput performance of 180-190 PAX/h per single lane (see Figure 36). In order to work out a "typical" security lane setup, ARC assessed the set-up of several security lane setups of former projects and also assessed typical achieved throughput capacities.

The lane setup is simulated under peak hour conditions which implies traffic volume of continuous passenger demand generated from an example flight schedule.

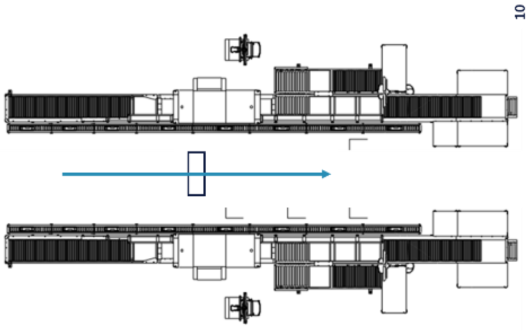


Figure 35: Sample Security Lane Setup

Table 13 shows the main input data of the baseline lane set-up which consist of two opposing lanes sharing one metal detector (WTMD). The total length of the lane setup is 14 m. The drop off positions of each lane can be used simultaneously. A passenger has a minimum of 1 up to a maximum of 4 trays. While the average time for divesting is assumed to be 35 sec/PAX, the average value for picking up items after scanning process is 45 sec/PAX. All passengers triggering an alarm require further pat search by staff. For pat search, both lanes are sharing 4 booths. For each gender, two staff members are available for manual passenger search while an overall gender distribution of 50/50 is assumed. The average time for pat search is 45 sec/PAX. The average screening time at the X-ray machine is 6 sec/Tray. Each lane consists of 2 positions for manual bag search which will take 60 sec/PAX on average.

Parameter	Value
Drop off positions	2 positions 3 positions
Avg. Number of trays per pax	2.4 trays/PAX
Avg. processing time for drop off	35 sec/PAX
WTMD alarm quota	25 % alarm
Pat search on pax triggering an alarm	90 % of alarm
Available staff for manual pat search	4 staff members
Manual bag screening by staff	15 % manual screening

Table 13: Main Input Data of Security Lane Setup

Interviews with airports stakeholders revealed that the processing time for divesting is likely to increase in times of COVID. Nowadays, security lane staff is not actively supporting passengers during divesting if items are placed incorrectly inside trays anymore. They rather give instructions and let the passenger do the reorganising himself which requires additional time. Furthermore, some airports changed their rules for loose items inside trays in the sense that they need to be stowed in bigger items like the carry-on pieces or a jacket. Eventually, the general uncertainty of passengers confronted with a changed security process due to

COVID can also have impact on processing time as well as the usage of hand sanitizers and disinfection products while entering the lane. In order to reflect these impacts on divesting procedures, the processing time for drop off is increased by 20% for all following scenarios assessing COVID impacts. Additionally, the number of allowed passengers in front of WTMD (Walk-Through Metal Detector) limited from 4 to 2 passengers due to physical distance rules.

Measure	Qualitative Impact	Quantitative Impact
Limitation of drop off positions due to physical distance	No simultaneously handling of pax allowed	Number of drop off positions limited by one position
Limited number of pax in tray pickup zone	Less pax allowed in pickup area due to physical distance	Max. 8 simultaneously pax (4 per lane) in pickup area allowed
Requirement to drop more items at drop off beforehand (e.g. shoes, belts)	Increasing number of trays and relating average processing time for drop off	1 additional tray for 75% of pax and additional time for dropping (+10%)
Repeated pax scans (in combination with dropping more items)	Pax use metal detector/body a second time and might also drop further trays	Alarm triggering pax (25%) 80% drop further items in additional tray 100% use WTMD a second time
Repeated X-Ray scans of trays	Further scanning time per item required	20% of trays are scanned again

Table 14: Selected COVID Measures

Table 14 shows all 5 COVID measures selected for the analysis in scope of the study. All of these measures are currently carried out in response to COVID by several airports. However, there are further COVID measures which also can have an impact on throughput capacity of security lanes which are beyond the scope of this study (e.g. disinfection of lanes, prolonged manual checks).

1. **Limitation of drop off positions**

   Since the divesting process at the security control usually takes place simultaneously and close to each other, former configurations of adjacent drop off positions do not correspond to physical distance regulations any longer. Therefore, the measure of reducing drop off positions will be simulated in different extent by reducing from 2 to 1 as well as from 3 to 2 drop off positions.

2. **Limited number of passengers in tray pick-up zone**

   This measure is related to physical distance in lanes and shall ensure that there are not as many passengers in the rear section of the lane as before COVID. Since passengers normally are waiting close to each other at the pick-up zone, a staff member at the WTMD shall constantly observes the situation and hold back passengers while interrupting the scanning process in case there are too many passengers in the area. In alignment with physical distance rules, only 8 simultaneously dwelling passengers (4 per lane) are now allowed in the rear section of the lane.

3. **Dropping further items beforehand**

   Since the risk of exposure for staff is relatively high during detailed passenger screening ("pat search"), passengers are asked to drop off more items beforehand. This usually concerns shoes, belts and other loose items in pockets which are likely to trigger alarms and need further investigation by staff. However, dropping more items will also increase the number of trays per passenger and affects the related time required for divesting. For the simulation, it will be assumed that 75% of passengers require one additional tray. Furthermore, since taking off shoes or belt will require extra time, a further additional processing time increase factor of 10% is applied for all passengers.

4. **Repeated WTMD scans of passengers**

   Passengers triggering an alarm are sent back to the divesting area for dropping all loose items in pockets or putting down further items (e.g. belt, sweater). Afterwards, they use the WTMD for a second time. Only by triggering another alarm, they are manually checked by staff. Similar to the measure mentioned before, this measure aims to reduce manual inspection by staff. Among those passengers triggering an alarm, 80% drop further items while using another additional tray. Afterwards, all redirected passengers are required to use the WTMD for a second time.

5. **Repeated X-Ray scans of trays**

   In case that the contents of a scanned item at the X-Ray machine cannot be identified and usually would require a manual bag search, the item will be rearranged and scanned again allowing to achieve insights from a different angle. This measure aims to reduce the chance of manual bag screening procedures where the risk of exposure for staff is increased. For the simulation, it is assumed that 20% of trays are rearranged and scanned again at the X-Ray machine.

2.3.2.2 Scenario Setup of macroscopic Security Control Checkpoint

For the macroscopic view on a security checkpoint, the generic airport selected for this study is used. The checkpoint consists of a central lane setup of 15 lanes for economy and additional 3 lanes for premium passengers (see Figure 36). The traffic volume of the example flight schedule complies with an airport of 27 mppa. The simulated security lanes have a throughput capacity of 180 PAX/h per lane.

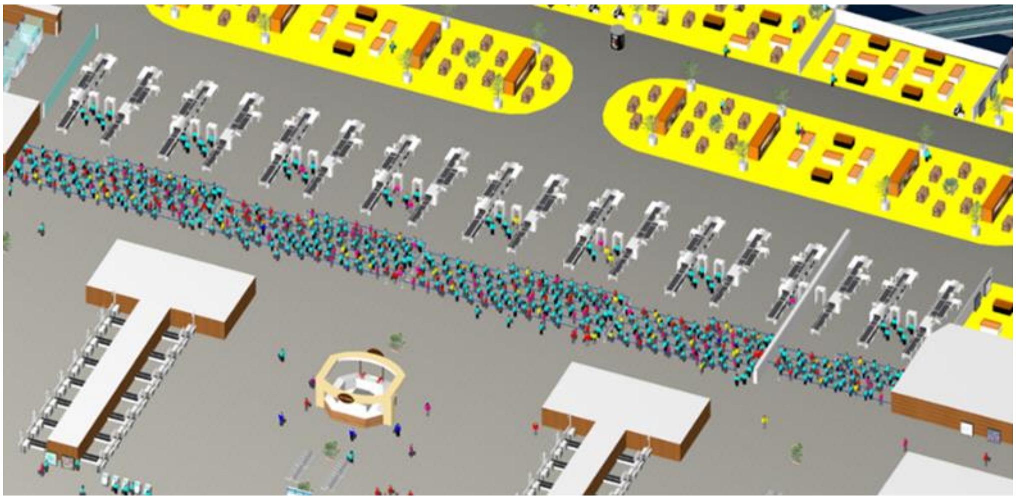


Figure 36: Security Checkpoint Setup

2.3.3 Results

In the following, the study's result on security process are discussed in three main sections. The first section is covering the microscopic simulation of a security lane while assessing the impact of several COVID measures on throughput. It is followed by a queue space analysis and the related waiting time equivalent impacted both by physical distance regulations and reduced throughput capacity of lanes. The last section deals with the interrelation of throughput, staffing, traffic reduction as well as available queue space which leads to the requirement of a COVID related staffing supplement.

2.3.3.1 COVID Impacts on Security Lane Throughput

Originating from the baseline setup, which achieved a throughput capacity of 185 PAX/h per lane, the different COVID measures lead to different levels of impact (see Table 15):

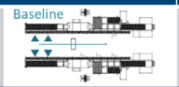
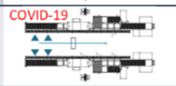
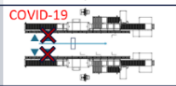
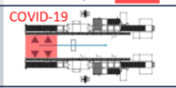
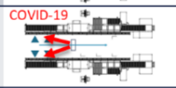
Scenario			Throughput	Throughput Reduction	Comment
Baseline			185 PAX/h	-0%	-
Increased Divesting Time			160 PAX/h	-15%	More instructions, stowage of loose items lead to increase
Increased Divesting Time	1 Drop off position		90 PAX/h	-50%	Major capacity drop
	Limited Number of Pax in pickup zone		155 PAX/h	-15%	Higher impact expected with more performant lanes
	Drop more items beforehand		125 PAX/h	-30%	Reduction strongly depends on trays and divesting time increase
	Repeated pax scans with dropping additional items		150 PAX	-20%	Impact assumed to be higher if body scanners in use
	Repeated X-Ray scans of trays		155 PAX/h	-15%	Low impact on sample security setup

Table 15: Overview of Throughput Reduction of COVID measures

The increased divesting time of +20% due to further instructions by staff and other factors already lead to a throughput reduction of -15%. This implies that the divesting process represents a bottleneck of the evaluated sample security lane setup. It can be expected that further extra time for divesting will lead to further drop of the lane's throughput capacity.

1. **Limitation of drop off positions**

   Reducing the drop off position from 2 to 1 position leads to a major capacity drop of 50%. Since the possibility of simultaneous divesting is fundamental for this security lane type, limiting the divesting sub-process by one position has such a high impact leaving only half of the former throughput performance. However, a further sensitivity scenario shows that for lanes using more than 3 drop-off positions, the capacity drop is likely to be lower. A pre-COVID baseline setup with 3 drop off position led to a throughput of 215 PAX/h. Now, reducing the drop off position from 3 to 2 positions (leaving the middle position empty) showed a reduction of smaller extent of -25% in COVID conditions. However, even in this sub-scenario the divesting area is still a critical sub-process leaving to major capacity decline.

2. **Limited number of passengers in tray pick-up zone**

   This measure shows a rather low impact on throughput capacity since the divesting time already leads to a throughput reduction resulting in less waiting passengers in the rear area of the lane. However, a higher impact is expected regarding other security layouts with a high passenger throughput in the front section of the lane (e.g. divesting area, bag/passenger scanner).

3. **Dropping further items beforehand**

   If a passenger is obliged to drop more items than usual, the number of trays as well as the required time for divesting are likely to increase. In the example setup, this led to a capacity drop of -30%, which is the second highest drop after reducing drop off positions. However, the magnitude of throughput reduction with this measure strongly depends on tray number and divesting time increase for taking off further items like shoes or belt. For example, the divesting time can be decreased by signage during queuing as well as providing preparation tables in front of lanes. Further sensitivity scenarios with varying tray number and divesting time resulted in a reduction in the range of -25% (140 PAX/h) up to -40% (110 PAX/h).

4. **Repeated WTMD scans of passengers**

   Since a WTMD scan is usually fast and does not require passengers to dwell and wait for scanning results, the throughput limitation due to rescanned passengers is rather negligible. However, most of the passengers are redirected to the divesting area to drop further items. Therefore, they not only block one drop off position for a short while but also increase the number of used trays in the lane. In the example setup, with -20% the throughput reduction is rather low. However, other scanning devices like body scanners require a higher process time per passenger scan, therefore the impact is expected to be higher with other scanning devices.

5. **Repeated X-Ray scans of trays**

   In the sample security setup, repeated X-Ray scans of trays have only low impact on sample security setup. Sensitivity scenarios showed that only rescanning more than 50% of trays would have higher impacts on the lane's throughput. However, the impact of this measure is highly dependent on different factors, like the performance of the X-Ray scanner, number of trays to be scanned as well as required time for staff to view the image.

After evaluating impacts of single measures on throughput capacity, the interaction of several measures applied at the sample security model at the same time are evaluated.

On the one hand, it is expected that some measure combinations will generate a further reduction in throughput capacity decline while others do not show intensifying effects.

Figure 38 shows an example, where 1 of the 3 measures (limitation of drop off positions) is already creating a main bottleneck. Therefore, the other two applied measures (repeated X-Ray scans and limited number of passengers in pick-up zone) show no further effects. The drop off position reduction is reducing the

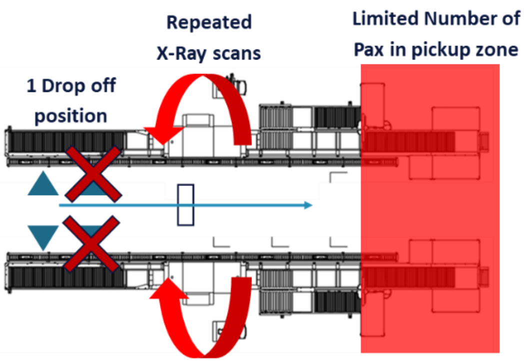


Figure 37: Measure Combination without further Limitation

throughput in such a high extent that it is dominating and overruling all potential limitation effects of the other two applied measures.

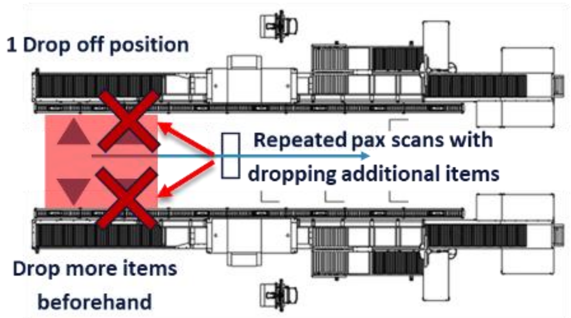


Figure 38: Measure Combination with further Limitation

On the other hand, there are measure combinations causing intensifying effects on throughput reduction. Figure 38 shows the situation where the COVID measures of drop off reduction, dropping more items beforehand as well as repeated scans of passengers are applied. All three measures are affecting one critical sub process of the lane: the divesting process. Hence, in combination the measures are causing further throughput reduction.

Reduction of drop-off position	Drop more Items	Repeated pax scans	Throughput [PAX/h]	Reduction
Baseline			**185**	**0 %**
✓	✓		65	**- 65 %**
✓		✓	75	**- 60 %**
	✓	✓	120	**- 35 %**
✓	✓	✓	60	**- 70 %**

Table 16: COVID Throughput Reduction caused by Measure Combinations

Table 16 shows the degree of throughput reduction of selected measure combinations on the sample security setup. In the sample setup, the divesting process did already represent a bottleneck in pre-COVID situation. Therefore, all measure combinations which are impacting the divesting process are generating further throughput reduction. All other possible measure combinations include one or more dominating measures which are overruling the effects of at least one other COVID measure.

Hence, only the measure combination listed in the table are leading to further capacity reduction. Figure 40 illustrates these measure combinations leading to a further throughput drop by red dots. In conclusion, abolishing some measures will not necessarily lead to an enhancement of throughput if other dominating measures actually causing the main capacity drop are still maintained. Figure 40 also shows that all measure combinations including the measure of reducing drop off positions will lead to high performance drop in the range of -50% up to -70% (see red dotted line).

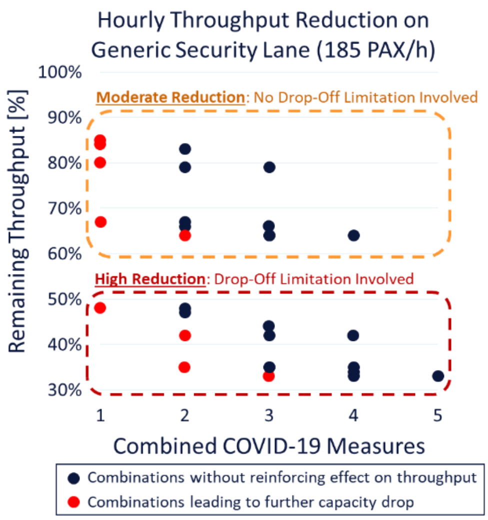


Figure 39: COVID Measure Combinations

The reduction off drop off positions is one typical initial measure airports introduced shortly after the COVID outbreak in order to comply with enforced physical distance rules. Some airport respondents reported even more strict measures like the closure of every second security lane, resulting in operating only half of available lanes of a checkpoint. However, in course of the project, stakeholder interviews revealed that some airports already start to loosen up measures or adapt measures due to the observed high throughput decline mentioned above. As a mitigation, instead of complying with physical distance in the process, short time violations can be tolerated while alternative measures still allow health safety of passengers. Installing dividing walls in between a double lane setup as well as between divesting drop off positions (e.g. Perspex walls) or allowing passengers to constantly wear face masks during security check process enables the abandonment of a former highly restrictive measure like closing drop off positions and helps to increase throughput again.

If drop off positions were no longer limited, the throughput reduction in the sample security setup were in the range of -15% up to -35% (orange dotted line in Figure 40). Also, other measures are possible to loosen up, like enforced dropping of shoes and further items for all passengers. Instead of letting all passengers take off their shoes, profiling and spot checks can help to increase security throughput again.

In course of the study, the impacts of several COVID measures were examined. However, there are other airport specific lane setups with different setups where other sub-process are likely to create bottlenecks. Therefore, the examined and other COVID measures impact the lane types differently. In the following, some examples of other lane types and possible impacts of COVID shall be discussed.

1. Lane with shared WTMD and 2 divest positions

This setup corresponds with the sample security lane examined in scope of the study. The bottleneck is manly driven by the divesting process, therefore all COVID measures that refer to the divesting process are likely to cause throughput reduction.

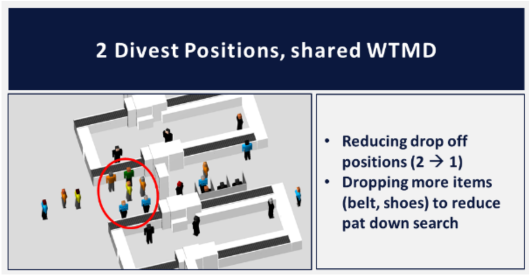


Figure 40: Lane with 2 divest pos. and shared WTMD

2. Lane with shared body scanner and 2 divest positions

In a lane setup using a shared body scanner, the lane's performance is often also driven by the throughput capacity of the body scanner unit. Therefore, not only measures that refer to the divesting process but also the passenger screening process via body scanner are likely to have an impact on throughput performance. Therefore, repeated passenger scans in order to avoid pat search are expected to have a higher impact.

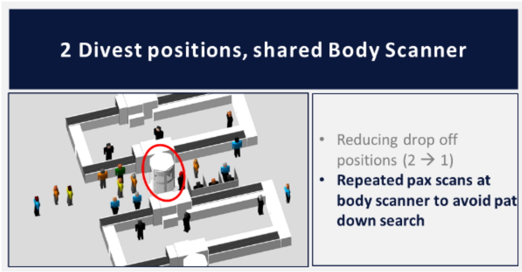


Figure 41: Lane with 2 divest pos. and shared Body Scanner

3. Lane with dedicated WTMD and 3 divest positions

In lane setups with comparatively high throughput performance, further sub-processes like the baggage handling do have a bigger influence on performance. Hence, the length of the lane, belt speed and consequential possible tray capacity as well as the performance of the X-Ray unit are likely to be main driver of the overall throughput.

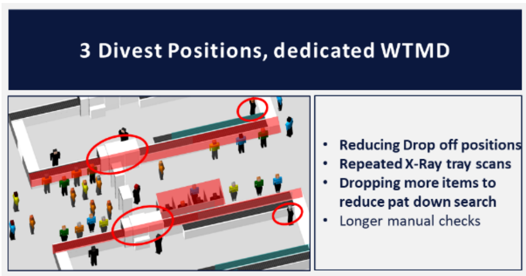


Figure 42: Lane with 3 divest pos. and dedicated WTMD

Hence, the COVID related measure of repeated tray scans add to measures impacting the throughput capacity. Additionally, since more passengers are involved simultaneously in the process depending on staff availability, manual checks impacted by COVID (longer checks due to hygiene procedures) may also impact the lane's performance.

4. Lane with dedicated body scanners and 3 divest positions

The setup of this lane type correlate with the same lane setup using WTMD. However, when body scanners are used, a further sub-process influencing the throughput is added to this highly coordinated setup of sub processes.

Therefore, in addition to the COVID measures affecting baggage processes and manual checks, also the passenger scanning itself is likely to influence the overall throughput capacity depending on the body scanners performances. There are even more complex setups using a mixture of WTMD and body scanners.

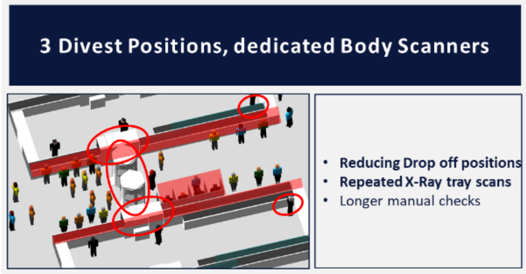


Figure 43: Lane with3 divest pos. and dedicated Body Scanner

Due to the diverse structure and airports specific lane setups, it is not possible to assign each COVID measure with a certain throughput reduction factor. This study illustrates the impacts on typical sample lane setup which gives the chance to get an impression of potential drops for other types of lanes. However, ARC recommend to analyze the lane structure and potential bottlenecks of each security lane type and carry out further investigations potentially supported by simulation studies in order to assess specific limitation factors and mitigations.

2.3.3.2 Security Queue Space and Time Analysis

In pre-COVID times, passengers in queue system used to keep a certain distance to other queueing passengers in order to maintain a minimum of spatial privacy. Therefore, they had the opportunity to decide themselves whether to stand close to other persons or not based on their own perception. According to IATA Level of Service Standards (ADRM 11. Edition), which are often used for planning queue systems, the typical space consumption of a passenger in a security checkpoint queue in pre-COVID times was 1m². However, due to physical distance these requirements are changing and passengers in queue are now instructed to keep a minimum distance to other passengers.

The minimum distance requirements in times of COVID do strongly depend on the respective country and federal rules in place and are subject to constant change over time (e.g. shortly after the outbreak, due to varying recommendations some subsequent adjustments of initial physical distance rules took place). Although there are various recommendations of aviation organisation and other institutions like ICAO, EASA or ACI, until today there is no general rule applied to all European countries

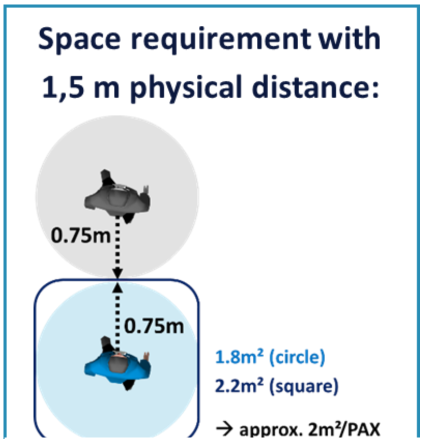


Figure 44: Space Requirements of Physical Distance due to COVID

regarding physical distance requirement. However, at the time the majority of European countries did apply the physical distance requirement of 1.5m distance. In terms of space requirements this would mean a space consumption of 2m² per passenger (see Figure 45). In comparison with the 1m² per passengers in pre-COVID times, this means that in post-COVID times passengers need double the space or in other words the queue space capacity is reduced by 50%.

This new reduced queueing capacity does bring a new waiting time equivalent for a filled queue system. While a certain number of passengers in a queue system did imply a certain waiting time before COVID, these waiting times do now change since less passengers do fit in the queue systems due to physical distance rules. As an example, a queue system of 450m² could accommodate 450 PAX in times before COVID (space requirement: 1m²/PAX). With all available security lanes open during peak, this represented a waiting time of 10min (see Table 17). However, with physical distance, space consumption per passenger increased and the same queue system of 450m² can now only accommodate 225 PAX with physical distance of 1.5m (space requirement: 2m²/PAX), which are half of the passengers. By implication, this also means half of the waiting time, so that a full queue system does now represent only 5 minutes waiting time. With higher physical distance, the waiting time in a full queue system of original size is even reduce further (e.g. 3 min with physical distance of 2m).

Available Queue Space	Physical Distance Rule	Space Requirement per Pax	Max. Number of Pax in Queue Space	Open Security Lanes	Waiting Time Equivalent (180 PAX/h per Lane)
450m²	1m	1m²/PAX (=IATA Standard)	450 PAX	15 Lanes	10 min
	1.5m	2m²/PAX	225 PAX	15 Lanes	5 min
	2m	3.5m²/PAX	130 PAX	15 Lanes	3 min

Table 17: Security Checkpoint Waiting Time Equivalent

Figure 45 shows the situation of a queue system before and after COVID with same number of waiting passengers. The only difference is the space requirement per passenger which changed from 1m²/PAX in pre-COVID to 2m²/PAX during COVID. The left picture shows the pre-COVID situation where all passengers fit in the available queue system with a waiting time of 10 min. The right picture shows the situation with the same waiting time of 10 min after COVID where now only half of the passengers fit in the original queue system and the other half spills into the check-in hall.

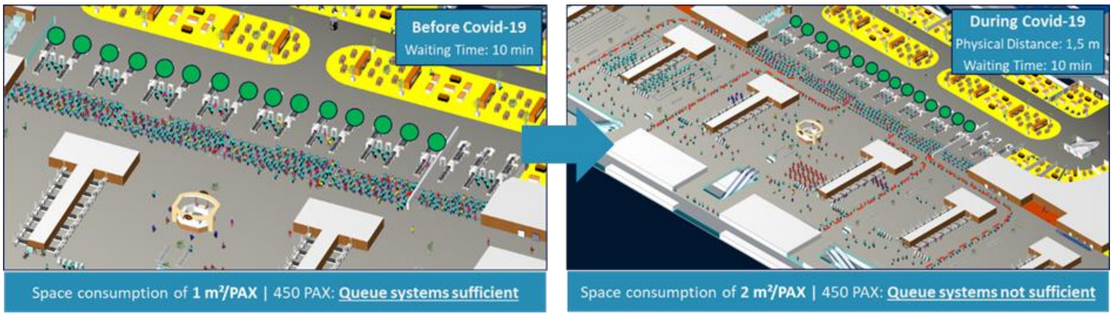


Figure 45: Queueing Situation at Security with and without Physical Distance

The described situation leads to two main conclusions:

1. **Space availability did become more relevant than before COVID**

   The changed space requirements due to physical distance and the resulting waiting time equivalents show that space availability is more critical than waiting time

2. **Due to COVID, previous waiting time targets are not valid anymore**

   There is a need for revised waiting time targets of security checkpoint considering space availability as one of the main drivers for planning.

2.3.3.3 Assessment of Security Queuing System and Staffing

In the previous sections, it was evaluated how the COVID measures influence security lane throughput and physical distance affect queue system capacity. In order to do a more comprehensive analysis of security control checkpoint, another important factor needs to be considered, which is the staffing of lanes.

In order to achieve a realistic setup, the traffic volume of a peak situation generated by the example flight schedule (27 mppa) selected for the generic terminal is reduced in order to simulate traffic structures in times of COVID. Therefore next to a scenario with pre-COVID traffic (100%), also a scenario with 75% as well as only 50% of the former traffic volume is simulated (see Figure 47).

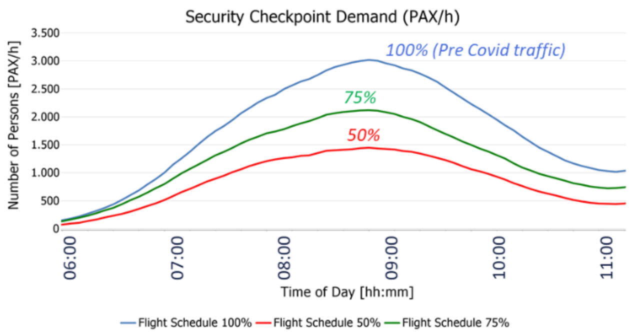


Figure 46: Traffic Reduction Scenarios

In case that an airport has spare space which can be used as queueing area for security checkpoint, one mitigation to cope with pre-COVID situations could be to use this additional space. However, Table 18 shows that the requirement of additional space strongly depends on the interaction of traffic volume, throughput reduction as well as lane staffing (e.g. 100% means available queue system is fully utilized, 200% means that double of the initial queue space is required). For some configurations, providing additional space might be a feasible option (e.g. 75% traffic with 100% staffing and -25% throughput reduction = 110% queue space utilisation). However, as soon as the throughput reduction exceeds a certain threshold (e.g. -50% throughput reduction and more), the queue space requirement is expanding drastically (e.g. 50% traffic with 60% staffing and 50% throughput reduction = 800% queue space utilisation).

Increase Factor of Queue Space Utilization		Traffic Volume & Staffing compared to Pre-Covid					
Security Throughput compared to Pre-Covid	Traffic	50%			75%		100%
	Staffing	60%	80%	100%	80%	100%	100%
	35% 60 Pax/h	> 600%					-
	50% 90 Pax/h	800%	450%	105%	>900%	800%	-
	65% 117 Pax/h	400%	< 100%	< 100%	700%	250%	-
	75% 135 Pax/h	200%	< 100%	< 100%	400%	110%	-
	100% 180 PAX/h	< 100%					100%
Queue Space Utilization based on:		2m²/Pax (Post Covid)					1m²/Pax (Pre-Covid)

Table 18: Increase Factor of Queue Space Utilisation

Due to physical distance requirements and decrease in throughput, the requirement for balanced staffing of lanes is becoming more relevant. This raises the need for a staffing supplement which is dependent on traffic volume as well as throughput reduction.

In a pre-COVID situation, a traffic volume of 100% traffic in combination with 100% staffing of lanes lead to a typical peak situation in the sample setup. Although the queue system is fully filled, it still can accommodate all waiting passengers (see Figure 47).

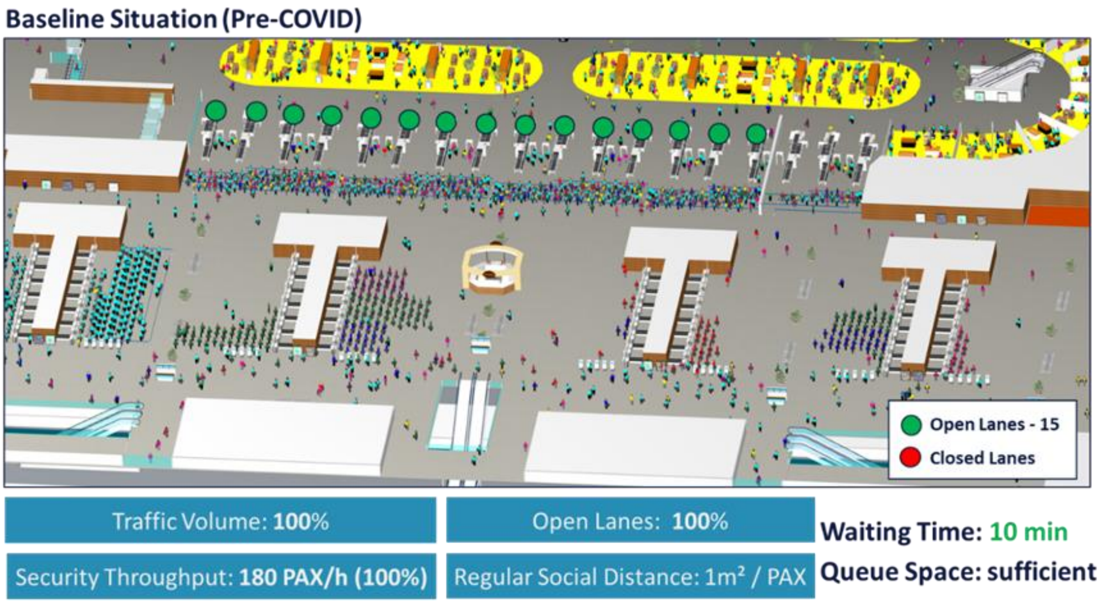


Figure 47: Security Checkpoint Baseline Situation (pre-COVID)

In times of COVID, an unbalanced staffing can lead critical situations quite fast. In the situation below, the two limiting factors of throughput reduction (-25%) as well as physical distance in queues (1.5m minimum distance) lead to a situation where 50% traffic in combination with 50% staffing lead to many passengers spilling out of the queue system into check-in area (see Figure 48).

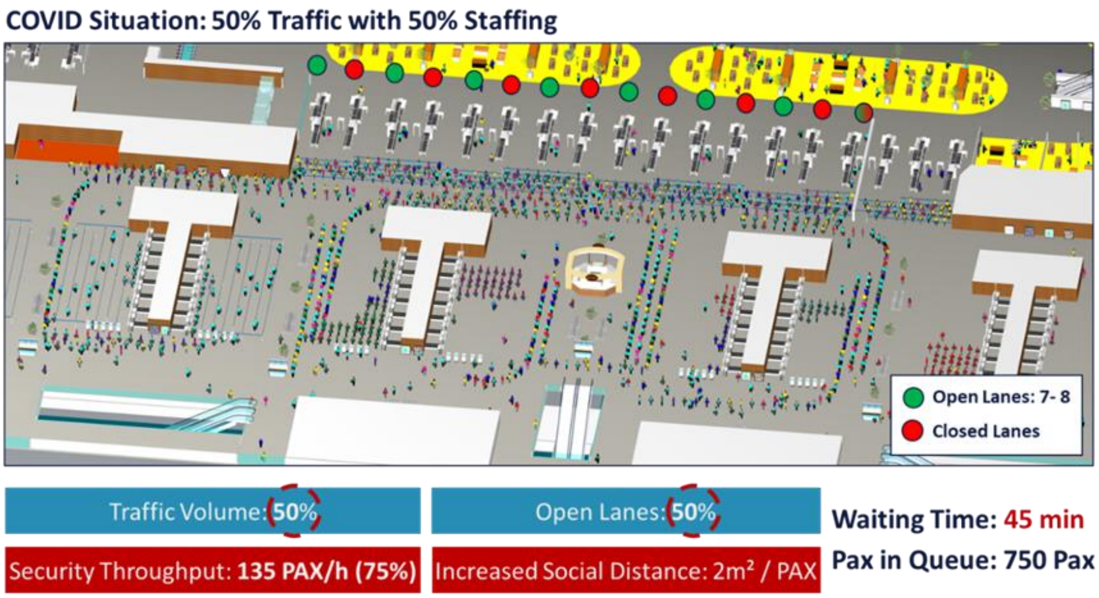


Figure 48: Security Checkpoint (COVID Situation) with unsufficient Staffing

In order to prevent these critical situations, a staffing supplement needs to be applied. Therefore, instead of staffing only 50% of the available lanes, a staffing of 70% (x1.4) could resolve the critical situation and allow queue systems to accommodate all waiting passengers again (see Figure 49).

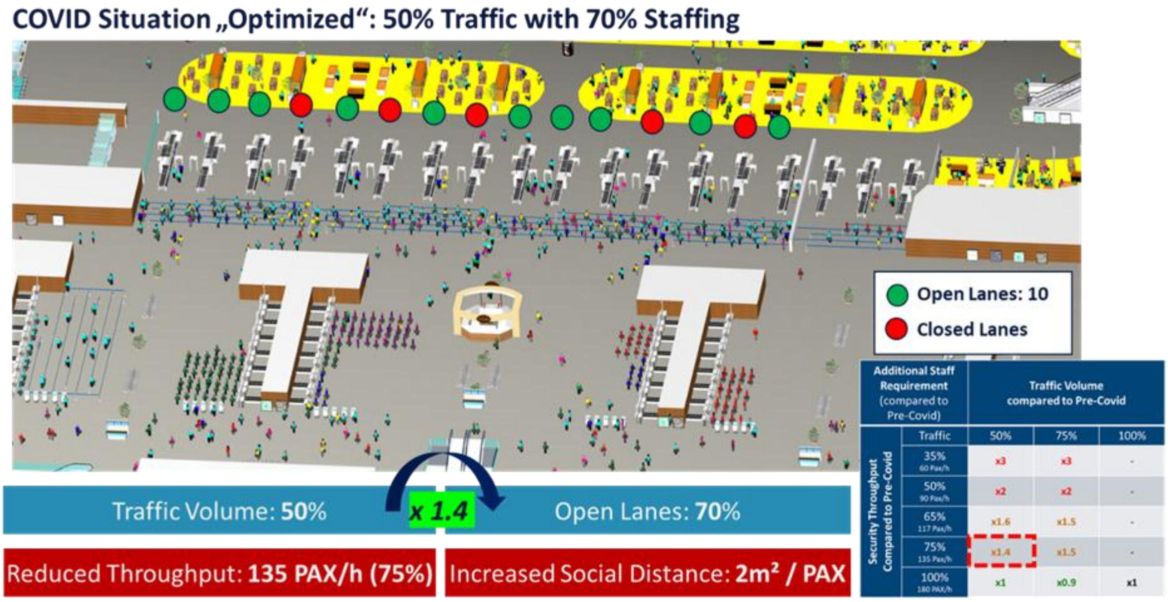


Figure 49: Security Checkpoint (COVID Situation) with sufficient Staffing

Table 19 shows the staffing requirements for different scenario setups. While the relative value indicates the staffing required (100% = all lanes staffed), the second value is to be understood as Staff-to-Passenger ratio (e.g. x1 = 100% Staffing with 100% Traffic and x2 = 100% Staffing but only 50% Traffic). The table shows that in COVID times, staffing of lanes should not be planned only in correlation to traffic reduction (e.g. 50% traffic reduction does not mean that only 50% of lanes should be staffed). Similar as with the evaluation before, also the staffing ratio is sensitive in relation to traffic volume and is likely to increase even with a low throughput reduction (e.g. traffic reduction of 75% and throughput reduction of -25% results in Staff-to-Passenger ratio of x1.5, which means that related to reduced traffic, still more staff is required). The main reason for the requirement of further staff even with reduced traffic volume are both factors of reduced security throughput provoked through COVID measures as well as the additional space requirement due to the physical distance in queue systems.

Additional Staff Requirement (compared to Pre-Covid)		Traffic Volume compared to Pre-Covid		
Security Throughput Compared to Pre-Covid	Traffic	50%	75%	100%
	35% 60 Pax/h	150% (x3)	220% (x3)	-
	50% 90 Pax/h	100% (x2)	150% (x2)	-
	65% 117 Pax/h	80% (x1.6)	110% (x1.5)	-
	75% 135 Pax/h	70% (x1.4)	100% (x1.5)	-
	100% 180 PAX/h	50% (x1)	70% (x0.9)	100% (x1)
Queue Space Utilization based on:		2m²/Pax (Post Covid)		1m²/Pax (Pre-Covid)

Table 19: Staffing Supplement for different Scenario Setups

2.3.4 Conclusion

The potential COVID related issues for security can be grouped into the following 3 categories:

1. **Organisation of queues**

   Due to physical distance, queue systems of security checkpoint experience a capacity drop of -50% or even more depending on physical distance regulations.

   The existing queue space is more relevant than before COVID since overflow situations can occur earlier than before. Space availability is more critical than waiting time considering Level of Service targets, therefore there is a need for revised waiting time targets.

   Security throughput reduction of 50% and less (mostly driven by limitation of divesting positions) will most likely lead to critical situations with recovering traffic since queue space is insufficient.

2. **Throughput of security lanes**

   For the example security setup, COVID measures are likely to cause throughput capacity drops. Limiting from two to one drop off position brought major reduction in the range from -50% up to -70% depending on combinations with other measures. However, the example of reducing from 3 to 2 drop off positions showed a less critical reduction in the range of -25% up to -40%. The impacts of other measures than limiting drop off positons showed a throughput reduction in the range of -15% up to -35%.

   Especially reducing drop off positions but also dropping more items beforehand in combination with increased divesting time have a major impact on throughput of the sample setup.

   Some measure combinations will not further reduce the throughput if there is one measure causing the bottleneck and overruling the effects of other COVID measures.

   Due to the diversity of security lanes, it is recommended to evaluate the impact of COVID measures in airport specific studies (e.g. manual search processes were not causing capacity drop at the sample model but can also lead to further reduction in other lane setups).

3. **Staffing and shifted demand**

   Ad-hoc bookings as well as passengers arriving earlier than usual lead to unpredictability and make reliable forecast and balanced staffing planning more challenging.

   Staffing of lanes should not be planned only in correlation to traffic reduction but due to physical distance and changed space requirements also in regard to queue space availability. This also implies that waiting time targets at security checkpoint need to be adjusted. Furthermore, in COVID times, more staffing in relation to passenger volume is required, leading to the revision of rules for staff planning.

   Stress on the security checkpoint can also be reduced by optimized balancing between decentralized checkpoints.

The Figure below summarises the recommended mitigation measures:

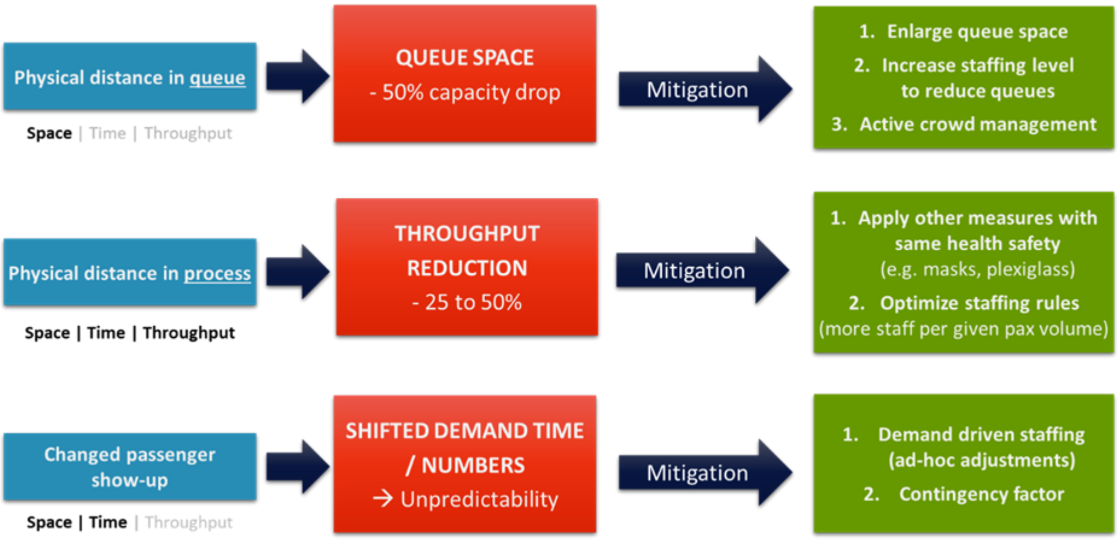


Figure 50: Mitigation Measures for Security Control

2.4 Departure Gate Areas

2.4.1 Introduction

Boarding gate areas as main dwell areas for passengers at an airport are directly affected by physical distance requirements. Thus, an airport may need to rethink its entire allocation principles in terms of which flights could still be accommodated by each gate holdroom.

In order to support airports in this task, this study aims to give guidance on the following topics:

- What is an estimated new capacity for holdrooms under physical distancing conditions?
- Which gate holdroom layouts seem to be most critical?
  - Which number of flights would represent a saturation capacity?
  - Which mitigation options are possible?
- What would an earlier show-up of passengers mean for boarding gate areas?

At the time of the study, the airport stakeholders described the following key changes compared to Pre-COVID:

1. **Use of every second seat only**

   As one of the immediate measures airports introduced to facilitate physical distancing was marking every second seat as "blocked". Although this would not necessarily meet the recommended distance of 1.5m from head to head, this approach has been broadly applied by airports as suitable trade-off between health safety and capacity (in particular when masks are worn now).

2. **Physical distance for standing passengers**

   Physical distancing for standing passengers cannot be implemented as easy as for seated passengers. Only for closed gates airports can directly control the number of passengers per area but in an open gate concept this must be left self-organised to the passengers (but supported by information about physical distancing).

3. **Limited availability of retail areas**

   In the early phase of post-COVID, many retail / VIP lounge areas were still closed due to low passenger numbers. With recovering passenger volumes, it is expected that they re-open. Anyway, the capacity of restaurants is still limited and these central areas cannot accommodate as many passengers as Pre-COVID

4. **Earlier show-up of passengers**

   As mentioned for check-in, several factors may trigger an earlier show-up of departure passengers at the airport. If check-in allows an earlier handling, passengers will also arrive in the gate area earlier and occupy it for a longer time. This additional load on the boarding areas could get problematic when traffic numbers increase again.

2.4.2 Scenario Setup

In order to cover a wide variety of situations, this study examined various gate layouts and corresponding flight schedules of ARC's data pool.

2.4.3 Results

2.4.3.1 Capacity Calculation Pre- vs Post-COVID

Airports face the task of calculating new saturation capacities for their boarding gates as input for their further decisions about allocation and other operational measures. This task is demonstrated here for an example gate holdroom.

As general capacity pre-COVID the IATA methodology is used as guidance. Anyway, it is not followed 100% because this initial calculation shall represent a saturation capacity (hard limit).

Example Gate Holdroom:

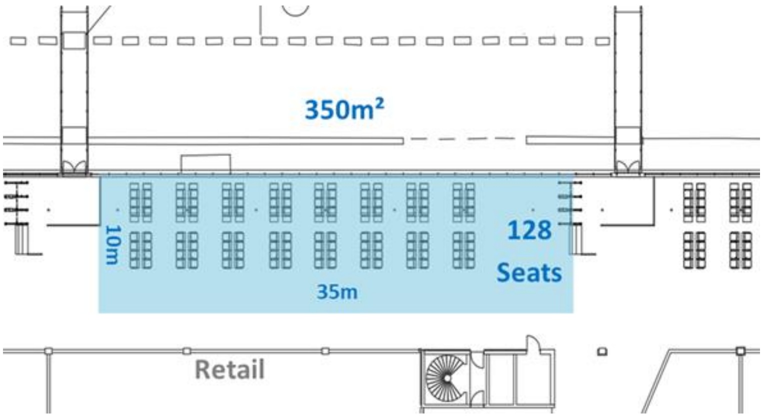


Figure 51: Example Gate Holdroom for Capacity Calculation

The example boarding gate can be described by the following key characteristics:

- 350m² gross space
- 128 seats (requiring 1.6m²/seat acc. to IATA) = 205m²
- 145m² remaining standing area

Saturation Capacity Pre COVID:

Considering that only up to 70% of available seats are typically used (as passengers avoid sitting next to strangers), such a gate would take hold of **90 seating passengers**. Inside the standing area each passenger would require approx. 1.1m². In combination with the same utilisation factor of 70% this results in further **90 passengers standing**. This would sum up to **180 passengers as total gate capacity**. It has to be noted that this capacity does not comply with IATA's side requirement for passenger comfort, which states that around 70% of passengers should find a seat. Thus, this calculated limit should only be reached shortly before boarding proceeds.

Saturation Capacity Post-COVID:

By blocking every second seat, 64 of 128 usable seats would remain in the example gate. Due to the systematic way of blocking seats, each remaining seat would offer free seats next to it. Thus, it is considered as realistic that all remaining seats will be taken in this case. This means a capacity of **64 seating passengers.** The remaining standing area shall now be used in a way that passengers can keep physical distance, which relates to approx. 2.2m²/PAX (box of 1.5 x 1.5m) and thus **66 standing passengers** as best case.

In total this results in a new **capacity limit of 130 passengers** (64 seated + 66 standing passengers, this represents approx. **70-75% of former capacity**).

Such a calculation can be used as first guidance. Though, there are further factors, which should be considered. Previously described post-COVID capacity can be understood as temporary saturation capacity. It does not comply with desired comfort objectives, e.g.

- 60-70% seated passengers
- assuming that not all still available seats are taken
- keeping the desired physical distance when moving inside the gate

In such a more conservative approach the gate capacity could decrease even to 50%.

In contrast to above negative impacts, there might be positive effects, which increase the practical capacity. For flights with many groups (e.g. holiday) not all passengers need to keep physical distance. In case boarding starts early because of adjusted boarding procedures, not all passengers of one flight might be in the holdroom at the same time (in particular business flights).

2.4.3.2 Impact on Allocation

For single closed gates the decision whether a flight can still be allocated there is relatively easy to answer; however, the elaboration of allocation principles for open gate areas, where passengers also use space of nearby gates, can be more advanced.

The following example assumes a peak situation with 3 flights departing at a similar time from adjacent gates. Each flight just fits into its dedicated area Pre-COVID (see Figure 52).

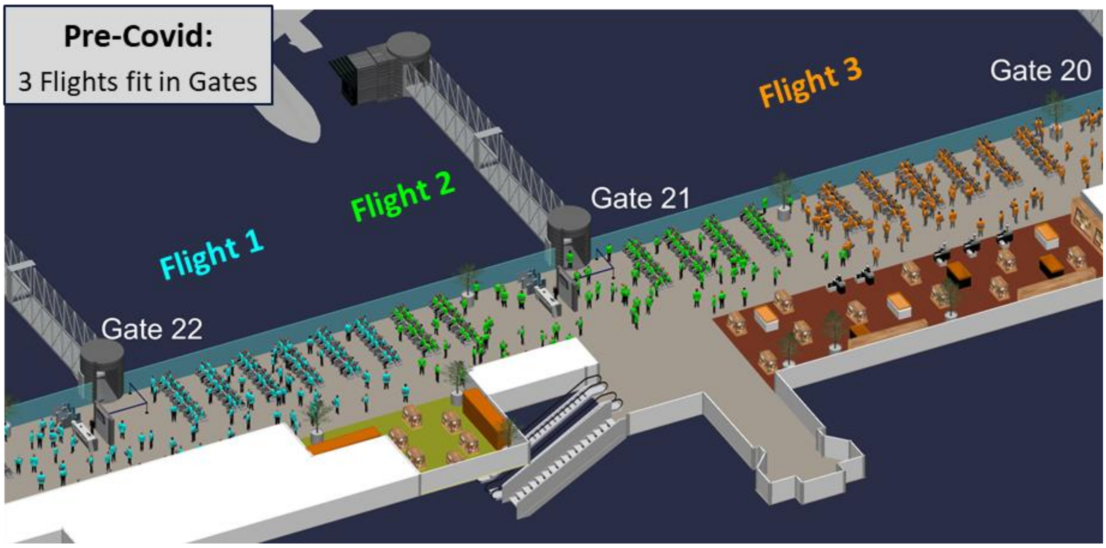


Figure 52: Boarding Gate Area (Pre-COVID)

If the same flights (= same passenger number, same time) shall now be handled under Post-COVID conditions with consideration of physical distance, this would mean a heavy overflow into other areas (circulation corridors, retail stores - if existing) or simply an unacceptable situation if no overflow space is available (see Figure 53).

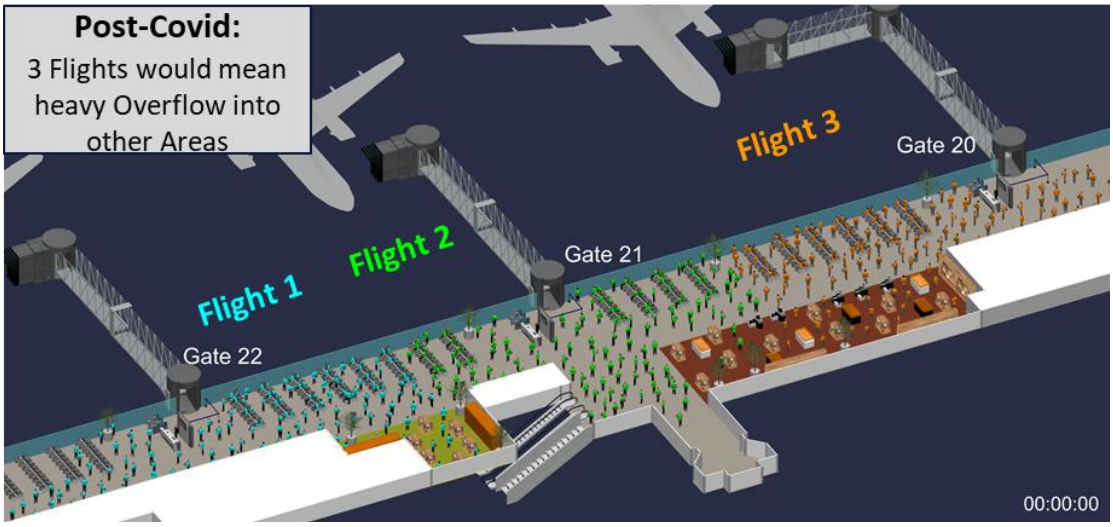


Figure 53: Boarding Area (Post-COVID, Do-Nothing)

An acceptable situation can only be reached again, when one flight is re-located to another area. In general, it can be said that flights will occupy 1.3-1.5 times the area, they used before. Thus, the middle gate would almost be used by the outer flights (see Figure 54).

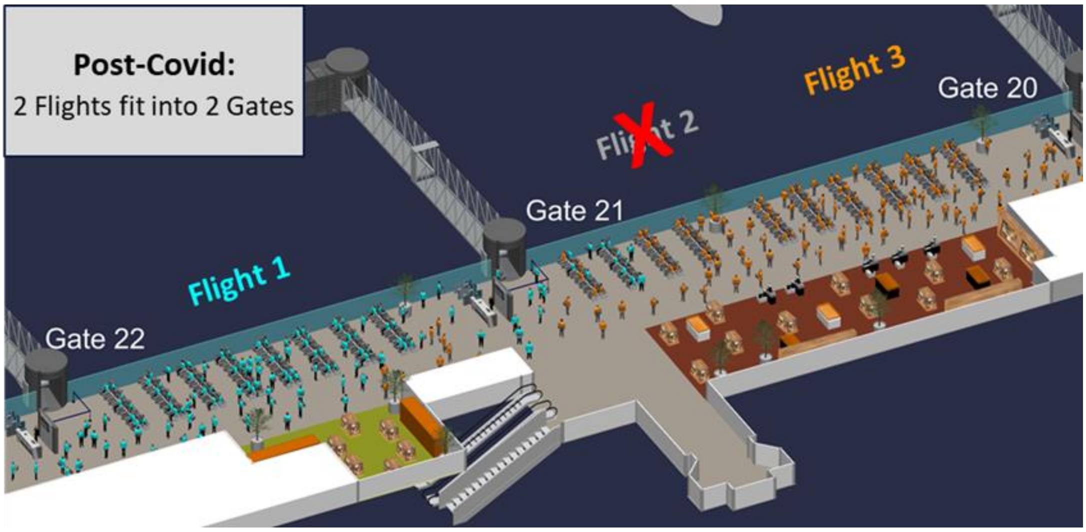


Figure 54: Boarding Gate Area (Post-COVID, optimized):

If infrastructure allows it, an airport should try to distribute the flights as good as possible, e.g. by

- Maximizing the time interval between consecutive allocations to the same gate
- Maximizing the difference in STD between flights allocated next to each other
- Distributing simultaneous flights in the pier by leaving gaps (unallocated gates)
- Keeping in mind the (changed) passenger numbers and load factors to avoid overlapping of several well-booked flights in the same area

2.4.3.3 Impact of earlier Passenger Show-Up

The reduced gate capacity could be intensified by another impact, which is the earlier show-up of passengers in the boarding gate. Anticipating a more complicated handling process and/or long waiting times passengers reach the airport earlier and when these expectations are **not** met, they also arrive in the departure gate earlier.

Using an example situation with 3 flights à 150 passengers, the regular show-up behavior Pre-COVID is assumed to meet the regular gate capacity.

Post-COVID, two factors accumulate:

- Reduced capacity due to physical distancing
- Earlier show-up, e.g. because of anticipated longer waiting times, which actually do not occur

In consequence the gate holdroom gets overcrowded (utilisation of 185% with an assumed earlier show-up by 30 min)

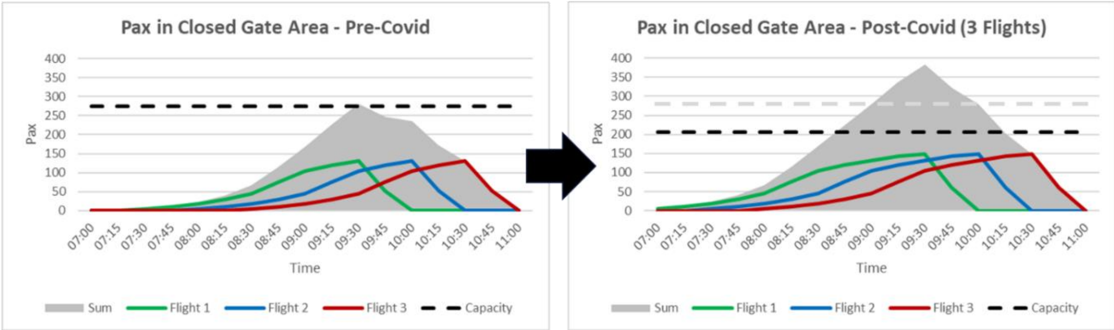


Figure 55: Impact in Gate Area: Reduced Capacity and earlier Passenger Show-Up

In order to limit the occupancy in such holdrooms, it is thinkable to limit the inflow into the corresponding area, e.g. by not letting passengers pass a gate security control. However, this would create new issues:

- other dwell areas are needed in front of security
- potential delayed boarding of the third flight (→ impact on turnaround time)

Thus, it seems more reasonable to allocate one of the flights to another gate, if infrastructure allows.

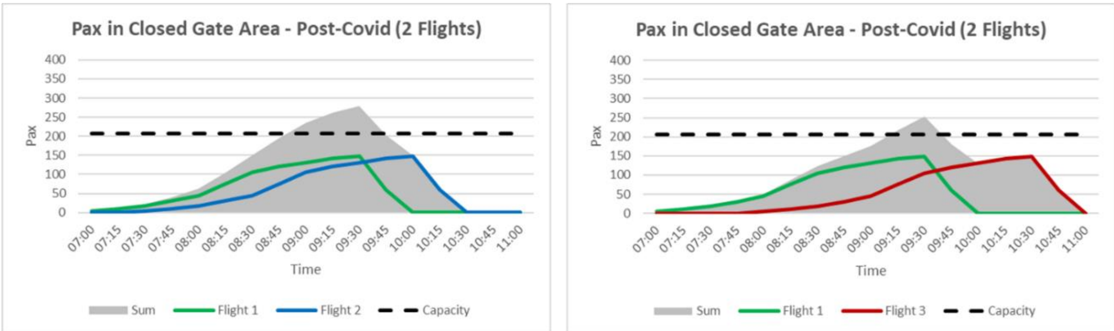


Figure 56: Scenarios of Removing one Flight of Gate Area

2.4.3.4 Likelihood of earlier Passenger Show-up

The previous chapter demonstrated the impact of an assumed earlier passenger show-up in the boarding gates. The applied shift of typical show-up distributions by 30 min represents a hypothesis and shall mainly support the understanding of related effects. It is recommended to repeat similar airport specific calculations and once reliable measurements about the passenger show-up at security control and in the boarding gates are available. At the time of the study, actual measurements were only available for the early recovery phase of May and June 2020. An analysis of the security control show-up behavior done by ARC for two medium size European airports did not indicate the expected earlier show-up for all flights yet.

Anyway, this does not necessarily mean that passengers have not arrived earlier at the airport. When the check-in opening times are not adjusted, it is logical that passengers cannot proceed earlier to airside but must wait in the departure hall (see check-in chapter 2.2).

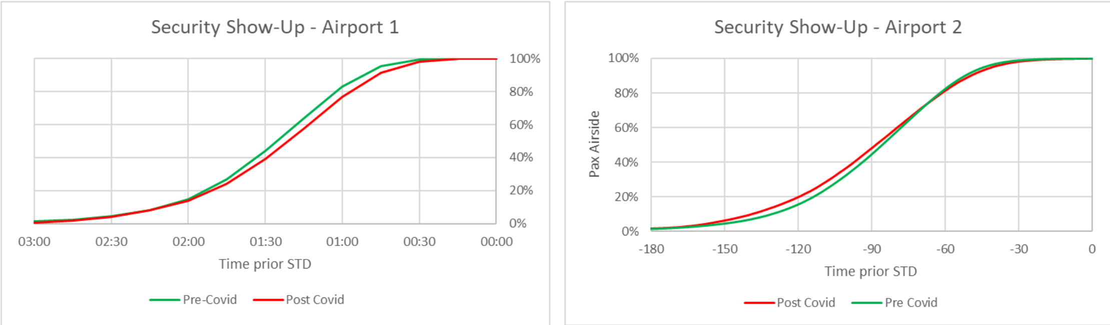


Figure 57: Passenger Show-Up Distribution at Security Control (Pre- vs. Post-COVID)

However, for certain flight types an earlier show-up could be observed indeed. This mainly occurred for ethnic flights, e.g. to Turkey, where the operational procedures due to travel restrictions lead to uncertainty for the passengers. In response this resulted in the expected earlier show-up.

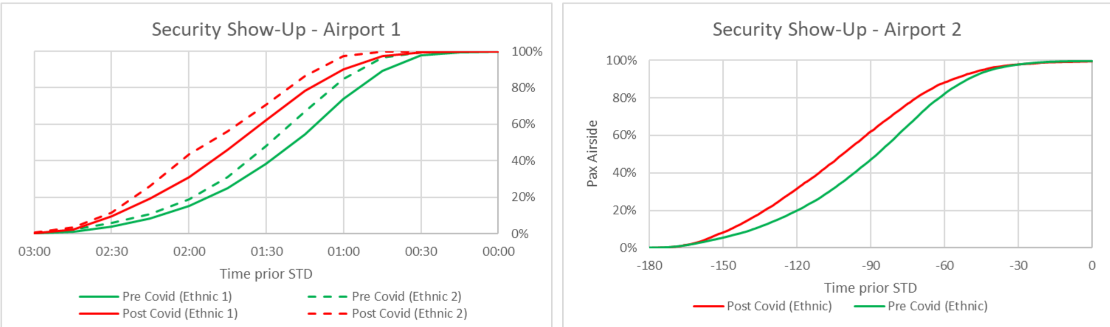


Figure 58: Earlier Passenger Show-Up on certain Flights

In summary, it is difficult to judge any general trend and the amount of earlier show-up. It can rather be expected that the passenger behavior changes short term and temporary, e.g. on certain triggers such as:

- Introduction of health (certificate) checks for departure
- Uncertainty about travel restrictions (passenger expect additional document check)
- Reports in the news about long waiting time (e.g. on holiday start)

2.4.3.5 Saturation Capacity Calculation (Example: Bus Gate Building)

Once the new gate capacities under COVID conditions are known and the airport has a suitable knowledge in which extent passengers show-up in the boarding gates earlier, the traffic a boarding area can still handle can be calculated.

This study did such a calculation for an example bus gate building. In contrast to contact gates, bus gates do not have a stand driven allocation limit. Thus, many airports use bus gate areas as overflow areas. In consequence, these bus gate areas were often overcrowded Pre-COVID already. Although Post-COVID many airlines / airports avoid bus operations and prefer contact stands (which is also recommended), these bus gate areas could turn into bottlenecks when traffic volumes are getting closer to Pre-COVID numbers and all contact stands are used again.

<u>Step 1: Calculation of passenger capacity of bus gate area</u>

In reference to the capacity calculation recommendations done above, an airport would calculate the number of passengers the area of interest can hold. In the best case, the gate area offers good line of sight to all gates, which would simplify dwelling in other areas, located not directly in front of the actual gate. If not, a further reduction factor might be considered or a more advanced allocation model could be used.

	Available Space	Space Requirement	Passenger Capacity
Pre-COVID	3,000 m^2	2.0 m^2/PAX (in reference to IATA)	1,500 PAX
Post-COVID		2.7 m^2/PAX	1,100 PAX

Table 20: Capacity of Bus Gate Area

<u>Step 2: “What-if” calculations with reduced flight schedule</u>

Either the airport owns forecast flight schedules with different traffic scenarios already or the planner would iteratively remove flights from a pre-COVID schedule. By applying inflow (gate show-up distribution) and outflow (boarding time) assumptions, the current number of passengers in the gate area can be calculated.

The flight schedule, which lets the passenger number meet the new capacity can be considered as saturation flight schedule for this area.

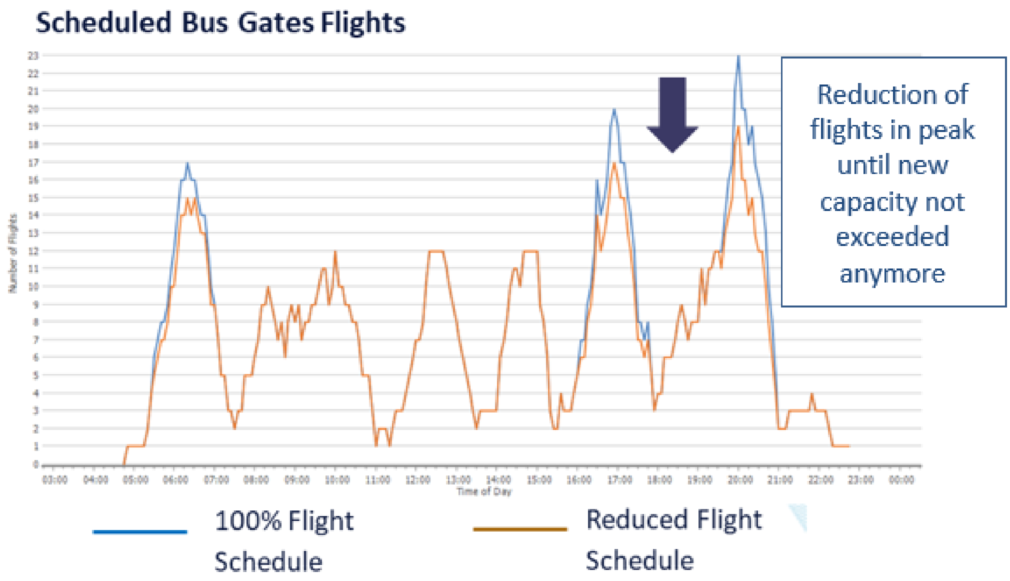


Figure 59: Flight Schedule Reduction

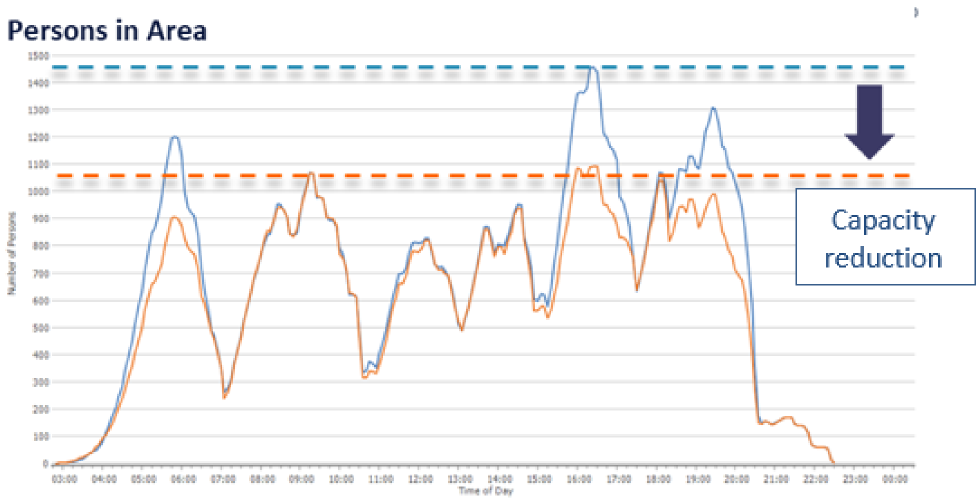


Figure 60: Resulting Passenger Number in Gate after Flight Schedule Reduction

In the example, the gate capacity reduces to approx. 70-75%. This means, also the number of flying passengers must be reduced accordingly. Depending on how this required reduction splits on load factor reduction and cancelling of flights, the reduction of flights will differ. For the later recovery phase it is expected that airlines have adjusted their schedules in a way that most of the flights can be offered with reasonable load factor again. As a rule of thumb, it can then be said that it will probably not be possible anymore to allow one quarter of the Pre-COVID bus gate flights, if the bus gate was already saturated before.

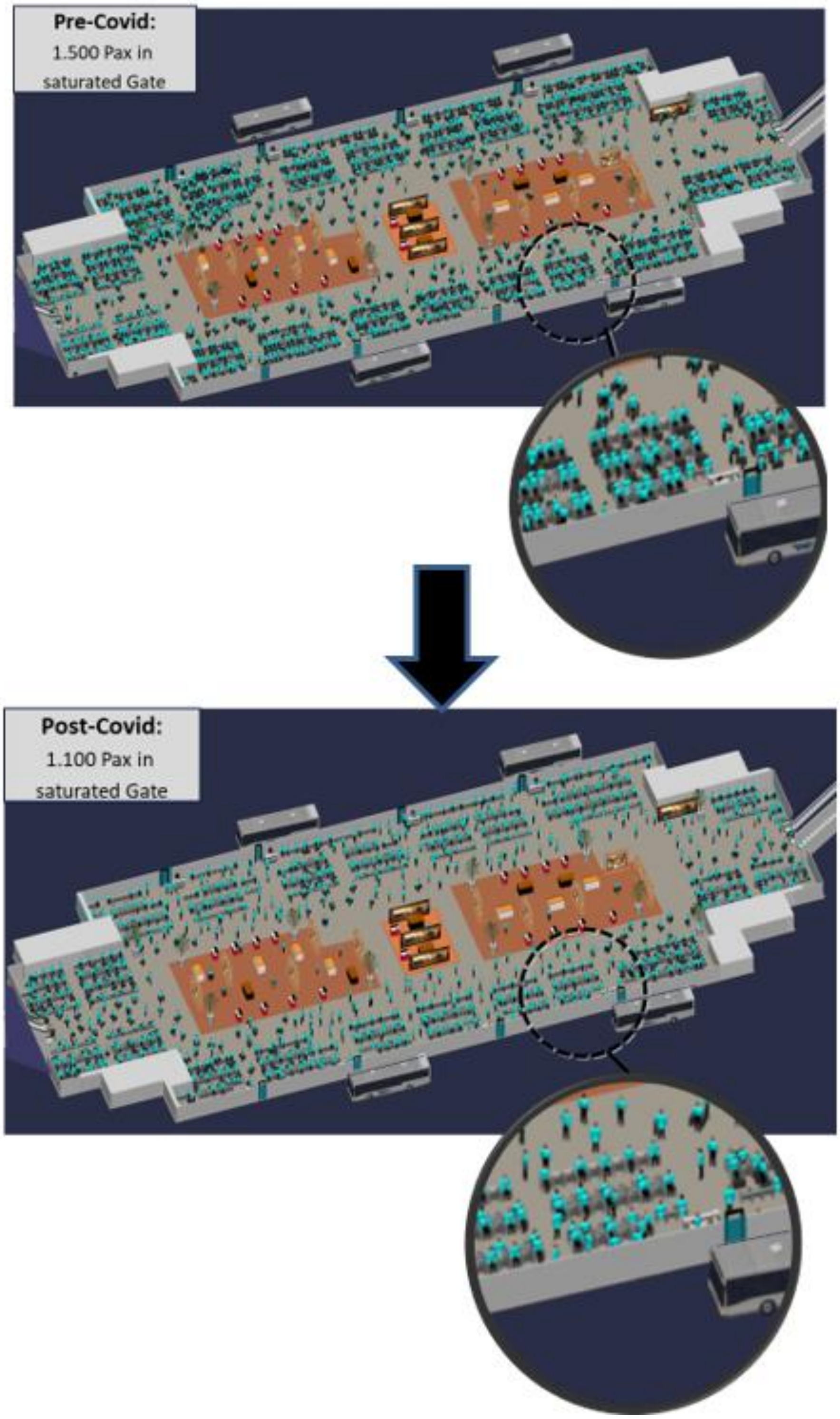


Figure 61: Visualisation of Bus Gate Occupancy (Pre- vs. Post-COVID)

2.4.4 Conclusion

In a greater extent than other passenger handling areas, the boarding gates are immediately affected by physical distancing. In general, it has to be expected that the capacity is reduced by at least 25%. In special cases or when the capacity calculation is done more conservatively (e.g. putting more emphasis on passenger comfort), this can reach up to even 50%.

This capacity drop will have an impact on allocation: closed gates may even not be usable for the passenger numbers, which they served pre-COVID, and in open gates the allocation must be adjusted.

The following optimisation measures may be applied in general:

- Allocation
    - Avoid simultaneous use of adjacent boarding gates; distribute flights as much as possible
    - Prefer bigger and open gates; avoid gates with bus transportation
- Passenger information
    - Announce gate early in advance, when general seating area is limited
    - Simplify use of other dwell areas, even without line of sight e.g. by reliable boarding calls / notification via text message
    - Do not ask passengers for early arrival at airport, when not necessary
- Operational optimisation
    - Avoid pre-boarding, when no benefit anymore (e.g. when cabin determines boarding rate and not the counter process)
    - Support re-opening of restaurants, retail stores and lounges to reduce the load from seating areas

Actual measures with highest benefit are quite layout specific. Therefore, the following table gives an overview on typical gate layout and terminal principles as well as targeted mitigation measures.

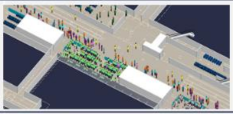
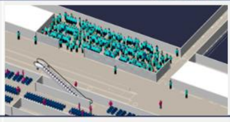
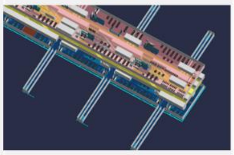
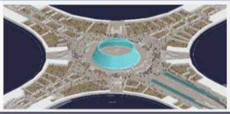
Gate Layout		Covid-19 Impact	Recommendation
Open gate concept, all **adjacent gates in line of sight** to each other		**Low:** Passengers can automatically spread to nearby gates (occupy 1.3-1.5 times the previous area)	Allocation of every other gate, as long as possible.
Generally open gate concept but infrastructure divides them into **different zones**		**Medium:** Passengers cannot simply use other areas, as they don't see when boarding starts etc.	Avoidance of simultaneous allocation in same zone as long as possible. Improved passenger information.
Closed gate concept, access for allocated flight only		**High:** After entering, no overflow into other area possible anymore.	Avoid closed gates when not necessary.
Dual gate concept with Schengen and NonSchengen gates at different levels serving one stand		**Low – Medium:** With 'equal' Schengen and NonSchengen flights, theoretically every second gate not in use. Issue, when mainly Schengen flights remain.	Alternating allocation of Schengen and NonSchengen flights.
Main central dwell area and late announcement of actual gate		**Low – Medium:** Central area may get overcrowded, in particular with closed/limited restaurants.	Early announcement of actual gate to distribute passengers.

Figure 62: Mitigation Measures for Boarding Gates

2.5 Remote Bus Handling

2.5.1 Introduction

Remote bus handling was introduced as an additional subject to the current study, after the topic has been raised in several interviews taken to airports. It was observed that especially airlines with short turnaround times and related bus stand preference were currently requesting to use contact positions. Thus, in the current study, ARC aimed to understand how the COVID related measures could affect the bus remote handling of passengers.

Physical distancing rules affect bus remote handling in particular, since less passengers can fit into one single bus, resulting in a higher number of buses needed to handle the same flight. As an example, the study's stakeholders communicated that the regional government in the region of NRW (North Rhine-Westphalia, location of airports Cologne and Düsseldorf) in Germany has given instructions to use apron buses with maximum capacity of 110 passengers for 25 passengers only. This results in a practical usage of one quarter of its theoretical capacity. At many other airports on contrary, an agreement to use one bus for every 50 passengers has been made.

The variety of applied measures leaded ARC to investigate the effect of the application of physical distance in bus handling. The aim of the current subject is to determine the increase in the number of buses needed for the same traffic volume, compared to pre-COVID situation and the traffic still manageable for the existing number of busses (saturation capacity). These two questions are addressed hereunder.

2.5.2 Scenario Setup

In order to provide answers to the above-mentioned questions, general research was performed followed by interviews with airport partners, in order to provide feedback regarding the input data assumed by ARC. Finally, allocation simulations with CAST were performed.

The input data necessary to perform the bus allocation in CAST is the following:

- Number of passengers considered per bus
- Required time usage of one bus for departure (DEP) and arrival (ARR) flight
- Flight schedule (FS) of bus gate flights

2.5.2.1 Bus Capacity

After performing an in-depth analysis, it can be stated that normally two types of apron buses are used in the majority of European airports: buses with a maximum capacity 110 passengers, the so-called "big buses", and the ones with a maximum capacity of 50 passengers ("small buses"). In this study, only buses with maximum capacity 110 passengers are considered.

The above-mentioned capacities are theoretical capacities. However, it is widely known that the practical capacity of the big buses is usually 80 to 90 passengers because not every set is occupied and passengers keep distance to each other even in times before COVID. Under these circumstances, normally two apron buses were required pre-COVID, in order to handle a typical narrowbody (NB) with 150-180 passengers on board.

When strict 1.5m physical distance rules are considered, only 17 passengers would fit into such a bus. This means that less than 20% of the former capacity could be used and 5 times as many buses would be needed to handle a mentioned narrowbody flight, as shown in Table 21. When family members or groups are considered, it is assumed that the capacity could be increased upon 25 passengers per bus. This corresponds to the NRW regional government instructions mentioned before.

Scenario	Used Seats	Standing Area	Physical Distance Rule	Space Require-ment	Total Capacity	Number of Buses needed
Pre-COVID	14 of 14	24m²	IATA Standard	0,25m²/Pax	110 Pax (100%)	2
Post-COVID	7 of 14		1.5m	2m²/Pax	17 Pax (<20%)	11 (x5)
	14 of 14		1m	1m²/Pax	38 Pax (<40%)	5 (x2.5)

Table 21: Capacity and number of buses needed for a 110 passengers' bus

Table 21 shows the results of calculated bus capacities for a 110 passengers' apron bus under various circumstances. It can be concluded, that the consideration of strict physical distance in buses results in a highly increased number of buses per flight. This is operationally difficult to implement when traffic starts recovering. Therefore, there exists a need of a trade-off between: health requirements and operational constraints. As a realistic capacity with trade-off, one bus for every 50 passengers was proposed to be considered. It would result in a usage of 50% of total bus capacity or 1.5 to 2 times the number of buses for a single narrowbody flight (depending on the load factor). This assumption is in agreement with the practical capacities used by some airports as states above.

2.5.2.2 Required Time per Tour – Departure Flight

The usage time of the apron busses per tour needs to be defined for the allocation. This is the time required by one bus to complete its tour for departure or arrival flight respectively. In order to do that, the bus tour cycle is subdivided into processes and the duration of each process is analyzed in detail. This will be done for the pre-COVID and post-COVID case.

Figure 64 shows an example pre-COVID apron bus tour cycle for a departure flight (DEP). The bus arrives at the terminal before the boarding start, with a 5-minute idle time. Afterwards, boarding starts and passengers are boarded to the bus. A boarding rate of 12 PAX/min is considered, which corresponds to the gate control throughput, resulting in 7 to 8 minutes bus boarding time (for 80 -100 passengers per bus). Subsequently, the bus drives from terminal to aircraft. After evaluating data from different airports, an average travel time of 5 minutes is considered. However, the travel time is highly dependent on airport layouts. Deboarding of passengers takes 2 minutes, taking into account a typical deboarding rate of 60 PAX/min. Finally, the bus travels to the next destination. Once more, 5 minutes travel time is assumed. Finally, an additional planning buffer time may be considered as well.

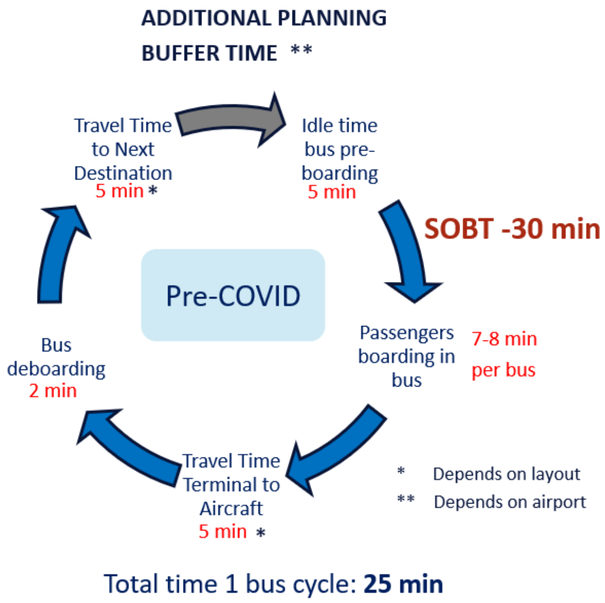


Figure 63: Tour Cycle Bus Pre- COVID (DEP)

The total duration of the pre-COVID bus tour for a departure flight is 25 minutes. Two (2) buses with maximum capacity 110 passengers are needed for a typical narrowbody flight. It is assumed that buses come one after another. This means, that the second bus should be available at the terminal when the first one is finishing boarding: 7 to 8 minutes later.

Bus number	Start bus usage relative to SOBT	Finish bus usage relative to SOBT
Bus 1	-35 min	-10 min
Bus 2	-28 min	-3 min

Table 22: Usage times apron buses Pre-COVID (DEP)

Table 22 shows the usage times of pre-COVID apron buses relative to SOBT for a departure flight. The absolute duration of the bus tour is 25 min and the second bus is available 7 minutes after the first one (conservative approach).

Figure 65 shows an example post-COVID apron bus tour cycle for a departure flight, when a capacity of 50 passengers per bus is considered. The main differences with respect to the pre-COVID cycle are the reduced boarding (4 min) and deboarding (1.5 min) times, due to the lower passenger number per bus, as well as the possible introduction of bus cleaning/disinfection between each bus tour cycle. Boarding and deboarding times are considered to be approximately half of the pre-COVID ones, since the usage of 50% of the bus capacity is assumed. Cleaning time is assumed to be 5 minutes, which is a reasonable time for a short cleaning. The total duration of the post-COVID bus tour for a departure flight is 20 minutes. When cleaning is considered, the time increases up to 25 minutes. In this case, 3 to 4 buses with maximum capacity of 50 passengers are needed for a typical narrowbody flight. Buses come one after another. This means, the second bus should be available at the terminal when the first one is finishing boarding: 4 minutes later.

Table 23 shows the usage times of post-COVID apron buses relative to SOBT, for a departure flight without additional cleaning. The absolute duration of the bus tour is 20 min and the consecutive buses are available 4 minutes after the previous one.

As a conclusion, the time per bus tour is the same or reduced compared to pre-COVID and more buses are needed per flight.

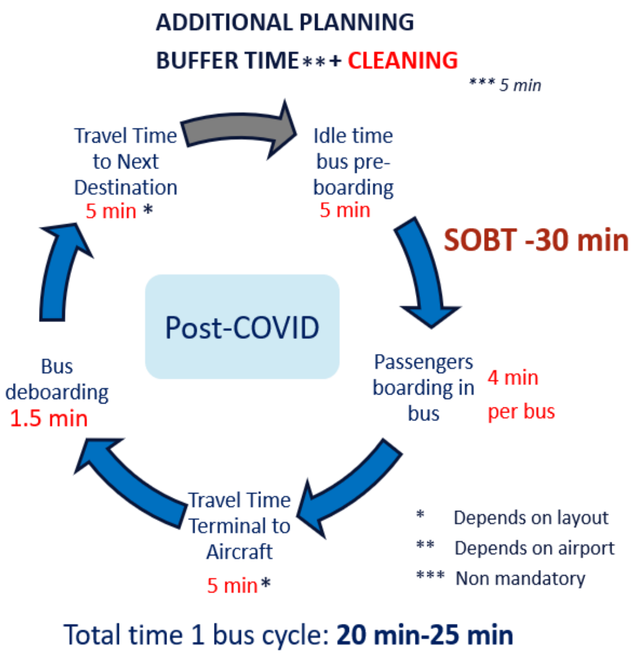


Figure 64: Tour Cycle Bus Post-COVID (DEP)

Bus number	Start bus usage relative to SOBT	Finish bus usage relative to SOBT
Bus 1	-35 min	-15 min
Bus 2	-31 min	-11 min
Bus 3	-27 min	-7 min
Bus 4	-23 min	-3 min

Table 23: Usage times apron buses without cleaning Post-COVID (DEP)

2.5.2.3 Required Time per Tour – Arrival Flight

As for the departure movement, also the usage time of the apron busses per tour for an arrival flight needs to be defined for the allocation. This is done in the same manner as for the departure flight.

Figure 66 shows an example pre-COVID apron bus tour cycle for an arrival flight (ARR). The bus arrives at the stand at the SIBT (Scheduled In-Block Time) and waits 5 minutes for the passengers to start deboarding the plane, aircraft door opening, stairs positioning and other related processes. After that, passengers board the bus. A boarding rate of 20 PAX/min is considered, which corresponds to the deboarding rate at the aircraft door, resulting in 5 minutes boarding time (for 80-100 passengers per bus). Subsequently, the bus travels from aircraft to terminal. An average travel time of 5 minutes is considered, after evaluating data from different airports. However, the travel time will be highly dependent on layout as already mentioned above.

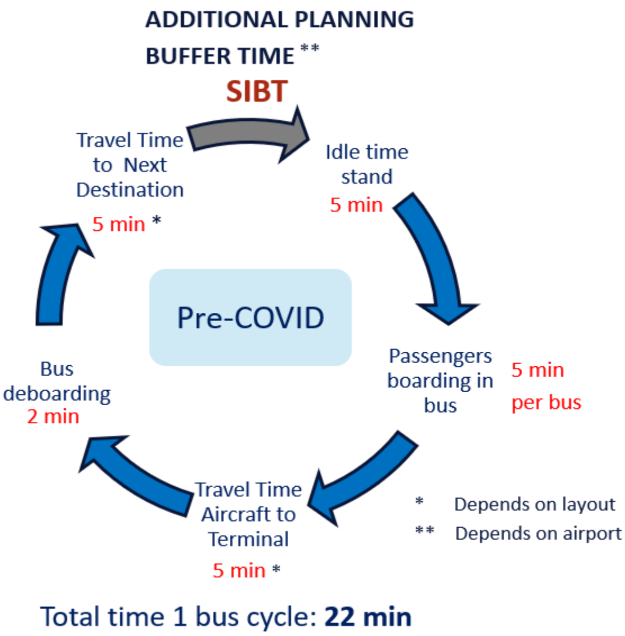


Figure 65: Tour Cycle Bus Pre-COVID (ARR)

Deboarding of passengers takes 2 minutes, taking into account a typical deboarding rate of 60 PAX/min. Finally, a travel time of 5 minutes to the next destination is assumed and an additional planning buffer time may be considered as well.

The total duration of the pre-COVID bus tour for an arrival flight is 22 minutes. Two (2) buses with maximum capacity 110 passengers are needed for a typical narrowbody flight. It is assumed, that buses are loaded simultaneously: one bus for the forward (FW) and another one for the aft (AFT) aircraft door. Buses are also unloaded simultaneously when enough terminal doors available.

The Table below shows the usage times of pre-COVID apron buses relative to SIBT, for an arrival flight (ARR). The absolute duration of the bus tour is 22 min and the second bus is available at the same time as the first one.

Bus number	Start bus usage relative to SIBT	Finish bus usage relative to SIBT
Bus 1	+0	+22 min
Bus 2	+0	+22 min

Table 23: Usage times apron buses Pre-COVID (ARR)

Figure 67 shows an example post-COVID apron bus tour cycle for an arrival flight, when 50 passengers per bus are considered. The main differences with respect to the pre-COVID cycle are the reduced boarding and deboarding times, due to the lower number of passengers in a single bus, as well as the possibility of introducing 5 minutes cleaning between each bus usage cycle.

The overall duration of the post-COVID bus tour for an arrival flight is 19 minutes and might increase up to 24 minutes when cleaning is considered. It is as well assumed that 2 buses are loaded simultaneously (one FW and one AFT door).

Table 24 shows the usage times of post-COVID apron buses relative to SIBT, for an arrival flight without cleaning. The absolute duration of the bus tour is 19 min, first two buses are available at the same time and so are the following buses 3 and 4.

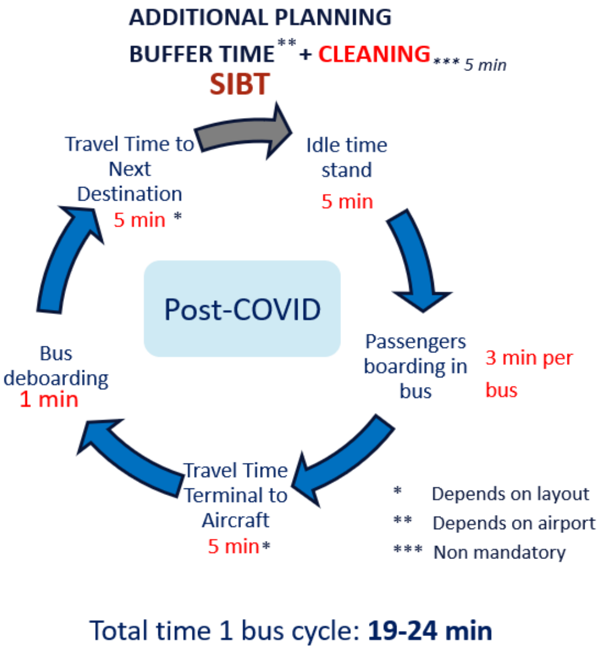


Figure 66: Tour Cycle Bus Post-COVID (ARR)

Note: the input data presented in the last subsections refers to a small size apron. For a big apron, an additional total cycle time of 5 minutes will be considered (for both, departure and arrival).

Bus number	Start bus usage relative to SIBT	Finish bus usage relative to SIBT
Bus 1	+0 min	+19 min
Bus 2	+0 min	+19 min
Bus 3	+3 min	+22 min
Bus 4	+3 min	+22 min

Table 24: Usage times apron buses without cleaning Post-COVID (ARR)

2.5.2.4 Flight Schedule Bus Gate Flights

The example bus gates flight schedule (FS) used for the current study has more than 20 departure and arrival flights handled remotely during the peak hour. This corresponds to more than 1,500 PAX/h (arrival and departure) in the peak as shown in Figure 68.

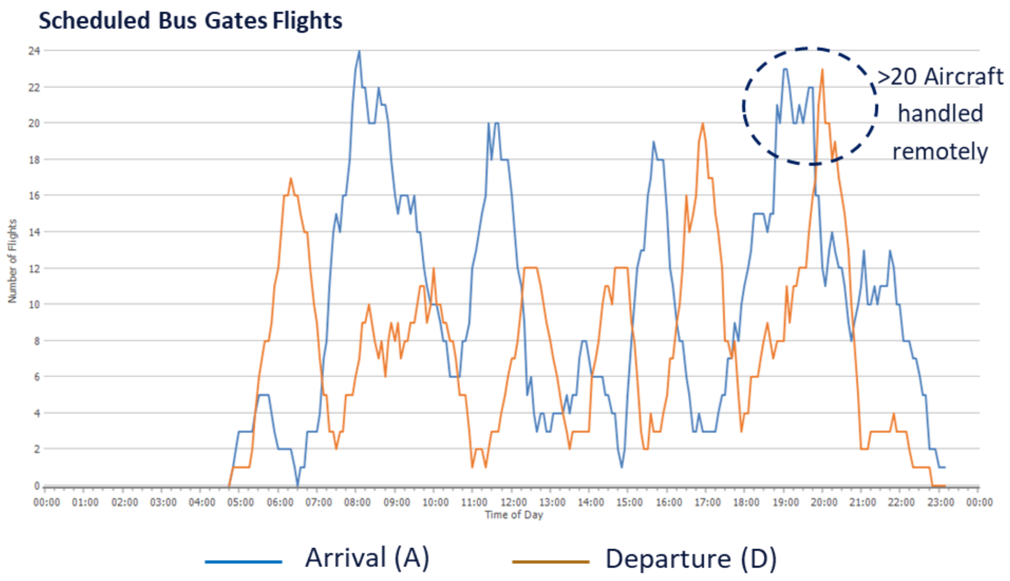


Figure 67: Scheduled Flights-Example Flight Schedule

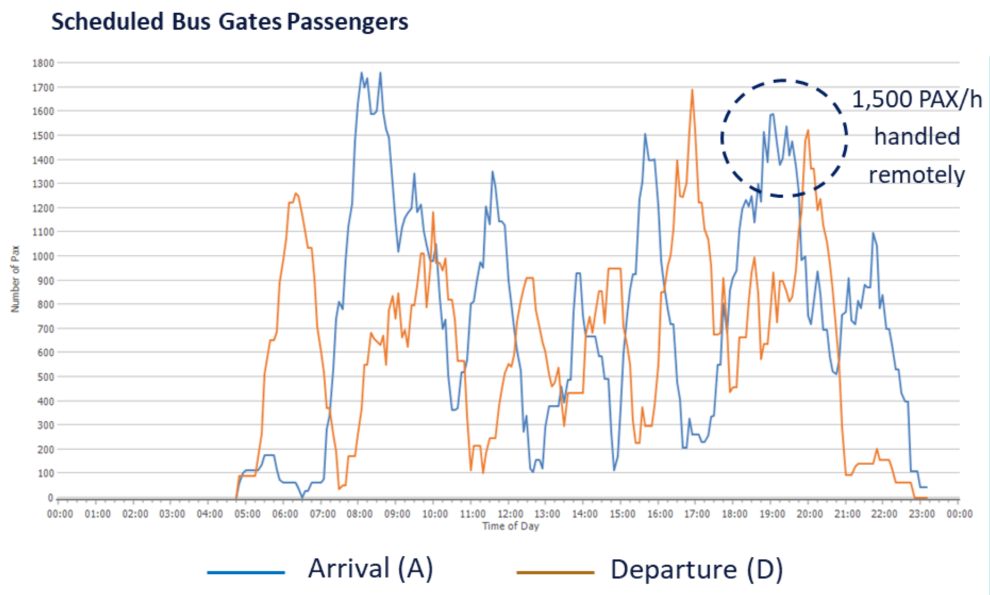


Figure 68: Scheduled Passengers-Example Flight Schedule

2.5.3 Results

In this section, the results of the allocation done with CAST are presented. First, the results regarding the increase in the number of buses needed for the same traffic volume compared to pre-COVID situation are shown, followed by the study of the saturation capacity of an example apron.

2.5.3.1 Bus Requirements during Peak

After performing a sample allocation in CAST, the graphs like the ones below are obtained. Figure 69 represents the comparison between the allocation of the apron buses for pre-COVID (left) and post-COVID (right) case, for a small size apron when physical distance is partly applied (50 passengers per bus considered).

As a result, for the pre-COVID case a maximum of 28 buses are needed for the example apron. For the post-COVID modeled situation, 41 buses are needed for the peak. This means, that 47% more buses would be needed post-COVID for the same traffic.

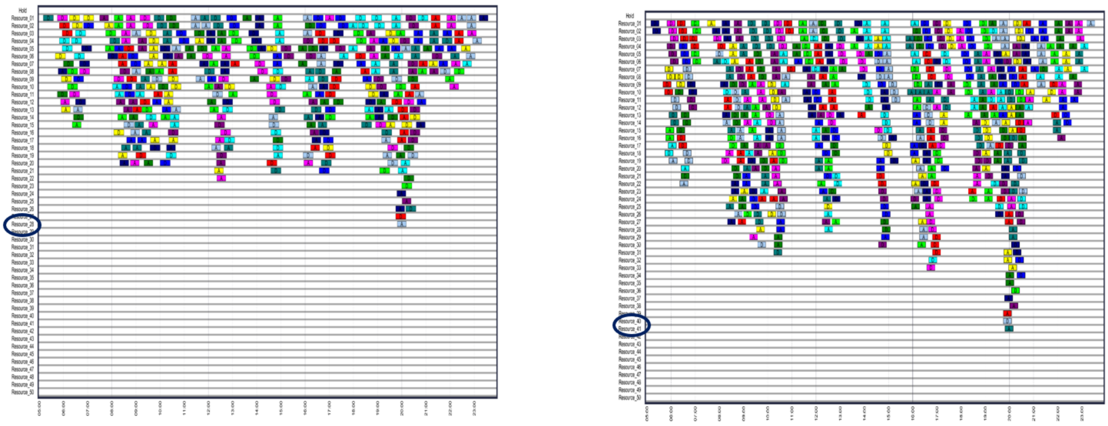


Figure 69: Resulting allocation pre-COVID (left) and post-COVID (right) small apron.

When additional cleaning is considered, the number of required buses in peak increases up to 49, as shown in Figure 70. This results in a 75% increase in the number of buses compared to pre-COVID, for the same traffic volume.

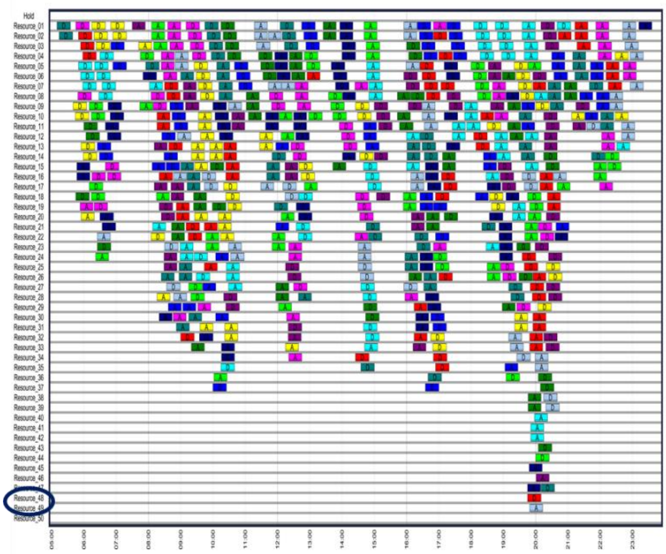


Figure 70: Resulting allocation post-COVID small apron including cleaning

The increase in the number of buses needed for the example flight schedule is also calculated with strict physical distancing rules (one bus for every 25 passengers). A big apron is considered for the bus requirement scenarios as well. On the left side, Table 25 shows the bus usage time considered in every scenario. These times are derived from the bus tour cycles presented above. For a big apron, an additional buffer time of 5 minutes is assumed as stated above.

Scenario		Pre-Covid		Post-Covid		Number of Buses required			Relative Change	
		Bus Usage Time DEP	Bus Usage Time ARR	Bus Usage Time DEP	Bus Usage Time ARR	BASELINE	Trade-Off: 1 Bus every 50 PAX	Strict: 1 Bus every 25 PAX	Trade-Off: 1 Bus every 50 PAX	Strict: 1 Bus every 25 PAX
Small Apron	NO Cleaning	25 min	22 min	20 min	19 min	28	41	70	+47 %	+150%
	Cleaning			25 min	24 min		49	85	+75%	+200%
Big Apron	NO Cleaning	30 min	27 min	25 min	24 min	31	49	85	+58%	+175%
	Cleaning			30 min	29 min		56	95	+80%	+200 %

Table 25: General Results-Scenarios

On the right side of the table, the increase in the number of buses for each scenario compared to pre-COVID is shown. Strict consideration of physical distancing in buses and/or cleaning after each tour leads to an unrealistic increase in buses (+150%). Even with a trade-off in terms of bus capacity, the increase is considerable for pre-COVID traffic. Thus, the flights should be assigned to contact positions as long as it is operationally possible.

2.5.3.2 Saturation Capacity

It is considered unlikely that airports invest in additional buses in the near future. Thus, it is analyzed which traffic volumes can still be handled with the existing number of buses. An example apron and 50 passengers per bus are considered. In the analyzed example situation, 60-75% of the bus gates traffic volume could be handled.

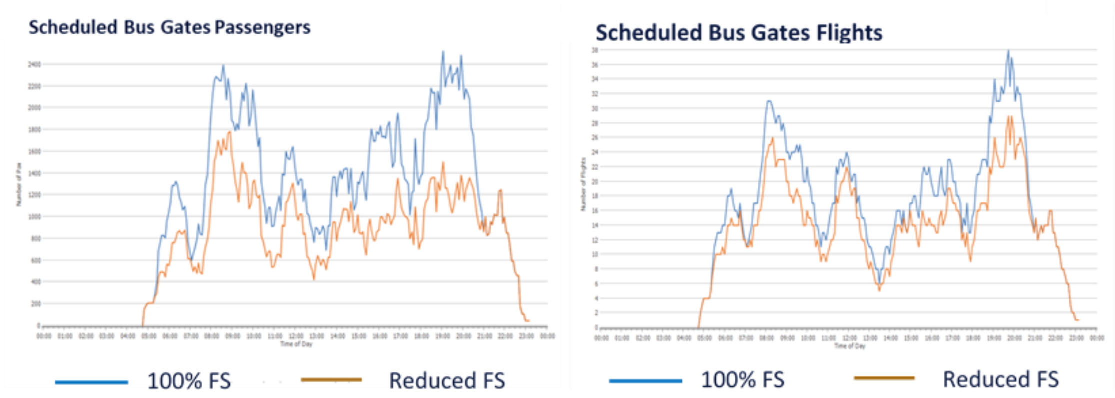


Figure 71: Scheduled Bus Gate Passengers and Flights of 100% and Reduced Flight Schedule

2.5.4 Conclusion

The usage of 1 bus for every 25 passengers would comply with strict physical distancing rules but results in high number of additional busses required (>+150%). This is operationally impossible to implement once traffic starts recovering. Additionally, more buses also include the risk for a prolonged boarding time with potential negative impact on the overall turnaround time.

The usage of 1 bus for every 50 passengers, represents a compromise between health requirements and operational constraints. Between approx. 50% and 80% more buses are needed to operate the pre-COVID traffic with COVID related measures. Saturation capacity of the available resources is around 60-75% for the analyzed example layout.

The introduction of 5 min cleaning between each bus usage cycle results in an additional 20-25% increase in number of buses needed for the example airport.

Due to the considerable increase in the amount of buses compared to pre-COVID, flights should be assigned to contact positions as long as operationally possible.

2.6 Immigration

2.6.1 Introduction

As the speed of the COVID outbreak has probably been increased by air traffic, additional health-related checks of incoming passengers are very likely in the future. Immigration as main government-controlled checkpoint in the passenger flow could play an important role here.

Although harmonised regulations were still pending at the time of the study, it is thinkable that the regular passenger flow through immigration will change, at least as ad-hoc measure before more advanced dedicated checkpoints take over the additionally required tasks of health-related processes.

With the purpose of preparing airports for those potentially occurring changes, this study looked at certain "What-if" scenarios to give decision support for the following questions:

- Should a health certificate check be integrated in an
  - existing immigration or
  - be outsourced at a different location?
- At which traffic levels would an immigration checkpoint be saturated?
- How would it look like if the arrival flow changes
  - for all passengers?
  - for flights from certain risk regions?

At the time of the study, the airport stakeholders described the following key changes compared to Pre-COVID:

1. **Passengers keep a physical distance in queue**

   Similar to other passenger handling checkpoints, airports support keeping physical distance by floor markings in the queuing area. The reduced capacity is described as most challenging for infrastructure without excessive arrival corridors but e.g. with dedicated immigration counters directly at the gate.

2. **Immigration officers need to perform additional tasks**

   In particular when short moment changes do not allow setting up a dedicated physical or IT infrastructure for additional health-related checks, these tasks may be assigned to immigration officers. This can range from asking health-related questions to collecting self-declaration forms or any other local activity. Logically, this would increase the processing time dependent on the complexity of the additional task.

   One noteworthy airport example demonstrates potential side effects of this approach: the necessary quarantine for passengers arriving from risk regions required immigration officers to register these passengers. As consequence, E-Gates were not operational then. Such a major change will mean a significant reduction of handling capacity.

3. **Flight from Schengen risk regions are handled as Non-Schengen**

   At the time of the study the various European countries followed individual classifications of countries respectively regions as risk area. Although most of these risk regions are out of the Schengen zone, even certain regions inside Schengen may be considered as risk area. Typically, passengers arriving from another Schengen country do not need to pass any checkpoint but can immediately proceed to the airport exit. Depending on local regulations, this might change for Schengen risk regions. Depending on infrastructure and operational procedures, this could mean a separate checkpoint or the fact that a Schengen flight is handled as a flight from Non-Schengen.

2.6.2 Scenario Setup

For capacity calculations of the immigration checkpoint typically the following parameters are relevant:

- **Flight schedule peak structure**

  In particular for arrival facilities the detailed peak structure ("peak in peak") can make a difference. A passenger demand well distributed over the peak hour would be easier to handle than a steep short moment peak followed by an idle time. Thus, generic statements about immigration KPIs as waiting time and queue length are difficult.

- **Demand characteristics such as**
  - Passport type

    The type of passport (e.g. EU vs. Non-EU) describes on the one hand the complexity of the check and thus the required processing time and on the other hand if a passenger is eligible to use E-Gates.

  - E-Gate share

    The percentage of passengers eligible and actually willing to use E-Gates depends on the flight type, in particular the origin. While for a typical holiday flight many passengers are probably tourists with local passport (EU), an ethnic flight would have more foreign passport holders (Non-EU).

- **Offered capacity**

  As indicated, one major difference of offered handling facilities between airports is whether the airport offers E-Gates or purely manned counters.

  Another very airport specific parameter is the number of actually available officers.

The simulation analyses for decision support used a generic airport infrastructure and its corresponding Pre-COVID flight schedule as testbed. With the applied flight schedule the available infrastructure is saturated Pre-COVID.

As an example, the following detailed process parameters were used:

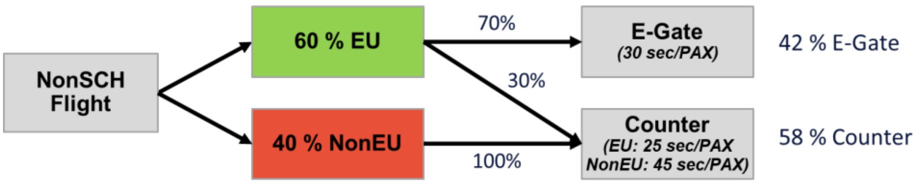


Figure 72: Immigration Process Parameters (Pre-COVID)

In order to consider a worst case scenario with prolonged processing time and no use of E-Gates anymore, this could turn into:

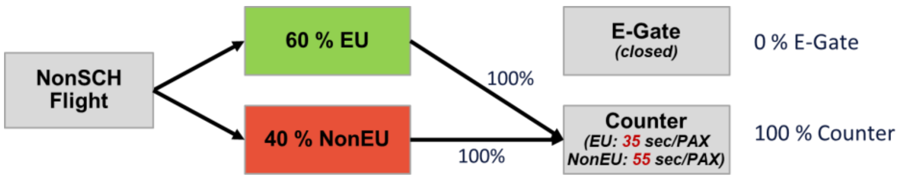


Figure 73: Immigration Process Parameters (Post-COVID)

2.6.3 Results

2.6.3.1 Airport without E-Gates: Impact by Physical Distance in Queues

If physical distance is considered, the queuing capacity can be reduced to half (from 500 to 250 passengers).

Example Airport	Pre-COVID (1m²/Pax)	Post-COVID (2.0m²/Pax)
Counter Capacity	500 Pax	250 Pax

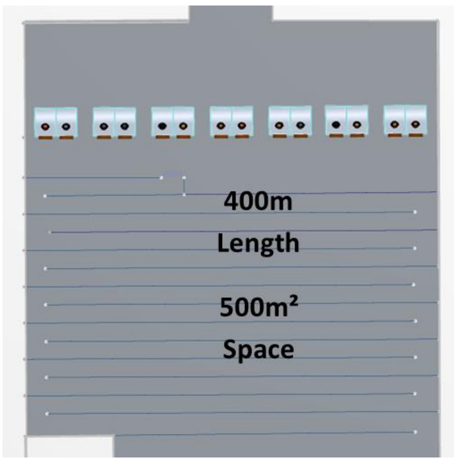


Figure 74: Queue Capacity Reduction at Immigration

Assuming that the immigration counter processing time has slightly increased (+10 sec for additional checks) a new saturation capacity would be in the range of 70% of Non-Schengen passengers (see Table 26). Similar to other processors, this threshold would be space driven; time is less critical. For an airport with sufficient overflow space this would mean that the saturation capacity is higher.

Note that this statement refers to the Non-Schengen traffic only. As the Schengen / Non-Schengen mix is very airport and even peak specific, no general statement is possible for the overall flight schedule saturation limit.

	Non E-Gate Airport	
Example Airport	Pre-COVID	Post-COVID
100 % Non-Schengen Traffic	500 PAX 20 min	640 PAX 32 min
75% Non-Schengen Traffic	-	380 PAX 19 min
70% Non-Schengen Traffic		270 PAX 14 min
50% Non-Schengen Traffic	-	140 PAX 7 min

Table 26: Immigration Saturation Capacity Assessment (Counters only)

2.6.3.2 Airport with E-Gates: Scenario with Mandatory Agent Immigration

In a situation that immigration officers need to perform any health-related checks (+10 sec processing time as mentioned above), the situation gets problematic for airports, which heavily used E-Gates before.

Example Airport	Pre-COVID	Post-COVID
E-Gate Capacity	8x 120 PAX/h = 960 PAX/h	Closed
Counter Capacity	10x 93 PAX/h =930 PAX/h	10x 84 PAX/h =840 PAX/h
Total Capacity	approx. 1,900 PAX/h	840 PAX/h

Table 27: Immigration Throughput Capacity Reduction (with E-Gates)

Loosing such a high amount of throughput capacity (-55% as in Table 27) can easily cause problematic situations (see Figure 75).

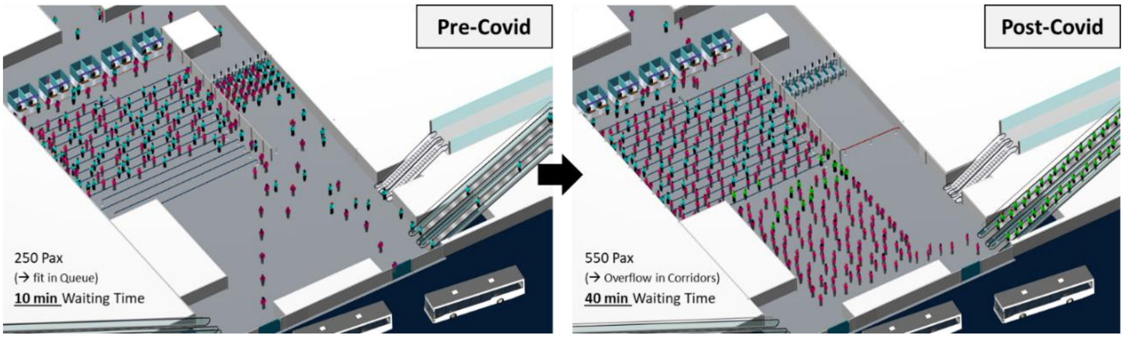


Figure 75: Visualisation of Situation at Immigration without E-Gates (Same Peak Hour)

When manned counters only represent e.g. half of the former throughput capacity, due to more space consumption with physical distance only 40-50% of the Non-Schengen peak traffic could still be accommodated in queues now, depending if E-Gate queue space is considered or not (see Figure 76).

Example Airport	Pre-COVID ($1m^2$/PAX)	Post-COVID ($2.0m^2$/PAX)
E-Gate Capacity	96 PAX	48 PAX
Counter Capacity	360 PAX	180 PAX
Total Capacity	approx. 450 PAX	225 PAX

- 50%!

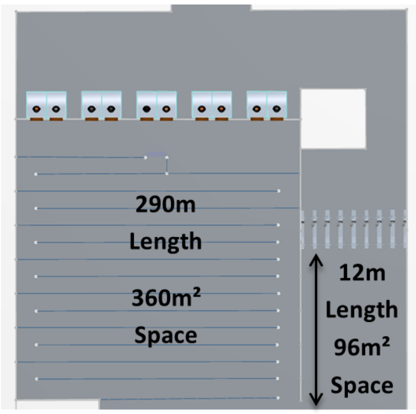


Figure 76: Queue Capacity Reduction at Immigration (with E-Gates)

This is a result of the two influences arising together: less queue capacity and throughput. Thus, a calculation of saturation capacity would result in very low numbers.

E-Gate Airport		
	Pre-COVID	Post-COVID
100 % Non-Schengen Traffic	340 PAX 16 min	650 PAX 45 min
75% Non-Schengen Traffic	-	450 PAX 30 min
50% Non-Schengen Traffic	-	240 PAX 15 min
40% Non-Schengen Traffic	-	180 PAX 13 min

Table 28: Immigration Saturation Capacity Assessment (with E-Gates)

2.6.3.3 Potential Passenger Flow Change

The arrival of flights from risks regions involves the risk that these flights will require a special control. This leads to a negative change of the process chain for such a risk flight, e.g. when this additional check is done by immigration officers or the airport's infrastructure forces a mixing of these Schengen with other Non-Schengen passengers. Potential issues when mixing with regular Non-Schengen passengers are:

- All must be considered "unclean"
- All will require full immigration check
- Transfer passengers will need more time (MCT increases)

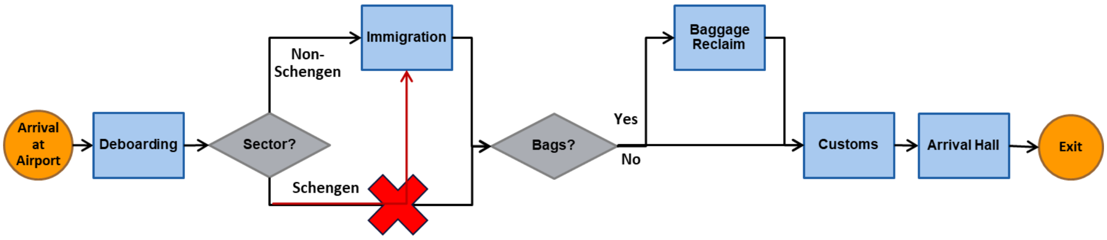


Figure 77: Process Flow for Arrival from Schengen Risk Region

The question of how much such a swap of flight(s) from Schengen handling to Non-Schengen influences the Level of Service at immigration cannot be answered in general. Naturally it depends on the amount of flights, for which such a swap happens, and the time (during peak or off-peak).

Current observations during the time of study indicate that the risk in this context is rather low because of the following trends:

- The number of "real" Non-Schengen flights is rather low, because recovery is slower than expected and thus immigration offers capacity anyway
- Additional health checks develop in a way that they are organised in a more structured way, which means separate checkpoints. In case of time-consuming tests, they even move landside.
- At many airports, the flight schedule structure is in a way that Schengen and Non-Schengen peaks happen at different times. If this is the case, a Schengen flight being handled as Non-Schengen would be less critical. Only in the few times of simultaneous peaks, the risk for a bad Level of Service is intensified.

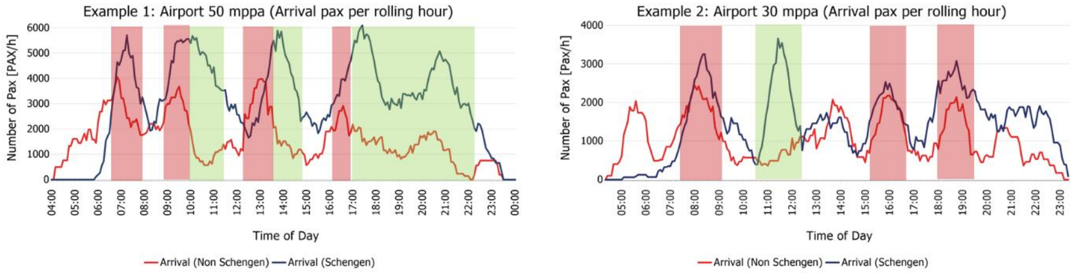


Figure 78: Flight Schedule Analysis to detect simultaneous SCH/Non-SCH Peaks

2.6.4 Conclusion

At many airports, immigration is a checkpoint, which operated close to capacity in Pre-COVID times already. Thus, COVID measures have the potential to affect this very sensitive checkpoint to a high degree.

In consequence any measures, which lower the throughput capacity of immigration should be carefully reviewed if there is no other option for the same benefit. As an example, health self-declaration forms could be checked at a separate checkpoint or by floorwalkers while passengers are queuing at immigration. In particular any action, which leads to the inability to still use E-Gates should be avoided. When this is considered, COVID impacts are limited to space restriction caused by physical distance in queues.

The immigration checkpoint takes advantage out of the fact that the Non-Schengen traffic recovery is slower. Thus, the calculated saturation capacities, which refer to the Non-Schengen traffic only, will mean a much less saturation level for the entire airport's traffic.

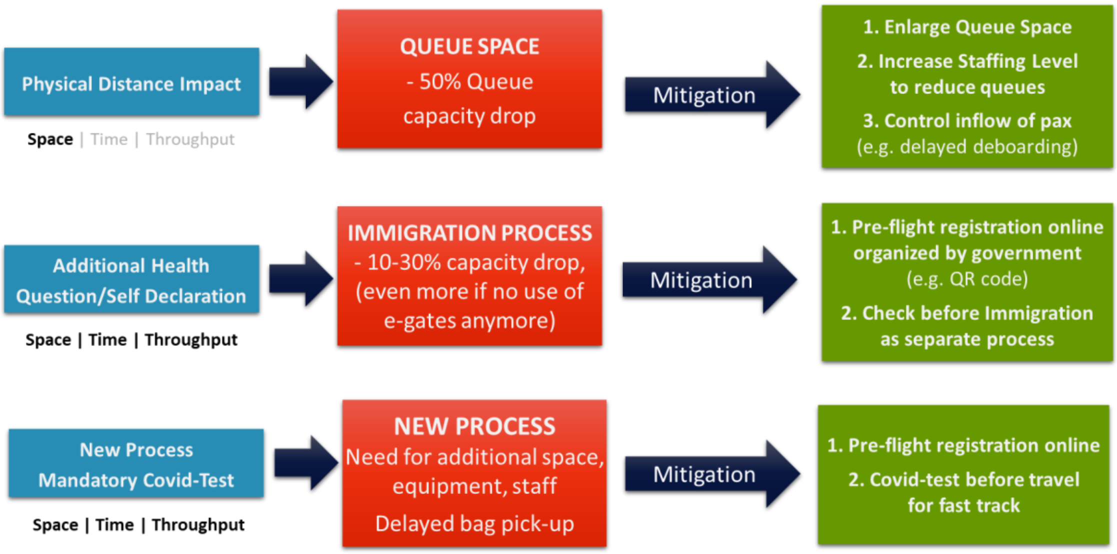


Figure 79: Mitigation Measures for Immigration

2.7 Baggage Reclaim

2.7.1 Introduction

Before the COVID outbreak, a typical situation at a baggage reclaim belt was characterized by dozen of waiting passengers from same flight standing side by side and often pushing into each other while picking up their bags as soon as the bags were identified on the reclaim belt. In times of COVID, suddenly this situation is considered as "critical" and should be avoided by all means which brings new challenges coping with the process of baggage reclaim.

In order to support airports in this task, this study aims to give guidance on the following topics:

- What does physical distancing mean for a baggage reclaim hall?
- Which mitigation measures are thinkable regarding?
  - Head start for luggage
  - Allocation of belts
  - Optimisation of pick-up layout

The interviews with airport stakeholders showed that the situation in baggage reclaim halls changes since COVID outbreak and new challenges arise:

1. **Space requirement of baggage reclaim hall are changing**

   Due to physical distance rules, passengers keep more distance to each other and therefore change the space requirement around a belt.

2. **Passengers violate physical distance while claiming their bags**

   Since there are always multiple passengers simultaneously involved in the baggage reclaim process, adhering to the physical distance rules is not always possible and unfavorable cross flow situations occur.

2.7.2 Scenario Setup

As scenario setup, different belt sizes are used for general capacity calculations. Since the procedure at single reclaim belt is similar as with other belts with comparable size, observations and findings retrieved from microscopic views are applicable on other situations. Therefore, instead of simulating a whole baggage reclaim hall, the approach is to rather look into detailed bag handling of single flights. In addition, general findings from interviews and research are discussed in the course of this topic.

2.7.3 Results

In the following, different challenges and possible mitigations for baggage reclaim processes are discussed. The first section is covering the changing space requirements of passengers in times of COVID. The following section then describes new requirement on existing belt allocation rules in order to cope with the situation. The last section covers the increased importance whether it is the bags or the passengers who are arriving first at a baggage belt and how this could be influenced.

2.7.3.1 Changing Space Requirements due to COVID

Before the COVID outbreak, passengers were used to wait quite narrow to each other at a baggage belt. In addition, they were also used to briefly enter the personal space of other waiting passengers while picking up their bags. According to IATA Level of Service Standards (ADRM 11. Edition), which are often used as basis for calculating and assessing belt waiting zones, the typical space consumption of a passenger waiting at a baggage reclaim belt is indicated with 1.6m². In addition, it is expected that all waiting passengers of an arriving flight with checked baggage to pick up shall fit into a waiting zone of 3.5m around the belt.

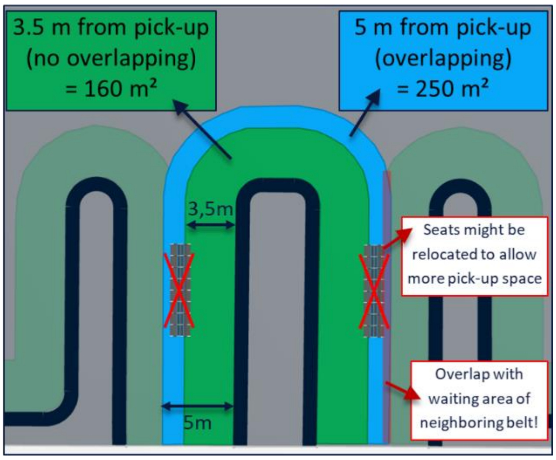


Figure 80: Illustration of Waiting Space around Belts

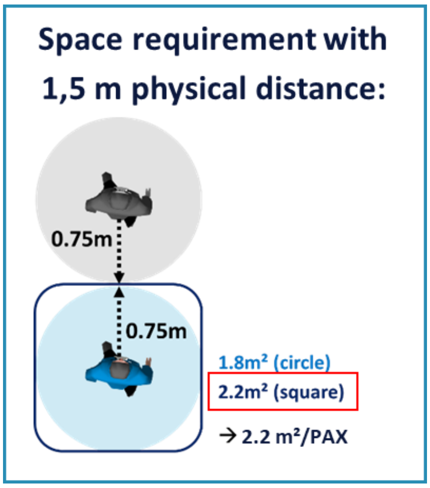


Figure 81: Physical Distance Requirements

In times of COVID, depending on physical distance requirements, passengers are now consuming more space than before. Differently from queue situations at security or immigration, passengers are not queuing in rows, but rather side by side and also often pass each other during baggage pick-up processes. In order to take that into account and guarantee the compliance of 1.5m minimum distance, each passenger would require a space of 2.2m² each while waiting at the reclaim belt. Dependent on physical distance rule that would mean a waiting area capacity drop of -25% (1.5m physical distance) or even -50% (3.5m physical distance).

Table 29 shows the number of passengers that would fit into the waiting area around the belt. In a pre-COVID situation a medium sized belt with 160m² waiting space could accommodate 100 passengers. With a physical distance of 1.5m now only 75 passengers are fitting into the same space. However, if feasible, it is recommended to expand the waiting area around the belt (e.g. 5 instead of 3m) in order to maximize the space usage and accommodate all waiting passengers again.

Belt Size	Waiting Space	Physical Distance Rule		
		1m	1.5m	2m
		1.6m²/PAX (=IATA Standard)	2.2m²/PAX	3.5m²/PAX
Small (30m belt length)	110m² (↔ 3,5m)	70 Pax	50 Pax	30 Pax
	175m² (↔ 5m)	-	80 Pax	50 Pax
Medium (50m belt length)	160m² (↔ 3,5m)	100 Pax	75 Pax	45 Pax
	250m² (↔ 5m)	-	115 Pax	70 Pax
Large (100m belt length)	300m² (↔ 3,5m)	190 Pax	135 Pax	85 Pax
	430m² (↔ 5m)	-	195 Pax	120 Pax

Table 29: Evaluation of Belt Waiting Space

However, the enlargement of queue space area around a belt brings new challenges. Eventually, obstacles around the belt (seating units, trolley pick-up machines, ticket booths, commercial displays etc.) need to be shifted or removed from the area. In case of neighboring belts, it is possible that the expanded waiting area overlaps with the waiting area of the adjacent belt. In this case, simultaneous allocations might lead to critical situations where passengers of different flights are mixing. Figure 82 shows a situation where in a pre-COVID situation waiting passengers of a narrowbody flight fit into the waiting area of 3.5 m around the belt (left picture). However, due to physical distance of 1.5m, an enlargement of the required waiting space around all belts was required in order to accommodate all the same number of waiting passengers. Due to the increased space consumption, passengers are now standing in the waiting zones of other neighboring allocated belts (right picture).

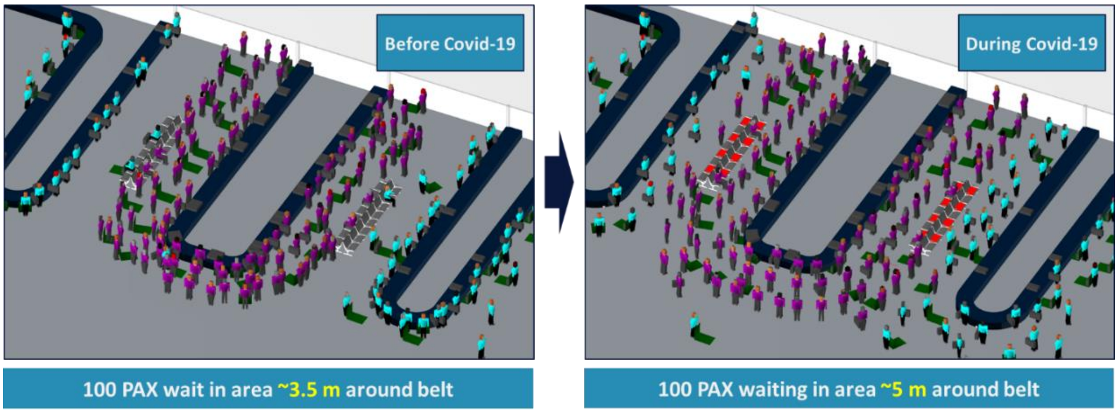


Figure 82: Illustration of Space Consumption around Baggage Belts

2.7.3.2 Changing Requirements on Baggage Belt Allocation Rules

This brings up a requirement to loosen up historic belt allocation rules (e.g. assigning certain airlines to specific belts) in order to avoid critical situations in times of COVID:

1. Leaving gaps of empty belts between simultaneously arriving flights
2. Allocate big belts also to narrowbody flights help to gain additional space for waiting passenger

Figure 83 shows a situation where every second belt is kept free and mainly large belts with bigger waiting space are allocated to flights. Since passengers still overspill from the initial waiting zone of 3.5m around each belt (yellow area), undertaking simultaneous allocations to the smaller belts would toggle critical situations.

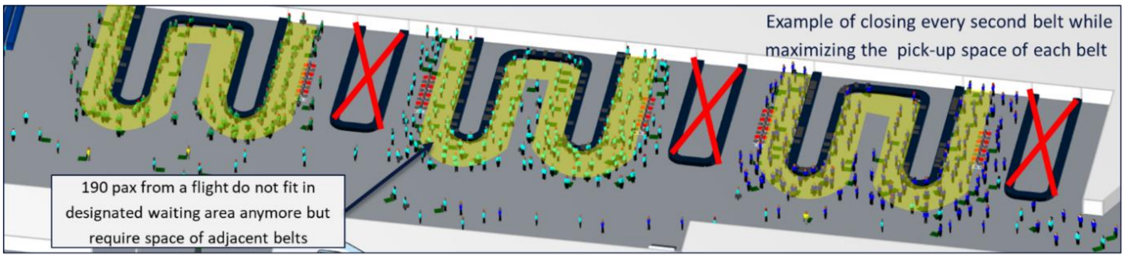


Figure 83: Example of Baggage Allocation with Gaps of empty Belts

However, this kind of interferences in allocation are only feasible as long as the traffic volume allows. In order to make the best use of available belt pick-up space, further actions are recommended. Instead of just increasing the waiting area around the belt, also secondary waiting areas for passengers not fitting into the primary area could help to accommodate waiting passengers for a limited time. Also, passengers travelling in groups should be motivated to send only selected person to pick up bags at the belt in order to relieve the primary waiting areas around the belt.

In addition, passengers should be encouraged to leave the baggage reclaim area as soon as they picked up their luggage and also not repacking bags close to the belt. This can be achieved by additional staff or information boards around the belt. As mentioned before, disturbing objects in the baggage reclaim hall should be rearranged or removed in order to gain more space. Especially ticket booths (e.g. tickets for public transport) should be moved to less critical areas or even removed from baggage reclaim hall, since they are likely to produce short-time queues.

Picking up baggage could be optimized using a circulation concept minimising the risk of exposure to other passengers as well as reduce dwelling of passengers in close proximity around the reclaim carousel. The situation in Figure 84 shows a situation where bags arrive earlier than passengers (triggered by immigration or possible health check). The early arrival of bags could also be actively controlled by optimizing the delivery itself or by delaying passengers. In this kind of situations, it should be prevented that the belt runs full, since that would cause more passengers waiting around the belt as soon as they arrive and the bag is not ready for picking up yet.

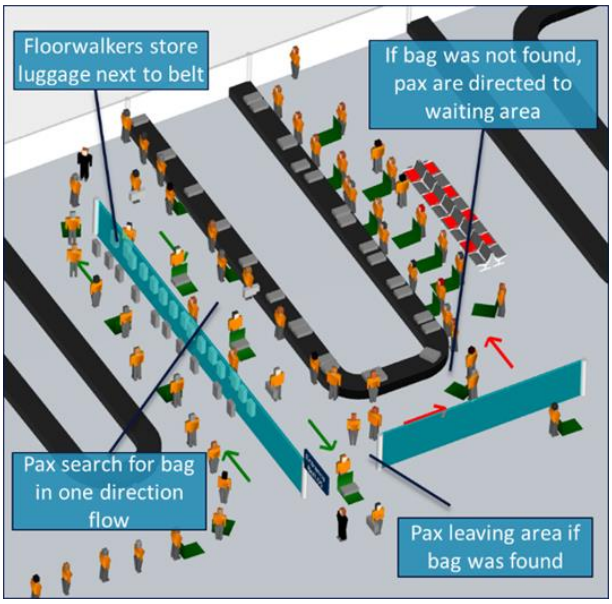


Figure 84: Circulation Concept for Bag Pick-Up

Therefore, floor walkers have already picked up bags from the belt and arranged them in walking direction of the controlled flow enabling easy pick up. This allows that passengers can immediately leave the area and do not have to wait further until they can locate reach bag on the carousel. In case that the passenger could not retrieve their bag right away, he will be actively guided to a waiting zone where he can wait for its bag to appear on the carousel.

2.7.3.3 Importance of Bag and Passenger Arrival Time at the Reclaim Belt

In case that the mentioned mitigations in the baggage reclaim hall are not feasible or insufficient, another possibility to ease the situation in the baggage reclaim hall could be to intervene earlier in the process, for example while affecting the deboarding process.

Figure 85 shows a Gantt chart of typical handling of Schengen as well as Non-Schengen flights. Since the process of unloading bags from the aircraft and bringing them to the allocated belt is the same for a Schengen and a Non-Schengen flight, the time of the first bag on the belt is similar for both. However, the time of the first passenger at the belt is different depending on the Schengen status. Since Non-Schengen flights usually require an immigration check, passengers are delayed and arrive later in the baggage reclaim hall than passengers from Schengen origins without further delay than the pure walking distance. Therefore, it is likely that passengers of Schengen flights arrive earlier at the belt than their bags. However, in times of COVID this is not desirable since accumulations of passengers around the belt are occurring and increase the risk of exposure. These situations are rather unlikely for arriving Non-Schengen flights. Furthermore, delay time for Non-Schengen flights could even extend due to possible PCR tests or health questions at immigration. Regarding passenger accumulation at belts, the handling of Non-Schengen flights is therefore considered as less critical.

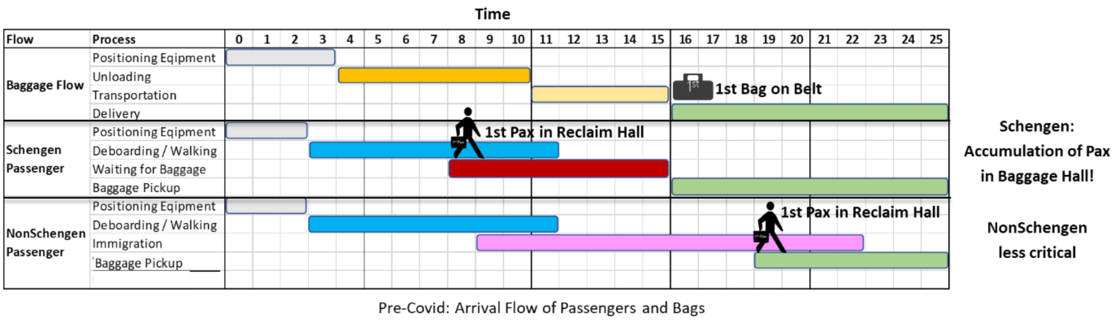


Figure 85: Pre-COVID Arrival Flow of Passengers and Bags

Figure 86 shows an evaluation of a sample airport. Passengers from Schengen flights (indicated by red points) usually arrive earlier than their bags at the belt and wait up to 10 min until the first bag is appearing on the belt. In contrast, passengers from Non-Schengen origins (green points) normally show-up later at the belt and therefore have the chance to pick up bags immediately without further gathering in waiting areas around the belt.

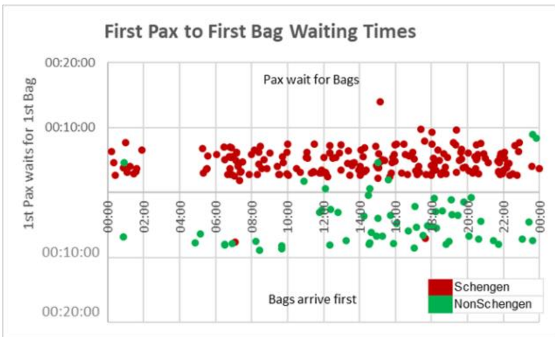


Figure 86: Analysis of Passenger and Bag Show-Up Times

As mentioned before, in times of COVID it is desirable that baggage is delivered before the passengers show up at the reclaim belt. This allows fast pick up from the belt and reduces accumulations of passengers around the belt. This can either be achieved through optimizing the bag delivery process or alternatively through delay of the deboarding process by letting passengers exit the aircraft later than usual. The waiting time passengers did spend directly at the belt before would now be shifted to the aircraft cabin. However, this also brings disadvantages, like possible prolonging of turnaround times and lack of understanding of passengers.

Figure 87 shows the principle of head start for luggage in the Gantt chart. Unlike before, holding passengers in the cabin after landing allows bags to be unloaded on the belt first. The duration of delay strongly depends on airport specific parameters, like baggage delivery times or walking distance and should be evaluated specifically.

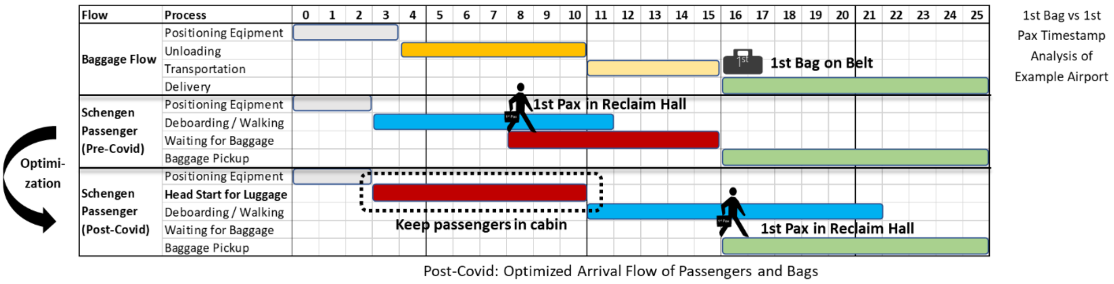


Figure 87: Optimized Arrival Flow of Passengers and Bags

2.7.4 Conclusion

The potential COVID related issues at baggage reclaim hall can be addressed by the following mitigations:

1. **Optimize waiting space**

   Maximize waiting space around belts and/or establish secondary waiting areas for passengers while also removing potential obstacles in close proximity to belts.

   Motivate passengers travelling in groups to send selected person to pick up bags at the belt and encouraged passengers to leave the baggage reclaim area as soon as bags are picked up.

   Introduce circulation concepts with the goal of minimising the risk of exposure as well as reduced dwelling of passengers around the reclaim carousel.

2. **Revise baggage belt allocation**

   As long as feasible with regard to traffic volume, leave gaps of empty belts between simultaneously arriving flights.

   Allocate big belts also to narrowbody flights help to maximize waiting space.

3. **Ensure that baggage is delivered earlier before passengers arrive at belt**

   This issue is related to Schengen rather than Non-Schengen flights, since passengers on Schengen flight usually appear early at the belt without further process in between.

   Allow head start for luggage either through optimized bag delivery processes or deboarding delay.

Figure 88 summarises the challenges as well as recommended mitigation measures for baggage reclaim process:

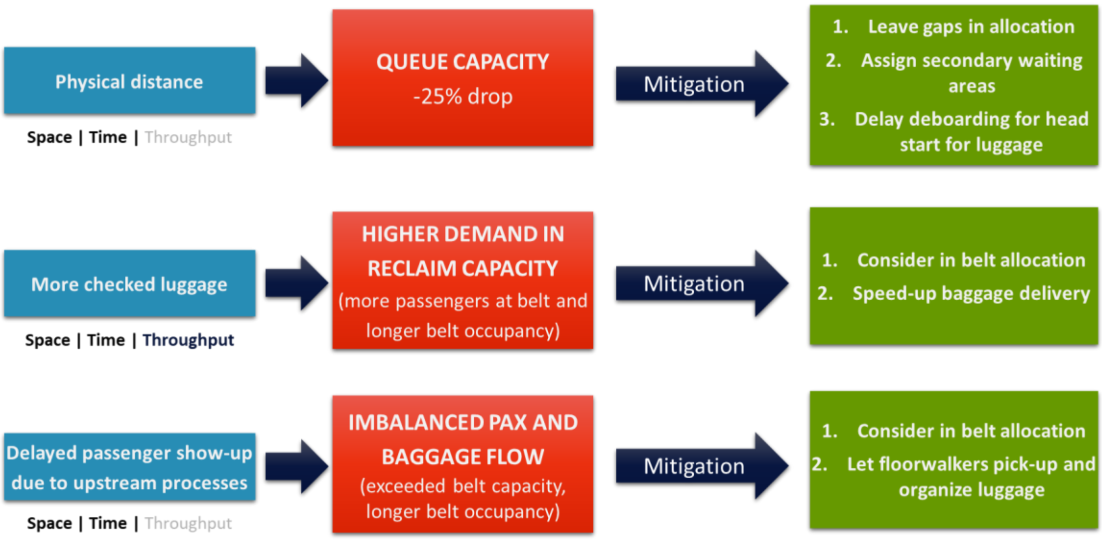


Figure 88: Mitigation Measures for Baggage Reclaim Belt

2.8 Transfer Passenger Handling

2.8.1 Introduction

Although passengers may prefer direct flights against connecting flights even more than before COVID (since that means less exposure for the passenger on its journey) and the recovery of long-haul flights takes longer, transfer numbers will raise again. During the recovery phase, it may even be the case that direct flights between two cities have not been reinstated yet, so that a connecting flight is required now.

The already described quickly changing regulations and uncertainty regarding health checks also affects transfer passenger handling. In the last decades, Europe has put lots of effort to offer a seamless transfer experience to passengers, e.g. one-stop-security or no need for passport control within the Schengen region. At many airports this allowed very efficient minimum connecting times, e.g. by immediately letting passenger disembark into the departure gate area.

In case this process needs to change, these efficient minimum connecting times are put at risk. Because of the lack of fixed rules about transfer passenger handling, at the time of the study no comprehensive calculation of new connecting time was possible. Also, the stakeholder airports reported less experience with transfer processes so far.

At this point in time it is unclear if any health checks or even tests will be introduced as mandatory and if transfer passengers will be handled at the transfer airport and/or at the final destination.

Anyway, all airports expressed big interest in the question of how the minimum connecting time might change and what this could mean for the airport. This study shall summarise potential operational scenarios and discuss them in a general way. Once regulations are clearer, it should be backed up with more analytical calculations and in the airport specific follow-up studies should also consider the actual infrastructure and typical delays at existing checkpoints.

2.8.2 Scenario Setup and Results

Inside the Schengen region there are generally four transfer types, for which many airports have assigned different Minimum Connecting Times (MCT):

- Schengen to Schengen
- Non-Schengen to Schengen
- Schengen to Non-Schengen
- Non-Schengen to Non-Schengen

Two cases shall be described here, as additional checks are either more likely here or a change of the process flow would have highest impact. These cases of interest are:

- Transfers from Non-Schengen origins
- Schengen to Schengen connections

2.8.2.1 Transfer from Non-Schengen Origins

In many cases, COVID risk regions are countries outside the Schengen area. This means, that the likelihood of health checks for Non-Schengen origins is relatively high. The previous chapters have shown that immigration is a sensitive process anyway and might be deteriorated even further, in case health checks are implemented / staffed in an insufficient way.

If there is a need of integrating a health-related process that shall also be mandatory for transfer passengers (asking health questions, requests PLC/forms, scan a QR code, or conduct any test), it would likely need to be carefully integrated in the area of the transfer security process (before or after the checkpoint), as this is a checkpoint, all passengers need to pass and it would minimise walking distanced to this health checkpoint.

Depending on the complexity of the process, an estimation for an adequate waiting and processing time would need to be added and prolonged the connecting time accordingly.

However, the MCTs from Non-Schengen already include buffer for waiting time at immigration and therefore are longer than Schengen-Schengen. In addition, Non-Schengen traffic volumes are currently low, so the airport should have the chance to keep waiting times low by suitable staff provision or offer a fast track for transfer passengers. Thus, any reasonable additional time might be easier to compensate here but an airport specific assessment is required still.

2.8.2.2 Schengen to Schengen Transfer

Without any necessary check Pre-COVID, the Schengen to Schengen transfer flow is the most efficient. In consequence, many airports have reduced their minimum connecting time to e.g. 40 minutes; basically, a result from de/boarding and walking time.

Note: depending on the specific size and layout of an airport walking time certainly can be longer than assumed in the following example.

Figure 89: Schengen to Schengen Transfer Flow (Pre-COVID)

Under the impact of COVID related limitations, this simple flow could not be possible for all Schengen origins anymore. It is thinkable that passengers would need to pass a health checkpoint. The waiting and transaction time of this checkpoint would apply for all passengers of the corresponding flight. Assuming that this checkpoint is properly organised and the desired waiting time leans on the IATA recommendations for waiting time, maybe 10 minutes have to be added.

Next to this main driver for a prolonged connecting time, there are two further factors:

- Due to physical distancing deboarding might take a little bit longer. The further a passenger sits in the back of the aircraft, the more he will be affected by this, because he needs to wait until all passengers in front of him exit the aircraft which costs time.

Though, in special cases also deboarding of the entire flight may be delayed for a couple of minutes to allow more time for luggage delivery. Anyway, it is not expected that this should take much more than 5 minutes.

- Passengers from a Schengen risk flight should not be allowed to immediately enter the Schengen departure gates. This could mean that such a flight has to be allocated to another part of the terminal. Alternatively, a bus transport may be necessary instead of simple usage of the boarding bridge. These risks are factored in by another 5 minutes supplement on MCT.

In summary, this would result in a new minimum connecting time of 60 min; which is 20 min more compared to Pre-COVID for the analyzed example.

Figure 90: Potential Schengen to Schengen Transfer Flow (Post-COVID)

Depending on what the terminal layout allows and how transfer flows are organised, the MCT increase may even be worse. The following worst case example describes some options, which should be avoided.

This example assumes that the airport does not operate a dedicated process for Schengen arrivals but it handles Schengen risk origins as if they were Non-Schengen. This includes the usage of the immigration checkpoint of Non-Schengen passengers and the potential risk of mixing with unclean passengers. The latter fact would require an additional security check.

When a health check is integrated into the regular immigration process, this would mean that Schengen passengers also undergo the regular immigration procedure, although this would not be necessary. It has to be expected that such a combined immigration/health checkpoint takes longer, in particular when it is already used by other Non-Schengen flights. Being rather optimistic, 15 min additional processing and waiting time are assumed.

One negative side-effect of this approach is that mixing of the risk flight with unclean passengers will mean an additional transfer security control, adding e.g. further 10 min.

In this worst case example, the overall connecting time requirement would add up to 75 min, which means a significant increase compared to the original 40 min.

Figure 91: Worst Case Example for Schengen to Schengen Transfer Flow (Post-COVID)

2.8.2.3 Affected Passengers

The previous food for thought has demonstrated that COVID measures have the potential to increase a minimum connecting time from e.g. 40 minutes to 60 minutes and even beyond if the new transfer flow cannot be limited to the actually needed processes but adds further checks because of mixing with other passenger groups.

Once an airport knows, how the minimum connecting time will increase, the next step is the analysis, if and how many passengers will be affected by this. Depending on this amount, several decisions are possible: a fast track for quick connections, in case the delay can be reduced by additional manpower or, if the high number of transfers justifies it, a dedicated health checkpoint for (Schengen) transfers.

In order to demonstrate such an analysis, ARC has evaluated the connecting time distributions of two major European hubs. In these examples, 30-40% of Schengen to Schengen connections are below 60 min respectively 45-55% below 75 min and would be affected by the described increase of minimum connecting time.

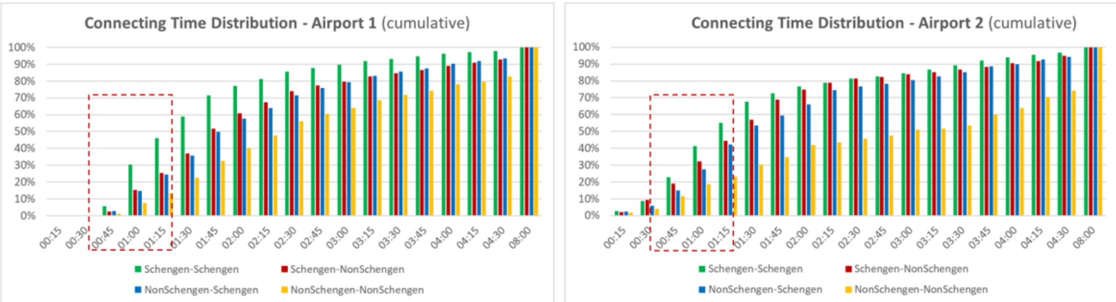


Figure 92: Connecting Time Distribution (2 European Example Airports)

2.8.3 Conclusion

Transfer passengers – much more than terminating passengers – rely on fast handling. Otherwise, the minimum connecting time would increase, which means a disadvantage for airlines and finally the airport itself.

Although no clear regulations have been submitted yet and transfer connections were rather low at the time of study, the transfer flow can be described as one risk factor for new COVID regulations. Once any additional check of transfer passengers is required, this will very likely mean an increase of minimum connecting time. The likelihood of such requirements is currently highest for arrivals from Non-Schengen origins. However, the highest impact could happen for Schengen to Schengen transfers.

Even when the additional check is organised in an efficient way, a connecting time increased by 20 min would affect many passengers (e.g. 1/3 at analyzed example airports). In a bad case (assuming +35 min) half of the Schengen to Schengen passengers could be affected.

This means, airports with many short connections should put all effort in ensuring fast handling as good as possible. This includes adequate staffing of relevant checkpoints but also smart passenger flows, which avoid unnecessary mixing with unclean passengers and thus the need for further “needless” checks (e.g. security check for passengers of clean country).

Figure 93: Mitigation Measures for Transfer Flows

3 Aircraft Turnaround

3.1.1 Introduction

Next to the described terminal processes, the aircraft turnaround has the potential to be affected by the COVID related measures as well.

In the operational guidelines jointly issued by the European Union Aviation Safety Agency (EASA) and the European Centre for Disease Prevention and Control (ECDC), boarding procedures that limit the contact risk between the passengers are recommended. Among these are boarding by rows starting with the furthest row from the aircraft door (Back-to-Front boarding) or alternatively, passenger boarding following the sequence: window seats, middle seats and aisle seats ("WILMA"). In addition, a possible delay of the deboarding process due to the compliance with physical distancing rules can be expected.

Special attention must also be paid in the aircraft cleaning process between two flights. In the beginning of the COVID outbreak airlines experimented with various technologies for sanitizing and disinfection (e.g. spraying or UV radiation). While the objective of some measures was certainly to get passengers' trust back, it is still under discussion how an effective cabin cleaning could look like in the future and if certain actions shall become mandatory.

All these factors, in addition to potential further issues may have an influence on the overall aircraft turnaround time. This chapter shall answer the following questions:

- What is the critical path in the aircraft turnaround?
- Which COVID measures could increase the aircraft turnaround time?
- What is the minimum time requirement for a turnaround after COVID?
- How can the critical path be optimized?

During the study, the airport stakeholders provided valuable information regarding the changes of turnaround related processes compared to pre-COVID:

1. **Limitation of carry-on luggage**

   Many airlines have reduced the allowed amount of carry-on luggage on board with the argumentation that this will decrease the interaction between passengers in the aisle, and therefore reduce the risk of infection. In addition, this measure leads to a faster de/boarding and can therefore (partly) compensate potential COVID-related delays.

2. **Change of boarding procedure to Back-to-Front by some airlines**

   Some airlines changed their boarding procedure to Back-to-Front as recommended by EASA (EASA/ECDC, 2020), in order to diminish the number of person-to-person interactions during the boarding. One major European airline, that implemented the mentioned change in procedure in addition to strict physical distancing rules inside the aircraft cabin, communicated a noticeable increase in boarding time compared to pre-COVID. Even airlines, who have not observed an increase in boarding time due to currently low load factors and hand luggage numbers, expect higher boarding times, when load factors get high and luggage is allowed on board again.

One airline, applying the WILMA principle gave positive feedback without concern about a significant delay.

Other airlines, however, did not implement any changes to the boarding procedures and continue random boarding.

3. **Discussion about delayed deboarding**

   With the objective of eliminating congestion in the baggage reclaim hall, the concept of a general delay of the deboarding start allows luggage to be delivered first, before passengers access the reclaim hall. This prevents that passengers would accumulate around the reclaim belt while waiting for their luggage. Though, at the interviewed airports, no active process has been implemented yet. The reason for that is that current low traffic allowed physical distancing at reclaim belts anyway. However, when higher load factors possibly lead to situations where the occupancy of baggage reclaim halls will get to a level that does not support the enlarged physical distance rules at airports in future, a delay of deboarding may become relevant and might be implemented then.

   It was noted as well, that decreased carry-on luggage and physical distancing rules (slowed down deboarding) may play a role in the deboarding time.

4. **Aircraft disinfection**

   A more intense cleaning and disinfection of aircraft is recommended. However, current observations show that airlines do implement the recommendations differently. Some include a short disinfection with the focus on frequent touchpoints during each turnaround and others do a more intense cleaning once a day during longer ground times.

5. **Increase in the overall turnaround time/ground times**

   At the beginning of the project, all the partners showed themselves very concerned about the increase in the aircraft ground time. Observations were made that some European airlines added between 20-30 minutes to their ground times, but the exact factor that influenced that increase was not known. It was discussed that this increase will make it impossible to meet the airport slot once traffic rises. Therefore, the reasons behind the increases should be investigated.

3.1.2 Scenario Setup

In order to obtain answers to the above-mentioned questions, the following methodology is applied. On the one hand, a passenger centric approach is adopted and the passenger handling processes at interface to aircraft are analyzed and simulated. On the other hand, an aircraft centric approach is adopted, which includes an analysis of a turnaround ground handling scheme and stand occupancy data analysis of a major European hub airport.

3.1.2.1 Critical Path Analysis of Ground Handling

In the Figure below, a typical ground handling scheme of a narrowbody aircraft of an European flight with an average load factor is represented. Such a narrowbody aircraft is considered most relevant in this study because of the following reasons:

- Narrowbody aircraft represent the majority of Europe's traffic
- In the upcoming COVID recovery phase the percentage of widebody aircraft will even be lower
- The ground time for narrowbody aircraft is often tighter compared to widebodies

The turnaround time of the example aircraft is approx. 40 minutes.

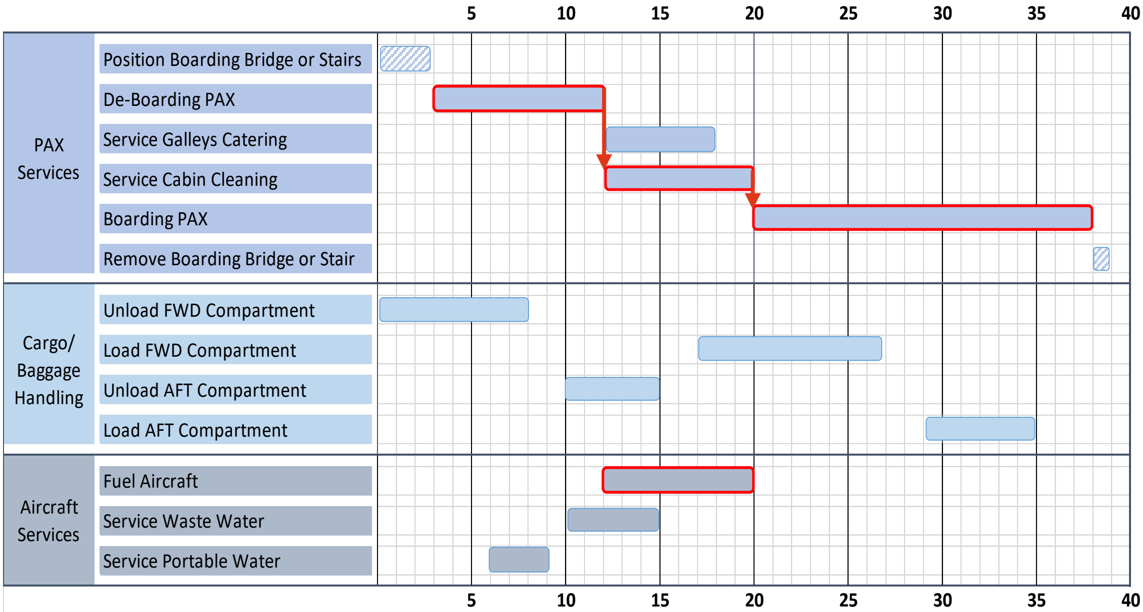


Figure 94: Example Ground Handling Scheme for a narrowbody aircraft pre-COVID

The critical path processes in ground handling of this example are marked in red. These include:

- Deboarding
- Boarding
- Cabin cleaning
- Aircraft fueling (eventually)

Regarding aircraft fueling, there are measures which allow aircraft fueling while passengers are boarding, on board or disembarking. In practice aircraft fueling should not represent a critical path in the aircraft turnaround. Therefore, the turnaround critical path corresponds to cabin related processes.

If COVID related measures delay these processes, this would have an immediate impact on the overall turnaround time. In Table 30 below, the impact of the COVID measures on each ground handling process is shown. The processes where the COVID measures have the greatest impact are:

- Deboarding
- Boarding
- Cabin cleaning

These unfortunately correspond to the critical path of ground handling. When these activities are delayed, there will be a direct negative impact on the overall turnaround time.

Process	Critical Path?	COVID Measure
Passenger Deboarding	yes	Slowed down to allow more distance between passengers
		Potential health check in boarding bridge (if applicable)
Unloading of Luggage	can be	Slightly more time when baggage numbers increase
Cleaning	yes	Deep cleaning / disinfection
Catering	no	No changed procedures with impact on required time known
Fueling	can be	No changed procedures with impact on required time known
Lavatory / Fresh Water	no	No changed procedures with impact on required time known
Loading of Luggage	can be	Slightly more time when baggage numbers increase
Passenger Boarding	yes	Slowed down to allow more distance between passengers
		Potential health check at gate counter (if applicable)

Table 30: Summary of the impact of COVID measures on each ground handling process

3.1.2.2 Deboarding Scenario

It is expected that post-COVID, passengers stay seated longer and keep a physical distance when disembarking. In order to quantify this effect a simulation model is used. Findings from the model are accompanied by the statements obtained in interviews with stakeholders.

As simulation setup, a full narrowbody aircraft consisting of 28 rows of 6 seats each (total of 168 seats) is considered. Deboarding is done through one door / jet bridge. Apart from the self-organised keeping of distance, no active change of the deboarding principle is applied.

3.1.2.3 Aircraft Cleaning / Disinfection Analysis

In contrast to most other processes, the new respectively changed cabin cleaning/disinfection is not well defined yet. Without any specified cleaning quality, it is not possible to calculate a representative time needed for an aircraft cabin cleaning. In consequence, the focus at the time of this study can only be the collection information from stakeholders instead of any simulations yet.

3.1.2.4 Boarding Scenario

Depending on the organisation of the boarding process, there are several potential issues leading to a prolonged boarding time:

- Boarding by groups (inefficiencies and idle times when calling to counter)
- Health or travel document checks, e.g. via Timatic check at gate counter (lower throughput rate)
- Back-to-Front boarding (less chances for passengers taking a seat simultaneously in the cabin)
- Physical distance in cabin (increased time for storing hand luggage).

Taking all the mentioned factors into account, a boarding simulation model is used to address the following scenarios:

1. Pre-COVID
    - Random boarding
2. Post-COVID
    - Random boarding + physical distancing
    - Back-to-front boarding + physical distancing
    - Further scenarios with varied load factors and number cabin luggage

As demonstrator, a full narrowbody aircraft with 168 passengers (28 rows of 6 seats each) is considered (see Figure 95). Boarding is done via one jet bridge at the front door.

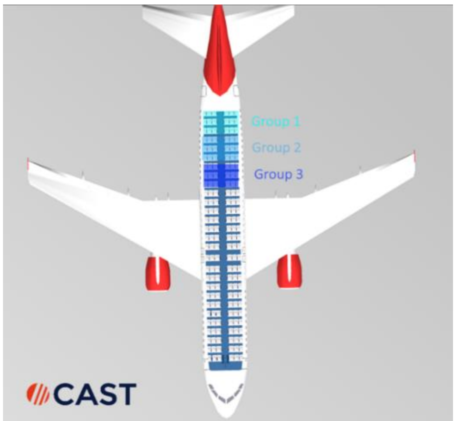


Figure 95: Aircraft model considered for simulation

In the back-to-front scenario simulation, groups of 3 rows (18 passengers per group) are considered. Rear rows start boarding first, followed by the three rows situated in front of the last ones. Passengers head to the gate control when previous group finishes boarding.

3.1.3 Results

The results presented in this section aim at two objectives: on the one hand, it shall be derived how much time the various actions may add to the overall turnaround; on the other hand, the study wants to collect more details about the currently used measures which follow-up studies can use as baseline.

3.1.3.1 Deboarding Process

Deboarding is delayed because passengers stay seated longer and keep a physical distance in the aircraft cabin and jet bridge. This behavior is mainly self-organised by passengers and not enforced by airline cabin crew. In addition, cabin crew has no benefit of holding passengers inside the narrow aircraft cabin or to advise them to slower leave the cabin (unless the entrance area in the terminal is space constrained).

In contrast to the boarding process, deboarding does not change in general, and is still performed front-to-back. Therefore, no significant delay for deboarding is expected. In case of less carry-on luggage, deboarding could be even faster than pre-COVID.

For a systematic assessment and visualisation purposes, ARC performed a deboarding simulation to compare the deboarding time before and after the COVID outbreak. Snap-shots of the video visualisation are presented hereunder (see Figure 96).

From the simulation it is concluded that deboarding may be delayed approx. 3 minutes under the mentioned circumstances (full loaded aircraft and carry-on luggage).

A complete visualisation of the deboarding process is provided in the video-link (https://youtu.be/AL_Cbc3Pwx4).

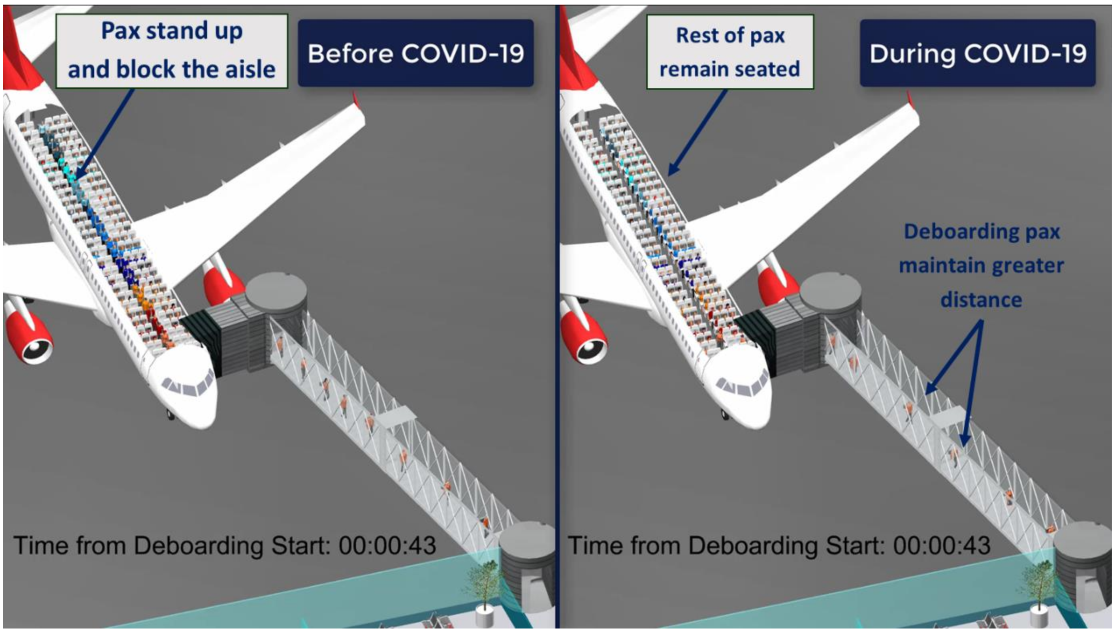


Figure 96: Comparison deboarding characteristics pre-and-post-COVID

3.1.3.2 Cleaning Process

Based on discussions and statements from interview partners it seems that airlines put into effect the recommendations about an intensified cleaning and disinfection in a different way. An intense cleaning and disinfection of the aircraft usually shall take place once a day during overnight or during longer ground times. A short disinfection of the frequent touchpoints may be done as part of the cleaning process during the turnaround. From a statement by a legacy carrier, additional spraying and disinfection of touchpoints is done within the turnaround cleaning process. This adds additional 2 to 5 minutes to the cleaning process.

During an interview of an aircraft cleaning company it was even stated that the actual cleaning process with additional disinfection of touchpoints is not prolonged, because the cleaning company uses more cleaning staff to do the additional disinfection process. The reason behind that, was to meet the times for cleaning agreed in the SLA contract (service level agreement) with the airlines that had not yet been adapted due to COVID.

From observation of one of the European major Low-Cost Carrier (LCC), it can be extracted that no cleaning on short turnaround is done. Only an intense cleaning is done once a day, during longer ground times due to crew change or overnight. Clearly, short turnarounds are critical for LCCs and an important factor of their business model. As long as there is no hard regulation prescribing disinfection as part of the turnaround, it is assumed that LCCs likely will not put emphasis in additional disinfection processes.

Following the before mentioned insights, during critical turnaround times it is not expected that there will be an intense disinfection of the aircraft. Airlines will schedule it when it fits best (e.g. overnight), as long as there is no regulation available. As a conservative approach for the current study, it is assumed that for those carriers that choose to do a disinfection after each flight, the cleaning process might be prolonged in the range of 2 to 5 minutes.

3.1.3.3 Boarding Process

Currently, in most cases it is the decision of the airline how much time they allow for boarding and which principle they follow. Back-to-Front boarding (recommended by EASA) is done by several airlines. Other airlines decided for **Wi**ndow-**M**iddle-**A**isle (WILMA) boarding, while others did not change their boarding procedure and stay with random boarding. The decision for one boarding principle certainly also depends on how much available time an airline has on the ground.

If any comprehensive boarding principle became mandatory, airlines with short turnarounds would be affected most. In order to contrast a pre-COVID situation with the Back-to-Front principle, ARC did a simulation video. Several snap-shots of this video are presented hereunder.

A complete visualisation of the Random and Back-to-Front boarding is provided in the video-link (https://youtu.be/TFfFoyrepb8).

At Boarding Start:

Pre-COVID, the majority of passengers started queueing at the gate counter before boarding start already. This means, idle times at the boarding counter almost never happened.

Post-COVID, passengers shall wait for their group to be called and stay seated until that to reduce the number of passengers at the counter. This certainly includes a higher risk for idle times.

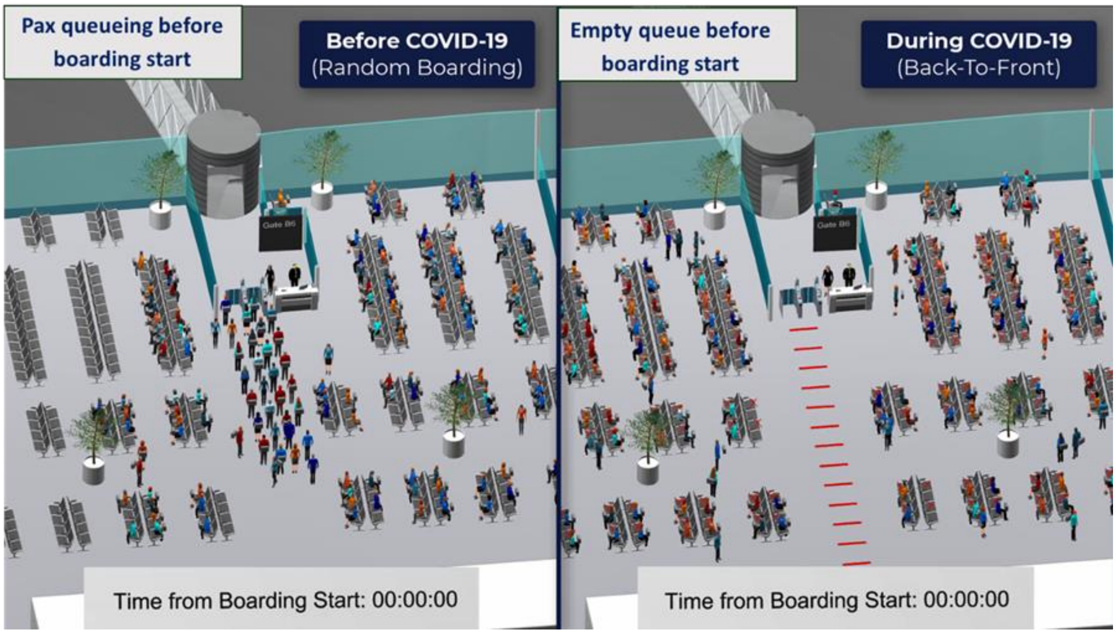


Figure 97: Boarding Video - Before Boarding Start

During Boarding:

Pre-COVID passengers would queue in any order, independent on their seat number. Without considering any distancing rules the throughput at the (often two) boarding pass control positions can be very high.

Post-COVID, passengers keep a physical distance while queueing and only members of the corresponding boarding group queue at the gate counter at the same time. Gaining this improved health safety means additional operational effort for the boarding agent and might also lead to a lower throughput at the counter. Though, in many cases the critical path is expected to be inside the aircraft cabin. This means, until a certain extent a reduced throughput at the counter should not have a negative impact on the entire boarding time.

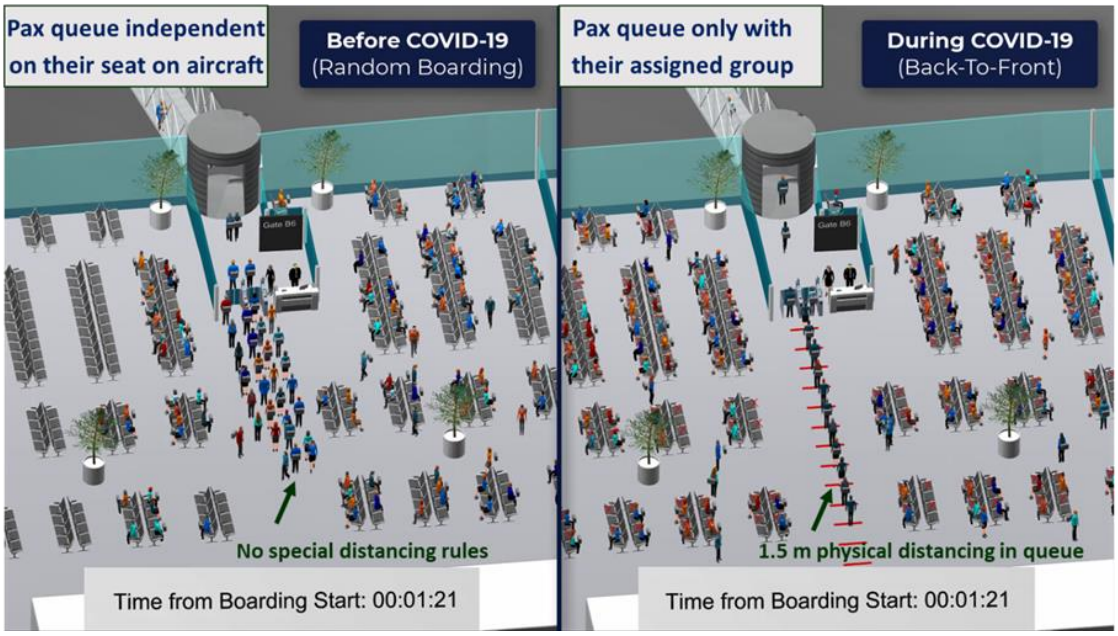


Figure 98: Boarding Video - Comparison Passenger Queueing Patterns

Inside the Aircraft Cabin:

Pre-COVID, random boarding allowed passengers to take their seats in different areas of the aircraft cabin simultaneously. This means, several passengers performed the time-consuming activity of storing hand luggage and getting into the seat row in parallel.

Post-COVID, Back-to-Front boarding would mean that there is always only a certain zone in the aircraft, where passenger take their seat. The rest of the passengers would just wait in the aisle. This means, the previously performed simultaneous activities turn into sequential ones, which is likely to result in longer boarding times.

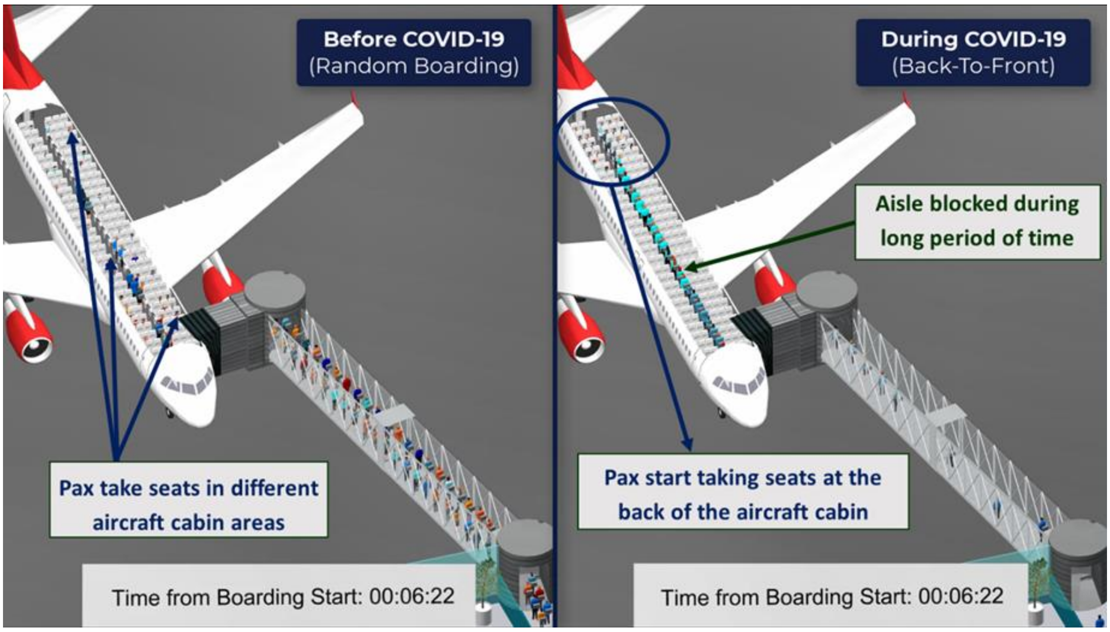


Figure 99: Boarding Video - Comparison Boarding Strategy in the Cabin

Boarding completed:

	Pre-COVID	Post-COVID				
Boarding principle	Random		Back-to-Front			
Luggage share	70%	70%	70%	70%	20%	20%
Load factor	100%	100%	100%	60%	100%	60%
Boarding Time Result	**18 min**	**20 min** (+ 2min)	**32 min** (+ 14 min)	**18 min** (± 0 min)	**21 min** (+ 3 min)	**11 min** (- 7 min)

Table 31: Scenario Specification and Results-Boarding Simulation

Pre-COVID, airlines main objective was to speed up boarding as much as possible. In the case of a narrowbody, boarding would usually be done in 15-20 min.

Post-COVID this time is likely to increase. In the current scenario an increase of 10 min to 15 min in boarding time with a full loaded aircraft cabin has been obtained from simulation with the Back-to-Front boarding principle (depending on the passenger behavior and physical distancing rules).

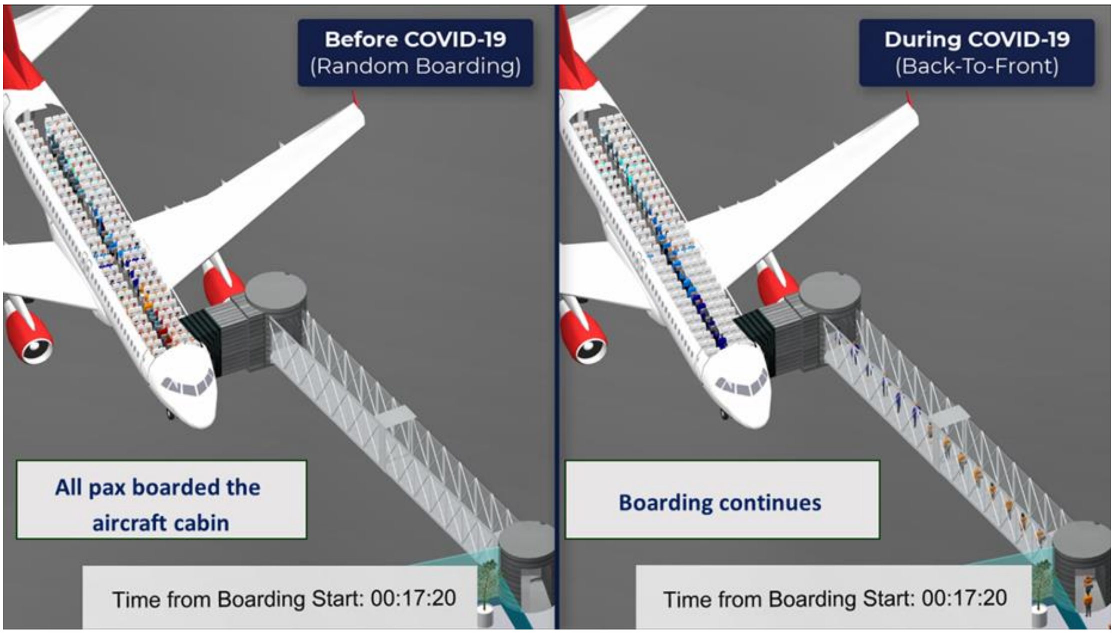


Figure 100: Boarding Video - Comparison of Boarding Time

Table 31 shows the range of boarding times for further scenario simulations.

From the results, the following can be concluded (see also Figure 101):

- Physical distancing in cabin as only parameter does not seem not to have a major effect on the boarding time (see scenario 1 and 2).

- However, applying Back-to-Front boarding is regarded as more critical. In particular with high load factors and carry-on luggage on board.
- When lower load factors are considered, boarding times might be similar to pre-COVID.
- Finally, the carry-on luggage on board seems to be as well an important driver for the boarding time. By reducing the amount of carry-on luggage, the boarding time can be lowered.

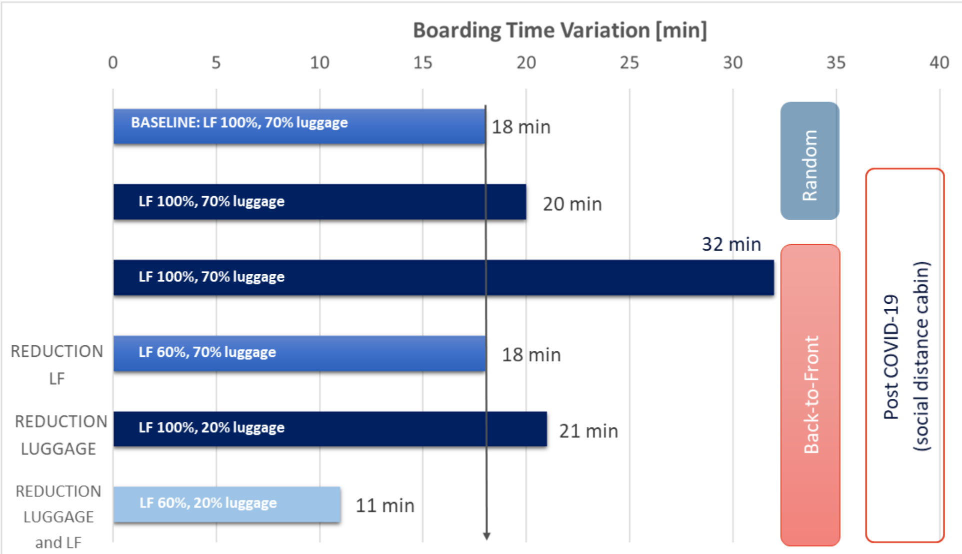


Figure 101: Boarding Time Results Comparison-Boarding Simulation

Due to the different influencing factors (aircraft load factor, carry-on luggage numbers and the boarding principle) the increase in boarding time differs. For the following overall analysis on turnaround it is therefore decided to assume that a 10 min increase in boarding time can happen.

Communication with stakeholders in the later phase of the project has shown that airlines started to implement the “WILMA” boarding strategy (as well recommended by EASA). This strategy assures similar risk of person-to-person interaction (health safety), but shall allow better results in terms of time used for boarding. One drawback of this strategy is that it unfolds its highest potential on a flight with many individual travelers only. Groups or family members seating in the same row represent a constraint for a perfect implementation of the WILMA boarding method.

In summary, the analysis revealed different KPIs for the analyzed boarding principles. A qualitative comparison between the three analyzed boarding strategies is shown in the Table 32.

Boarding principle / KPIs	Random	Back-to-Front	Wilma
Health Safety	low	high	high
Boarding Time	fast	slow	fast
Organization of Boarding	easy	medium	difficult

Table 32: Qualitative comparison between different boarding strategies

3.1.3.4 Overall Impact on Turnaround Time

Figure 102 shows the ground handling scheme of the example aircraft post-COVID. Based on the previous analyses the following changes are expected:

- It is likely that the deboarding time of an aircraft could increase for a few minutes, e.g. around 2 mins in the case of the analyzed narrowbody.
- If additional disinfection is done during each turnaround, this could increase the service cleaning time approx. 3 minutes when carried out simultaneously / overlapping with the regular cleaning.
- If changes to boarding procedures are made, boarding time could increase around 10 min.
- Loading and unloading of baggage from the aircraft belly may take longer time, as long as carry-on luggage is restricted on board. However, these do not have a direct effect on the critical turnaround time when compared to the considered factors.

It general the analyzed example indicated that with COVID related measures, an aircraft turnaround is likely to increases by 15 minutes (from 40 to 55 minutes).

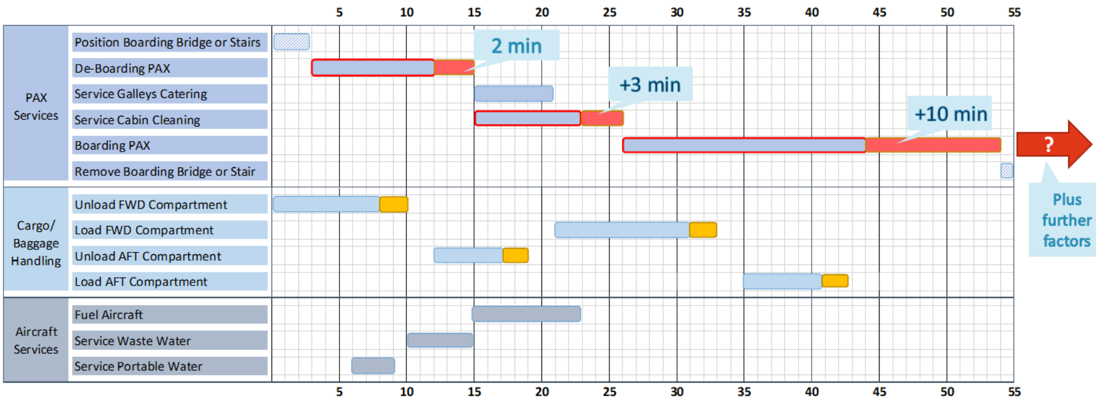


Figure 102: Ground Handling Scheme-Post-COVID

In addition to these more or less frequently occurring influences, there might be other factors that increase the aircraft turnaround time in specific cases. As examples one could mention:

- Late passengers' arrival at gate, due to inadequate staffing at security or a more complex transfer process (e.g. possible suspension of one-stop checks, new health checks, longer process time at transfer checkpoints without the MCT being adjusted)

- Delayed boarding due to a limited inflow into a closed gate or special issues (e.g. travel restrictions checks, health check during boarding, check-in of too much carry-on luggage, special PRM handling).
- Delayed deboarding due to limited space in immigration and/or baggage reclaim

3.1.3.5 Analysis of actual Data

In order to address the question about a prolonged turnaround from another perspective, in this section, an analysis of actual pre-and-post COVID data of major European airports is provided. These two data sets correspond to:

- Boarding times
- Overall ground times

Boarding Time Analysis:

Empirical data of boarding durations from one European airport pre- and-post-COVID was analyzed, in order to quantify the possible effects of COVID related measures. The data indicates very different results: for some carriers (Hybrid), there is only a slight difference in boarding times compared to pre-COVID. However, for others (Ethnic), this difference is considerably higher. This goes along with the conclusion that some airlines have implemented changes to their boarding procedures, which cause an increase in boarding times. However, when only physical distancing is implemented, only a moderate negative effect is observed.

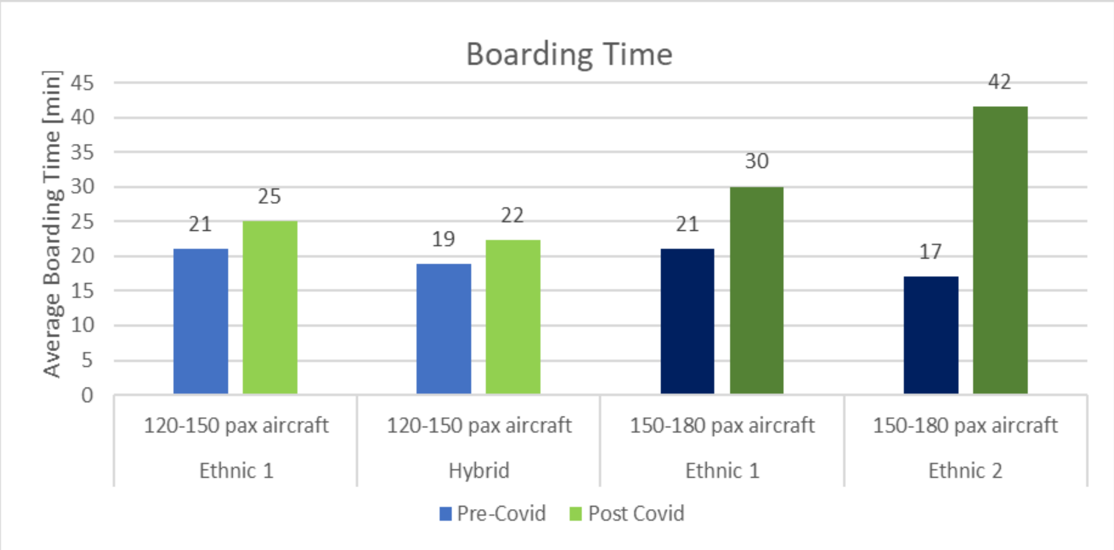
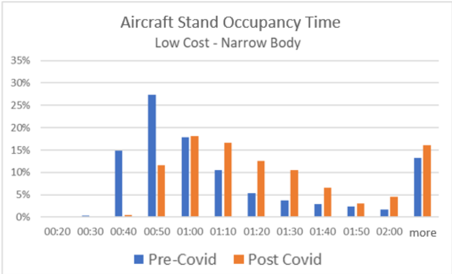


Figure 103: Analysis of boarding timestamps at a European Airport

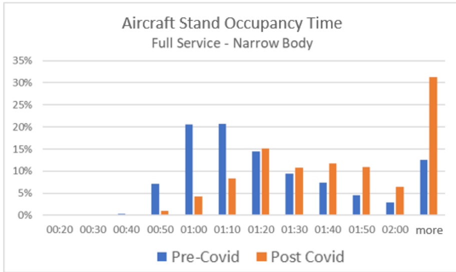
Ground Time Analysis:

Flight schedules with actual time stamps pre-COVID (prior to March 2020) and post-COVID (from May 2020) were provided by a major European hub airport. ARC performed a stand occupancy time analysis for narrowbody and widebody aircraft.

For the narrowbody aircraft, LCC and Full-Service carrier were analyzed separately and the focus was put on flights with at least 100 passengers. As shown in Figure 104, when the median is considered, the stand occupancy time of LCCs increased 18 min compared to pre-COVID and 29 min of the Full-Service carriers. However, when turnarounds with less than 2h are only taken into account, the stand occupancy times increase is assigned to be 17 min post-COVID.

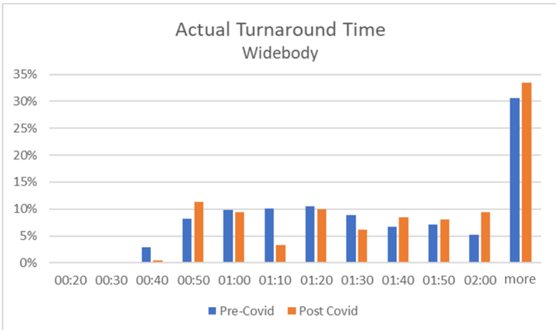


Low Cost	Pre-Covid	Post-Covid	
Sample Size	6,000	200	
Median	54 min	1h 12 min	+ 18 min



Full Service	Pre-Covid	Post-Covid	
Sample Size	15,000	1,000	
Median	1h 11 min	1h 40 min	+ 29 min
Median (<2h)	1h 07 min	1h 24 min	+ 17 min

Figure 104: Analysis stand occupancy times for narrowbody aircraft: Low-Cost carrier (left) and Full-Service carrier (right).



Low Cost	Pre-Covid	Post-Covid
Sample Size	7,000	200
Median	4h	4h 35 min

Figure 105: Analysis stand occupancy times for widebody aircraft

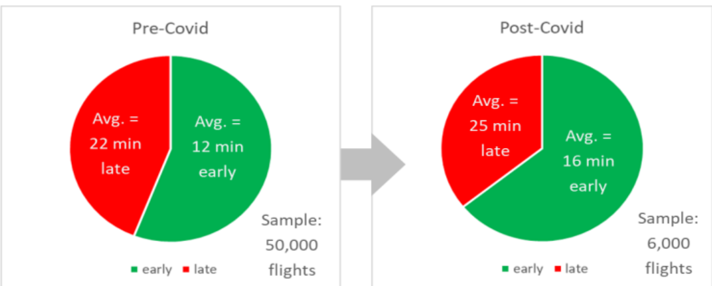
Stand occupancy time for widebody increased 35 min in the example airport. However, widebody aircraft are in general difficult to assess, since turnarounds are in general very long. With approx. 4h ground time, turnaround processes shall not face a time issue.

The actual data analysed proves that ground times are longer post-COVID. However, the observed addition is not **purely** a mandatory consequence of health measures. Certainly, it is partly a result of immediate COVID measures but also a side-effect of other drivers. These are mentioned in the table below.

	Turnaround / Stand occupancy time potentially increased by...	
	Immediate COVID measure	**Side effect of other operational requirements**
Aircraft Scheduling		• Less legs per aircraft per day • Early arrival due to empty airspace • No shortage of slots - late departure does not matter • Worldwide travel restrictions led to cancelation and/or disruptions of flights
Passenger Handling	• Slowed down deboarding and boarding to keep physical distance • Potential health checks during boarding • But less carry-ons, more hold luggage • LCCs: lower use of 2-door boarding due to high number of busses (3x) due to physical distance	• Additional check of documents considering travel restrictions (TIMATIC check) before boarding • Volatile booking numbers, last minute changes, disruptive operations, human factors • Late passengers at gate due to issue at another terminal processor
Aircraft Handling	• Disinfection / deep cleaning between flights	• No availability of GSE (e.g. buses)

Table 33: Summary of effects of increased ground times

Besides the passenger related effects already presented, it is important to consider that worldwide travel restrictions led to cancelation and/or disruptions of flights. Therefore, there are less legs per aircraft per day. An early arrival of flights is observed due to empty airspace and since no slots are assigned, a later departure is less critical than pre-COVID. Data analysis of the major European hub confirms that the decrease in traffic and more direct routes lead to shorter flight times and more early arrival of aircraft is experienced (64% of aircraft arrive early instead of 56%).



	Early	Late
Pre-Covid	56%	44%
Post-Covid	64%	36%

Figure 106: Comparison of early and late arrivals pre- and post-COVID

3.1.4 Conclusion

The aircraft turnaround time can be affected by a high number of drivers. In order to narrow down, which processes should be paid most attention, the critical path of the turnaround has been identified to be the passenger and cleaning activities in the aircraft cabin: boarding, deboarding and cleaning.

Even worse, these processes will be most affected by COVID measures:

Physical distance in the cabin during boarding and deboarding, change to Back-to-Front boarding strategy and an additional disinfection during the cabin cleaning may produce an increase in the minimum turnaround time. This increase is quantified to be around 15 min (from 40 to 55 min) for the analyzed example aircraft and turnaround scheme.

Window-Middle-Aisle and Back-to-Front boarding strategies are recommended by EASA. Similar health safety can be assured by both. "WILMA" seems to have higher potential for reducing boarding time but it may be difficult to implement, in particular on flights with many passengers travelling in groups (e.g. couples, families).

Empirical data as second source of information next to the interviews and simulation models verified the above findings in general. However, an empirical analysis of actual stand occupancy times should not be understood in a way that the observed increases are mandatory and only affected by health measures. Many other side effects contribute to currently long ground times as well (e.g. that an aircraft is currently just flying less legs per day).

3.1.4.1 Mitigation of the critical Processes

The following Figure 107 summarises the recommended mitigation measures for each critical process considered.

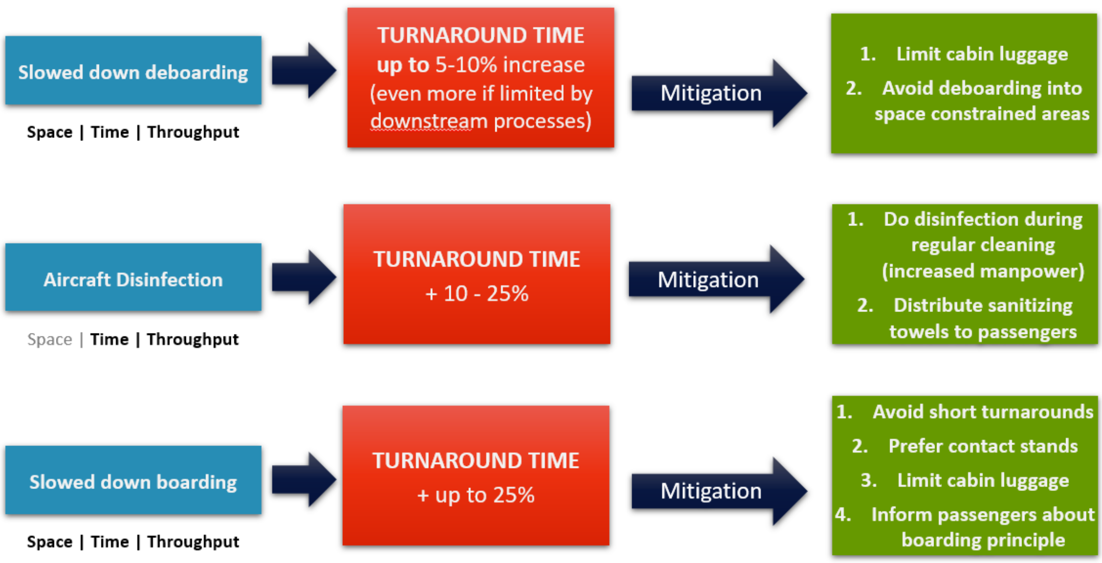


Figure 107: Mitigation Measures for Aircraft Turnaround

4 Conclusion & Recommendations

Air transportation could be one of the vectors for COVID transmission. With the wearing of masks, the risk on airplanes is probably lower than in many confined spaces: cabin air filtration systems enable a total flow rate equivalent to 20 to 30 air changes per hour. Nevertheless, passengers have to transit via airports to travel. These environments need to be secured in order to, first, minimise the risk of spreading the virus and, second, maintain trust and confidence into the mode of transport that has always been considered as the safest one. In order to support a safe and smooth recovery from COVID-19 lockdown, EASA/ECDC, ICAO, ACI, and IATA issued guidelines and recommendations.

It has been experienced so far by airports that COVID health measures have multiple impacts on the experienced level of service for passengers and the way an airport needs to organise its operations and facilities.

EUROCONTROL commissioned the Airport Research Center GmbH (ARC) to undertake a comprehensive study to assess the impact of the COVID-19 measures on on airport performance, and terminal operations in particular, with the aim to support the European network to better prepare for COVID-19 traffic recovery. Six external partners largely contributed to the project: ACI EUROPE and IATA, and 4 airports, namely Paris Charles-de-Gaulle, London Heathrow, Stuttgart and Swedavia airports.

In this study, the airport performance was analysed with the implementation of the COVID-19 measures (including 1.5m physical distance), compared to the pre-COVID situation. Based on data collected from the project partners and the simulation of a generic airport, the objective of this report is threefold:

(i) to have an order of magnitude of the impact of these measures on the passengers' journey time throughout a terminal,

(ii) to assess how much additional space is required for COVID-related facilities, if needed, and

(iii) to better anticipate when airports are likely to reach their saturation capacity, that is reduced with the implementation of COVID measures.

4.1 Impact Analysis on Passenger Journey

4.1.1 Departure Flow

As far as departures are concerned, the compulsory COVID measures might add up to 10 minutes to the passengers' journey. A low percentage of airlines may still ask passengers for agent check-in or apply more time-consuming boarding procedures. But even in these cases, the required additional time should not exceed 10 minutes.

One concern is the suitable provision of staff to support the COVID measures, especially to compensate a reduced security control throughput which, if not addressed, could lead to backing up passengers into the terminal areas.

In terms of space, the situation is more critical. Authoritative decisions about physical distance disrupt the airport's former queue and gate sizing. For the same passenger number in a queue in the pre-COVID period, much more space is required to manage COVID:

- 50% at check-in;
- 100% at security control; and
- 35-50% in boarding gates.

In case of more passengers waiting per resource, the required space increases even further.

Figure 108 and Figure 109 here below provide the summary of the additional time and space implied by the implementation of COVID measures for departure flow. Each process is summarised afterwards.

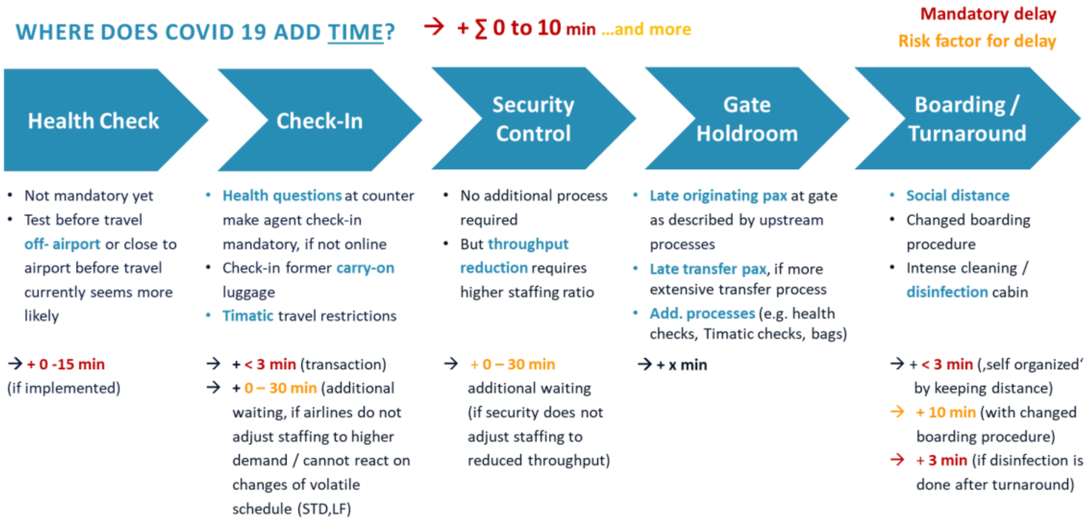


Figure 108: COVID-related Additional Time for Departure Flow (Time)

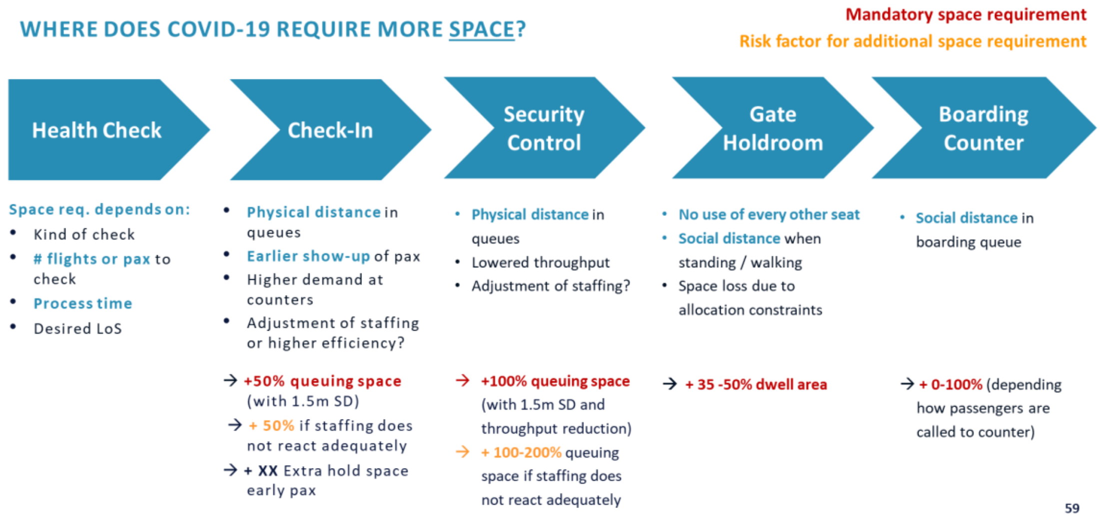


Figure 109: COVID-related Additional Space for Departure Flow (Space)

4.1.1.1 Health Check on Departure

Implementation of any health check would mean an all-new process in the departing passenger journey. At the time of the study, no clear technology or procedure has become broadly accepted; thus, any statement can only be speculative so far.

New health checkpoints on departure would entail additional waiting and service times depending upon how fast test results are available. Test analysis might take up to several hours for recent reliable tests, but research is still ongoing to speed it up.

Additional space provision is also required depending on the implemented test type. In particular, tests that do not provide results right away and require passengers to wait for their results would require big dwelling areas.

It can be concluded that such a health check centre for departures would have a great impact for both the passengers and the airport. Passengers might need to get to the airport much earlier and the airport would need to assign lots of space for such a new process. For airports, the implementation of this measure might turn into a trade-off between available space, tolerated waiting time and acceptable cost.

Therefore, current development indicates that health checks should rather be performed off-airport; in such a case, airports would ensure a quick health certificate check only. For that reason, any extra time for health checks is currently not considered in the overall additional journey time for passengers in this study.

4.1.1.2 Check-In

Mandatory agent check-in to answer health questions or show certificate has turned out to be the only COVID measure that directly affects the actual check-in process. Passengers who used online or kiosk check-in would need to see an agent, which is estimated to take less than 2-3 minutes for this process. However, such a re-organisation of check-in or other volatility in passenger throughput add further risk factors in terms of waiting time. As long as higher waiting times happen at the beginning of the check-in period only, the risk of missing a flight should still be low.

As far as space is concerned, the measure of several airports to use every second counter in the early phase of COVID has currently been substituted by protective walls between counters. Therefore, there is no additional infrastructure consumption in terms of counters anymore. The main driver for additional queuing space is directly related to the physical distance requirements. By carrying luggage, passengers already kept more distance to each other at check-in before the COVID (e.g. compared to security control). Consequently, the additionally queue space required with physical distancing (1.5m) is not as high compared to other handling facilities, but still accounts for 50% for the same passengers volume. Similar to waiting time, any inadequate staffing / opening time (e.g. when passengers show-up earlier) might affect the additional space required.

4.1.1.3 Security Control

Physical distancing at security has a significant impact on queues, even with a hand-luggage only. Compared to pre-COVID, the same number of passengers would require double the space with 1.5m physical distance.

In contrast to other processors, physical distancing at security control does not only affect the queuing capacity but also the actual throughput. This means that pre-COVID staff provision for a given number of passengers would result in higher waiting times with COVID measures. If waiting time needs to be kept at a pre-COVID level (or when it even needs to be lower because of the limited capacity of the waiting area), an airport would be obliged to open more lanes than it would do Pre-COVID for the same traffic volume. If this cannot be achieved, significant additional time and space must be envisaged.

This study indicated a very high sensitivity of the security checkpoint and thus a wide range of how queues and waiting times could grow.

4.1.1.4 Boarding Gate

The implementation of COVID measures in the gate hold rooms, such as blocking every other seat and providing sufficient space for standing passengers, lead to the conclusion that the same number of passengers would need 35-50% more space. Depending on the airport infrastructure, this means that certain gate infrastructure could not be allocated anymore. As physical distancing in gate areas is obligatory, an airport currently has no chance to bypass this requirement with other health measures <u>inside</u> the gate. Thus, mitigation measures are rather possible by an appropriate gate allocation, as distributed as possible.

4.1.1.5 Boarding

Although there is common agreement to keep a physical distance while boarding, no boarding principle has turned to be a standard or obliged by law. Thus, the additional time depends on the boarding strategy used by airlines. This study indicates a lower limit of approximately 3 min for self-organised boarding to further 10 min additional time, when specific boarding principles are used (e.g. Back-to-Front). This time could further increase, if additional COVID related checks are performed during boarding.

At the time of the study, it was reported that airlines use the time they have: in case of a long turnaround, airlines would probably let passengers more time for boarding than for a short turnaround.

4.1.2 Arrival Process

The additional time required for the arriving passengers' journey, due to the implementation of COVID measures, is within a range of 5 to 20 minutes.

However, the provision of space is quite critical. Immigration would need double the space and baggage reclaim would require 30-50% more space for the same passenger number.

New health checks measures on arrivals would have a considerable impact, in particular in transfers.

Figure 110 and Figure 111 here below provide the summary of the additional time and space implied by the implementation of COVID measures for arrival flow. Each process is summarised afterwards.

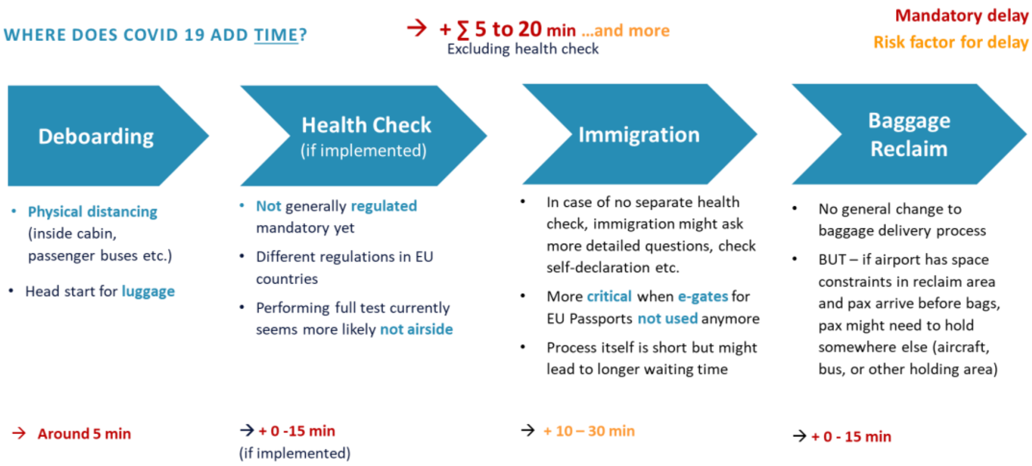


Figure 110: Additional Time Requirements for Arrival Flow (Time)

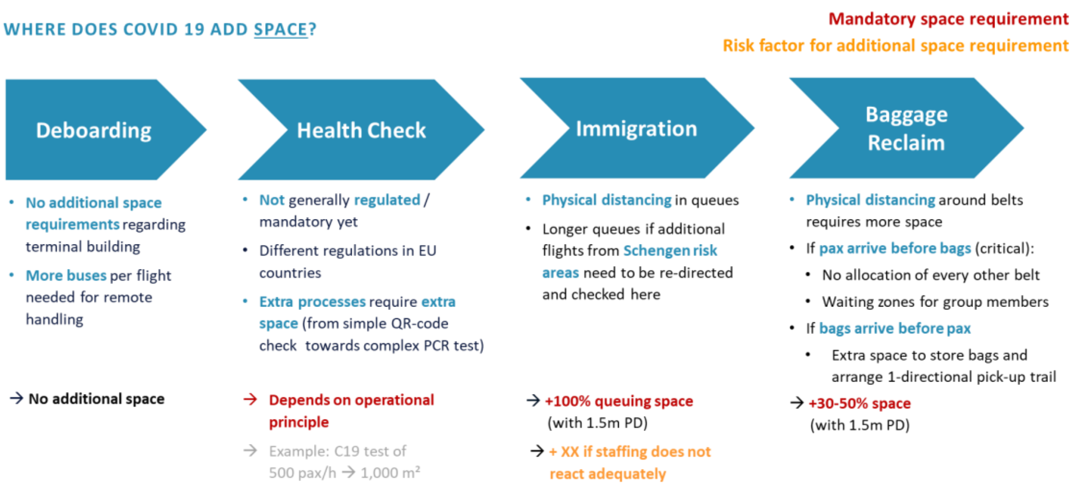


Figure 111: Additional Space Requirements for Arrival Flow (Space)

4.1.2.1 Deboarding

Without any real change in the process itself, the only COVID-related implication during deboarding would be that passengers keep a physical distance to each other. As deboarding is more or less self-organised by passengers, no significant additional time is expected (< 5 min).

Even more significantly that in pre-COVID situation, any bottleneck downstreams the terminal for arrivals (e.g. baggage reclaim, immigration) can lead to late deboarding in order to avoid the generation of peaks and uncontrollable delay – delay usually increases exponentially with traffic volume - within the terminal itself.

4.1.2.2 Health Check

There is currently no obligation for health check on arrivals.

Should this be envisaged, this would have a high influence on passenger flow, similarly to departures. In such a case, it is highly recommended to ensure health check off-airport.

4.1.2.3 Immigration

At many airports, immigration is a very sensitive and critical checkpoint, which already operated close to capacity in Pre-COVID times.

For the time being, there is no common agreement that the immigration process must undertake health checks. Should this be envisaged, it is to be stressed that, in addition to space restriction caused by physical distance in queues, any COVID measures might affect immigration to a high degree; any imbalance of staffing and demand can lead to temporary long queues.

4.1.2.4 Baggage Reclaim

Compared to other processes with well-defined lining, the queuing behavior at reclaim carousels is much less organised. This increases the need for airport providers to allow sufficient space for passengers so that they keep a physical distance even in a self-organised way. Similar to check-in, the additional space requirement would be up to 50% for the same number of passengers.

If enough space cannot be provided, one option is to let the flow in baggage reclaim regulate the deboarding process, i.e. let passengers dwell in the aircraft cabin longer to reduce the number of passengers in the reclaim hall.

4.1.2.5 Transfer Processes

At the time of the study, the COVID measures did not affect transfer passenger flows.

Several interviews with airport stakeholders indicated that changes might happen. In such a case, this would significantly affect minimum connecting time: depending on the requirements and organisation, minimum connecting times may increase by 20 to 35 min, which can affect a high percentage of connections.

4.2 Saturation Capacity

Beyond the passenger's perspective, airports are interested to know which traffic volumes they can accommodate whilst implementing the COVID measures, and when they are expected to achieve saturation when traffic will recover.

For those airports already saturated before the COVID, the general saturation capacity with COVID measures is expected to be in the range of 60-75% of their pre-COVID traffic volume during peaks. As shown on Figure 112, security control (in terms of throughput) and the boarding gates (in terms of space) are likely to be the limiting components of airport.

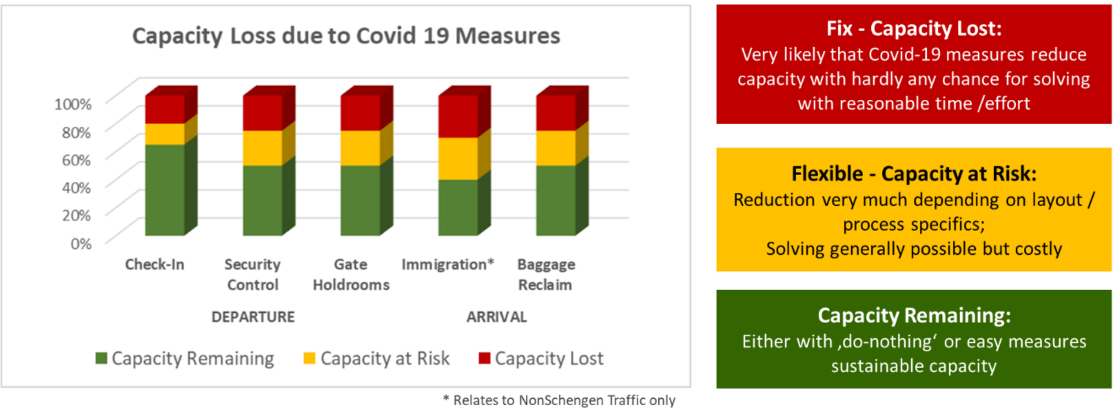


Figure 112: Capacity loss due to COVID Measures related to terminal areas investigated in this study

4.3 Further recommendations

Three major recommendations are to be formulated further to this study:

(i) The COVID crisis is quite dynamic, and everyday bears witness to the changes made to the management of the crisis. The input used in the scope of this study was defined from the best knowledge at the time of setting up and discussing scenarios with the project's contributors, including the 4 airports, ACI EUROPE and IATA. A significant evolution of the crisis would call for the review of the scenarios with the stakeholders.

(ii) It was aimed that the model used in this study is generic enough in order to get rid of local specificities that might bias the general impact of COVID measures, whilst being representative enough so that it can be customised to local airports with minimum effort, if needed. The application of the same methodology at 2 European airports by ARC shows that the weakest terminal components were different (due to specific layout and local operational conditions), but the capacity loss by area was in a similar order of magnitude for both airports as identified in this study.

(iii) Last but not least, this study identified that significant harmonisation of the measures is required and will be beneficial for all the parties involved. Consultation revealed that there exists a disparity in the implementation of the measures. Health forms should be harmonised at the European level as well as the criteria for the colour-coding used by the Member States and their regions to report about the pandemic evolution. It is strongly believed that this harmonisation at European level will improve the efficiency of the crisis management.

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