How to increase efficiency and capacity in a single runway airport? Study of the case: Viracopos Campinas Airport-VCP

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ABSTRACT

The Viracopos-Campinas International Airport (ICAO code: SBKP, IATA code: VCP) is an international airport in the city of Campinas, in São Paulo State. The airport settled in a region of the leading technological, logistical, and economic development. The Viracopos Cargo Terminal was elected in 2017 the second-best in the World by ACE (Air Cargo Excellence Awards) in the category up to 400 thousand tons/year and is one of the most agile and safe in Brazil. Viracopos has a new and modern passenger terminal with a capacity of 25 million people per year.

Viracopos has verified growth in passengers handled since 2008, with the start of operations of Azul Airlines. In 2012, the airport was conceded to Aeroportos Brasil Viracopos to manage, expand and modernize the airport complex for 30 years. In the first year of private operation, the airport transported 8.8 million passengers from the old terminal. In 2014, there were almost 10 million, and in 2019 Viracopos reached 10.5 million passengers after a prolonged recession in Brazil's economy. The airport always seek a continuous and constant growth of passengers and cargo

However, in 2020 the COVID19 pandemic devastated the aviation industry, generating economic loss due to passengers and aircraft movements' downturn. More than ever, improve operations efficiency and capacity is one of the way outs for the crises. This study aims to understand the VCP terminal airspace procedures, runway configuration, apron configuration, operations characteristics and study best practices applied in the single-runway global benchmark. After that, make recommendations to possible improvements in approach and departure procedure and airside processes and infrastructure to increase operations efficiency and runway throughput in VCP.

Keywords

Brazil, Viracopos Airport - VCP, Single Runway, Efficiency, Improvements

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LIST OF ABBREVIATIONS

A-CDM	Airport Collaborative Decision Making
ABV	Aeroportos Brasil Viracopos
ACC	Area Control Center
ACI	Airports Council International
ADRM	IATA Airport Development Reference Manual
AIP	Aeronautical Information Publication
ANAC	Agência Nacional de Aviação Civil (Brazilian CAA)
ANSP	Air Navigation Service Provider
APP	Approach Control
ATC	Air Traffic Control
ATCO	Air Traffic Controller Officer
CDO	Continuous Descent Operations
CINDACTA	Integrated Center for Air Defense and Air Traffic Control
DA	Decision Altitute
DECEA	Departamento de Controle do Espaço Aéreo (Brazilian ANSP)
DME	Distance Measuring Equipment
GMR	Ground Movement Radar
GNSS	Global Navigation Satellite System
IAC	Instrument Approach Chart
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LGW	London Gatwick Airport
MALSR	Intensity Approach Light System with Runway Alignment Indicator Lights
MSL	Mean Sea Level
NDB	Non-Directional Beacon
PAPI	Precision Approach Path Indicator
RESA	Runway End Safety Area
RET	Rapid Exit Taxiway
RETIL	Rapid Exit Taxiway Indicator Lights
ROT	Runway Occupancy Time
RRSM	Reduce Runway Separation Minima
RWY	Runway
SAC	Brazilian Civl Aviation Secretariat
SID	Standart Instrument Departure
STAR	Standard Terminal Arrival Route
TUBS	Taxiway Unavailable Bars

TWR	Tower Control
TWY	Taxiway
VCP	Viracopos Campinas International Airport
VFR	Visual Flight Rules
VOR	Very High Frequency Omnidirectional Range

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INTRODUCTION

In 2011, the Brazil Government kicked-off a public policy that allowed to hand over to the private sector majors of Brazilian airports that used to be operated by a state company, Infraero. By that time, Brazil was facing massive preparation for global sports events, such as the 2014 FIFA World Cup Brazil and Olympic Games Rio 2016. As a result, a gigantic modernization in Brazilian airports was necessary to handle domestic and international passengers.

From 2011 to 2020, twenty-two airports, among the largest and regional ones, were conceded to private operators. The privatization brought infrastructure investments to the country's aviation industry, especially to airports' airside and landside. These infrastructure improvements allowed the national aviation market experienced a growth in demand and capacity.

However, even before the COVID19 pandemic caused the most significant drawdown in global civil aviation, some concessions were struggling to breakeven their operation vis-a-vis the concession's infrastructure investments contract the Brazilian economic recession for the last few years.

In this context, Campinas Viracapos International Airport – VCP is among those Brazilian airports facing economic challenges to find a financial balance to its operations. Bearing in mind this challenging situation, adding the massive impact on the air transport industry brought by social distance and lockdown policies due to COVID19, the aviation industry needs, even more in these hard days, continuous reinvention. Seek safe alternatives to improve operations efficiency to mitigate the demand setback faced in the present time needs to be on the aviation industry's horizon.

CHAPTER 1 – GENERAL CONTEXT

1.1. Internship

I have performed my internship at the *Concessionária Aeroportos Brasil Viracopos – ABV* located in Campinas, State of São Paulo, Brazil, from 08 April 2020 to 12 February 2021, but a holding period from 15 April to 31 September due to COVID19 pandemic. This part is a mandatory requirement to complete the Ecole Nationale d'Aviation Civile (ENAC) Advanced Master called "MS ANM18 - Mastére specialisé - Air Navigation Management".

1.2. Internship Host Company – Aeroportos Brasil Viracopos (ABV)

In February 2012, due to federal government policy to privatize public airports, Consórcio Aeroportos Brasil won the right to manage Viracopos International Airport for 30 years through a public auction. The consortium was composed by the Brazilian companies TPI - Triunfo Participações e Investimentos, UTC Participações and the French Egis Airport Operation, and state company Infraero (Brazilian Airport Infrastructure Company) form an Aeroportos Brasil Viracopos Concessionaire, shown in Figure 1 (Aeroportos Brasil Viracopos, 2021).

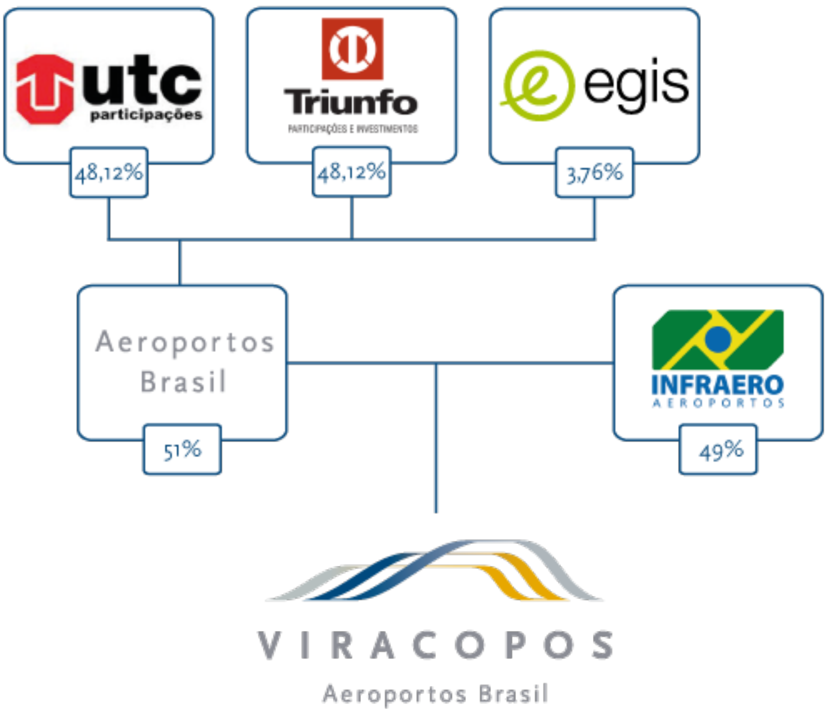

Figure 1 ABV's structural diagram
Source: (Aeroportos Brasil Viracopos, 2021)

Aeroportos Brasil Viracopos is the concessionaire responsible for the management and development of Viracopos International Airport. The airport locates in a region of the main centers of technological, logistical, and economic growth in the country. The Viracopos Cargo Terminal was elected in 2017 the second-best in the World by ACE (Air Cargo Excellence Awards) in the category up to 400 thousand tons/year and is one of the most agile and safe in Brazil. Viracopos has a new and modern passenger terminal with a capacity of 25 million people per year.

1.3. Internship tutor and internship duties

I performed my end of study project under the supervision of Mr. Marcelo MOTA, Director of Operations. All Agile VCP (IATA, Infraero, Azul Airlines, Gol Airlines, LATAM Airlines, ABEAR) greatly impacted and helped me succeed in my project since the AGILE VCP working group aims to increase efficiency and capacity to VCP operations. As an intern at Aeroportos Brasil Viracopos, I had the following duties:

- Be part of Agile VCP coordination to study and implement improvements in airport operations.
- Assist Agile VCP in meetings/workshop preparations.
- Identify the global best practices for single-runway airports.
- Assess the feasibility of 5NM separation in the final approach to implementation one departure between two successive arrivals.
- Assess specific projects related to Agile VCP.

1.4. Technical interest of the internship subject

I carried out the internship along with the AGILE VCP project. AGILE Project is an initiative of the Brazilian aviation industry to provide a particular and detailed view of a given airport or airspace, with the strategic objective of increasing the efficiency of the approach, landing, and take-off operations, improving performance operational flow.

The working group gets the participation of the Airspace Control Department (DECEA), the National Civil Aviation Agency (ANAC), Civil Aviation Secretariat (SAC/MINFRA), the Brazilian Airport Infrastructure Company (INFRAERO), Brazilian Association of Airline Companies (ABEAR), International Air Transport Association (IATA), Gol Airlines, Latam Airlines, Azul Airlines, Brazilian General Aviation Association (ABAG) and Guarulhos Airport (GRU Airport), Galeão Airport (RIOgaleão) and Campinas Airport (ABV) Airport operators.

Currently, work is being carried out for the São Paulo International Airport in Guarulhos (Project AGILE GRU), for the Rio de Janeiro Terminal Control Area (Project AGILE RIO), and the Viracopos Campinas International Airport (Project AGILE VCP).

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CHAPTER 2 – STUDENT INTRODUCTION

I am Bruno Fonseca Reis, 36 years old, telecommunication engineer, married, and father of two boys. I have 07 years experience in telecommunications as a technician and engineer combine. I used to work transmission core network maintenance, planning and further moved to 3G mobile networks planning and implementation.

I graduated in Telecommunication Engineering at Montes Claros Science and Technology Collegue (2007). Last year, I concluded a joint ACI-ICAO Professional Designation Program certification called Airport Safety Professional (ASP). Since then, I became an Airport Safety Professional.

Since I moved to the aviation industry, back in 2010, I became a civil servant working as a telecommunications engineer at DECEA, the major Brazilian ANSP. My activities were related to satellite and VHF communications maintenance and networking improvements performed in CINDACTA 4 (Amazon Center). This Area Center Control is responsible for controlling and coordinating all traffic in that flight information region (FIR).

In 2014, I moved to Civil Aviation Secretariat (SAC/MINFRA) to work with civil aviation public policies. I've already worked in regional airports investments policies during my first year at SAC. Currently, I am performing my duties in civil air navigation public policies for over 06 years. I am engaged in Brazilian air navigation working groups and forums as one of the SAC representatives.

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CHAPTER 3 – PROJECT PLAN

This chapter aims to present the project plan of this final advanced master study. The objective was to assist the Agile VCP working group, studying the cutting-edge procedures, global best practices to develop feasible solutions to improve airside VCP efficiency operations.

Accordingly, as the final result of this thesis, I aimed to deliver a proposal with some recommendations to the Agile VCP working group and VCP Airport Authority by performing my internship at Aeroportos Brasil Viracopos (ABV).

3.1 Problem to be solved

This study's primary goal is to increase efficiency and capacity in a single runway airport, focusing on the Viracopos Campinas airport case. The problem identified the airside constraints, bottlenecks, and inefficiencies in VCP operations to propose possible solutions.

3.2 Justification

Why increase airside efficiency and capacity in VCP? The answer came in Aeroportos Brasil Viracopos internal study that presented the hypothetical scenario. The premise was to measure the potential annual revenue for the Viracopos Airport, assuming an addition of one movement in four peak hours throughout the day. In other words, the aim was to calculate the potential economic impact of an increasing runway capacity in only one movement.

The hypothetical scenario consisted of an operation of one Embraer 195 (118 passengers' capacity) flight with a 90% load factor, i.e., 106 passengers. Assuming that 50% of passenger embark in VCP and the other 50% are from connecting flights, the airport fees comprise:

a) Embark fee: R$ 30.95 for 50% pax, resulting in R$ 1,640.35.
b) Connection fee: R$ 10.49 for 50% pax, resulting in R$ 556.
c) Landing fee: R$ 495.
d) Parking fee: R$ 106.
e) Domestic average ticket: R$ 7 per passenger, resulting in R$ 742.

The total airport fee noticed for one Embraer 195 operation was around R$ 3,600 or US$ 632. Once the premise was to add four daily movements that resulted in runway capacity improvement, the likely result was R$ 14,440 or US$ 2,528 per day.

Thus, the study extrapolated this scenario for 300 days per year will result in an extra potential airport revenue of R$ 4.32 million or roughly US$ 759 thousand for only one movement added in runway capacity.

3.3 Initial approach

As the ABV assessment identified the problem and the justification for the airport improvement, I joined as one of the Agile VCP working group coordinators at the beginning of the internship. I started preliminary research to set the internship plan based on Agile VCP activities and talks with experts.

After that, I have got the VCP airport situation awareness regarding airside operations. I have established a plan to walk through the internship period.

Due to lockdown and social distancing, I perform my internship remotely along with my daily duties at SAC. The first months were challenging to conciliate all activities. However, I have attended 05 Agile VCP meetings, and it was crucial to develop my work due to a vasty study, assessments, and operational improvements produced inside the scope of the working group

Initially, I had to establish a broad perspective of the problem and make a final proposition covering as many aspects as I identified.

After the third Agile VCP meeting, I decided to go in-depth with an interesting study done by Agile VCP. Consequently, I narrowed my recommendations, focusing on a few but essential aspects regarding the runway and taxiway.

3.4 Methodology

The main objective of this study project is to work along the Agile VCP. This industry working group aims to increase the efficiency of the approach, landing, and takeoff operations at Campinas International Airport (VCP). It is necessary to study the constraints, bottlenecks, and inefficiencies regarding VCP operations and deliver a proposal pointing out possible improvements and the most appropriate solutions to increase the airport operations efficiency.

Then, I have joined as one of the Agile VCP working group coordinators, and I have been attending all the meetings. During those meetings, I had direct contact with all stakeholders who are hands-on in daily operations, such as ANSP, Local Airport Administration, Airlines, etc. This open channel allowed me to apply the unstructured interview method with the professional experts to understand VCP operations its benchmarks.

At the beginning of my research, I have used secondary data collection methods to research international organization's documents. I used ICAO, ACI, IATA, national aviation documents as AIP, books, papers, specialized websites, unpublished data from the Agile VCP working group, among others, to go in-depth subject.

Then, moving on in the study, I analyzed various data to build the final proposal to VCP. During macro analysis, I used some primary quantitative data collection methods done by the Agile VCP working group, which was essential to developing the study findings. Together, the primary quantitative and secondary qualitative data collection method gave a solid foundation to understand the constraints, make analyses, compare processes and procedures and finally propose solutions.

Summarizing, these are the methodologic methods that I`ve adopted in my thesis:

- Unstructured interview.
- Primary quantitative data collection.
- Secondary data collection.
- International benchmark research.

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CHAPTER 4 – VIRACOPOS CAMPINAS INTERNATIONAL AIRPORT – VCP

This chapter brings an overview and a general background of the VCP situation regarding airport infrastructure, focusing on the airside, including the apron, runway, taxiways layout, and approach and departure procedure.

So, given the previous contextualization, this chapter aims to discuss the current operations and constraints justifying the need for airside operation improvements.

4.1 Viracopos Campinas Internacional Airport – VCP

The Viracopos Campinas International Airport (IATA code: VCP, ICAO code: SBKP) is an international airport that serves mainly the city of Campinas and its surrounding municipalities, located in the São Paulo State, Brazil. The airport is one of the largest national passenger hubs, with around 330 daily aircraft movements to more than 60 direct destinations in 22 different Brazilian states. The leading VCP operator is Azul Airlines which concentrates its national hub on the airport. Since 2013 the airport was handed over to private capital, which Aeroportos Brasil Viracopos manage operations.

The airport is in one of the most industrialized regions of the country. Viracopos was elected 13 times as the Brazilian`s best passenger terminal in Brazil, according to the "Aeroportos+Brasil," a SAC/MINFRA annual award (Aeroportos Brasil Viracopos, 2020). The Cargo Terminal is responsible for handling more than 1/3 of all imported air cargo in the country and among the besties in the world in the category of up to 400 thousand tons/year, being the only one in Brazil with this international recognition. (Aeroportos Brasil Viracopos, 2020)

In 2020, according to statistics data released by VCP, the airport handled 6,709,061 passengers and had 73,698 aircraft movements. It represents a 36.62% and 35.61% downturn in passengers and aircraft movement over 2019, respectively. On the other hand, cargo operations had an acceleration of 18.49% over 2019, considering cargo tons handled (Aeroportos Brasil Viracopos, 2021).

4.2 Current Infrastructure

According to AIP Brasil (DECEA, 2021), Viracopos airport is 18km from Campinas' downtown, 661m (2,170 ft) of elevation MSL, and reference temperature is 30˚ Celsius. VCP operates IFR (day/night) and VFR (day/night).

Given the physics characteristics and considering the airport operations focus on cargo and passenger hub models, a robust infrastructure is necessary to handle these two different demands.

VCP has in place the following infrastructure facilities, as shown in Figure 2:

a) Number of runways: 01.

b) Runway length: 3,240 long by 45m wide.
c) Rapid Exit Taxiways: 03.
d) Aprons: 06.
e) Number of terminals: 2. Terminal 1 - 178,000 square meters and Cargo Terminal – 84,000 square meters
f) Aircraft stands: 75.
g) Remote stands: 47.
h) Passenger boarding bridges: 28.

Figure 2 VCP airport site from the top
Source: Google Earth

4.2.1 Runway

Consider one of the main assets of an airport, VCP has one runway 15/33 (Figure 3) designed to serve aircraft from category E that means the critical aircraft in Viracopos airport is 4E. VCP belongs to the group of single-runway airports, which is among the majority of Brazilian airports.

Figure 3 VCP Runway
Source: Google Earth

According to Brazilian CAA, *Agência Nacional de Aviação Civil* – ANAC (ANAC, 2021) and AIP Brasil (DECEA, 2021), VCP runway 15/33 is 3,240 meters long by 45 meters wide, has 03 RET`s (Alpha, Bravo, and Foxtrot), the surface is asphalt with PCN is 56/F/B/X/T. Runway End Safety Area (RESA) was implemented in both runways 15 and 33.

Runway 15 holds 85% of VCP operations equipped with ILS CAT I AR with MALSR - Medium Intensity Approach Light System with Runway alignment indicator lights to precision approaches. Runway 33 handles the other 15% of VCP operations equipped with VOR/DME and NDB to non-precision approach.

In addition to ground-based procedures, there are satellite-based procedures (RNAV and RNP) procedures in place for both runways (DECEA, 2021).

Regarding declared distance, Viracopos Campinas Airport runway infrastructure has the following distances Table 1:

Table 1 VCP runway declared distances

RWY	TORA(m)	TODA(m)	ASDA(m)	LDA(m)	COORDINATES
15	3150	3390	3150	3150	S 22 59 55 W 047 08 49
33	3240	3390	3240	3150	S 23 00 59 W 047 07 19

4.2.2 Aprons

As a significant national hub to Azul Airlines and Brazil's top position in cargo operations, currently, the Viracopos airport infrastructure is prepared for commercial and cargo operations in terms of aprons.

Kazda et al. (2015) state aprons are designed for parking aircraft and turning them around between flights. The airport is served by 06 aprons, as follow:

a) Apron 1: Before the inauguration of the new Terminal 1, Apron 1 (Figure 4) was used for commercial aviation, specifically for the turboprop aircraft – ATR. Today its use is focused on the allocation of general aviation aircraft.

Figure 4 VCP Apron 1
Source: Google Earth

b) Apron 2: it has been used basically to allocate aircraft overnight or out of operation (Figure 5).

Figure 5 VCP Apron 2
Source: Google Earth

c) Apron 3: it used for cargo aviation (Figure 6).

Figure 6 VCP Apron 3
Source: Google Earth

d) Apron 4 (November): it used for commercial aviation and jointly with apron 5 (Papa), represents more than 95% of VCP operations (Figure 7).

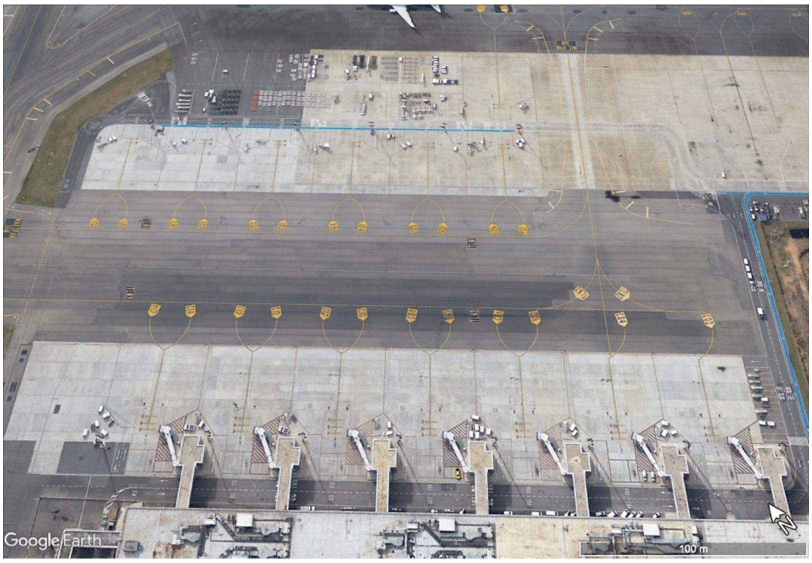

Figure 7 VCP Apron 4
Source: Google Earth

e) Apron 5 (Papa): it used for commercial aviation and jointly with apron 4 (November), represents more than 95% of VCP operations. Papa apron (Figure 8) is the most complex apron in the airport due to its 03 parallel taxi lanes.

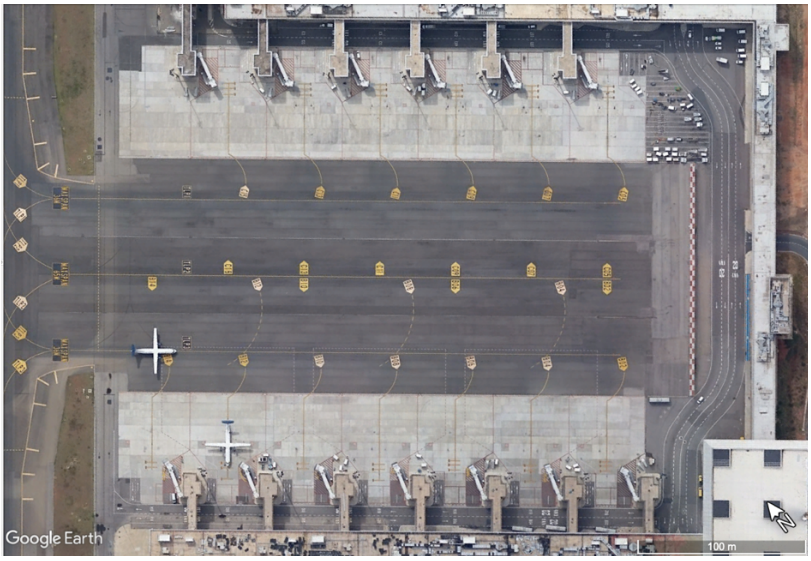

Figure 8 VCP Apron 5
Source: Google Earth

f) Apron 6 (Quebec): it used for international aviation (Figure 9).

Figure 9 VCP Apron 6
Source: Google Earth

4.2.3 Taxiways

According to Neufville et al. (2013), the taxiway system is designed to provide connections between the runways and the apron areas near and around passenger and cargo buildings, maintenance areas, etc.

The VCP airport has unique characteristics. At the same time, it stands as the national central hub of Azul Airlines and the big player in cargo handling national wide.

For this reason, it brings complexity to its airside infrastructure and its operations. Sort of complexity in the number of taxiways to connect the runway system to the aprons systems, as shown in Figure 10 and described below:

a) Taxiway A: is known as RET A its placed 1100m from runway 15.
b) Taxiway B: is known as RET B its placed 1357m from runway 33.
c) Taxiway C: it is a taxiway parallel to the runway.
d) Taxiway D: it is an entry point to runway 15.
e) Taxiway E: it is an entry point to runway 33.
f) Taxiway E1: it connects TWY E to the Azul Airlines hangar.
g) Taxiway F: is known as RET A its placed 2208m from runway 15.
h) Taxiway G: it is an entry point to runway 33
i) Taxiway H: it is an entry point to runway 15.
j) Taxiway I: it is an intersection between TWY G and TWY C used to access Apron 2.
k) Taxiway J: it is an intersection between TWY G and TWY C used to access Apron 1 and 3.

l) Taxiway K1: it is an entry point used only to access Apron 4.

m) Taxiway K2: it is an intersection between TWY G and TWY C used to access Apron 4.

n) Taxiway L1: it used to connect TWY M to TWY C and D.

o) Taxiway M: it used to access Apron 4, 5, and 6 and taxiways L1 e G.

p) Taxiway N1 and N2: these are an Apron 4 internal taxiway used to access stands and connect taxiway K1 to M.

q) Taxiways P1, P2, and P3: these are Apron 5 internals taxiways used to access stands.

r) Taxiways Q1, Q2, and Q3: these are Apron 6 internals taxiways used to access stands.

Figure 10 VCP Taxiways
Source: Google Earth

4.2.4 Future Infrastructure

Viracopos Campinas was among the first-round airport concession list. In 2012, the Federal Government conceded the airport for 30 years to the consortium called Aeroportos Brasil. In this first concession model, Infraero remained with 49% of the shares of the company.

With the concession contract signed, the new private operator assumed short-, medium-, and long-term investment obligations, as agreed under the auction terms.

In general terms, ANAC is responsible for oversight the concession contract set the timeline and triggers of the investment obligations assumed by the private operator, as followed:

- *June 14th, 2012 – Concession contract signature.*
- *July 11th, 2012 – Effective date of the contract.*
- *February 14th, 2013 – End of Phase IA. Transfer of operations from the Brazilian Airport Infrastructure Company (Infraero) to the concessionaire.*
- *May 11th, 2014 – End of Phase IB. Delivery of mandatory investments:*
  - *Passenger terminal with capacity to simultaneously process 1,550 boarding and 1,550 arriving passengers.*
  - *Patio for 35 aircrafts, with 28 parking positions to be served by boarding bridges.*

- *Access roads and parking lot with 4,500 spaces.*
- *Obstacle removal and providing of graded area of runway and taxiways strips, according to the critical operation for airplanes which the runway and taxiways are intended to serve.*

- *May 12th, 2014 – Start of Phase IC. Recovery of service level.*
- *May 12th, 2016 – End of Phase IC. Recovery of service level.*
- *May 13th, 2016 – Start of Phase II.*
  - *Maintenance of service level*.

  (ANAC, 2020)

Among other obligations firmed on concession contract, the 30-year concession set Investment triggers to airside, especially to the runway, as shown in Figure 11:

- *December 31st, 2018 – Delivery of mandatory investments: Implementation of new runway end safety areas.*
- *178.000 mov. / year demand or end of Phase II – Delivery of mandatory investments: Construction of second runway, with 3,600m length.*
- *351.000 mov. / year demand or end of Phase II – Delivery of mandatory investments: Construction of third runway, with 2,600m length.*
- *Reaching 456.000 mov. / year – Delivery of mandatory investments: Construction of fourth runway, with 2,200m length.*
- *July 11th, 2042 – End of Phase II.* (ANAC, 2020)

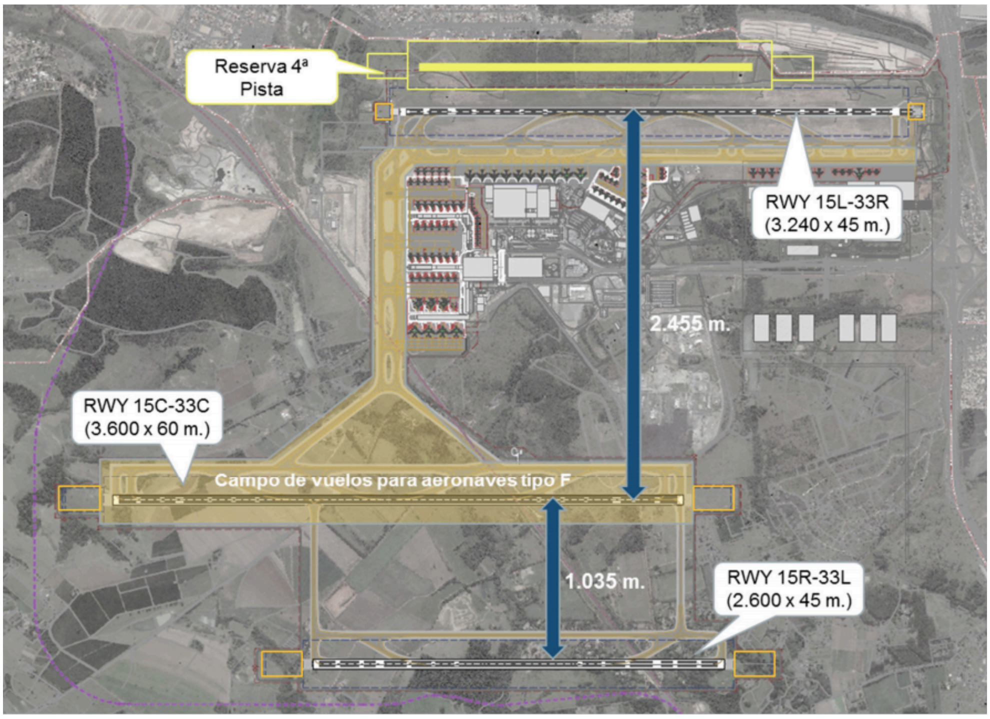

Figure 11 VCP Master Plan 30-year concession
Source: ABV

4.2.5 VCP Airside Operations - Approach & Departure

According to AIP Brasil (DECEA, 2021), flights within TMA-SP2 and CTR-Campinas shall be performed under instruments or visual flight rules.

Viracopos Campinas homologation allows operations in instrument flight rules IFR precision approaches. However, only RWY15 is equipped with an instrument landing system - ILS CAT I AR with MALSR - Medium Intensity Approach Light System with Runway alignment indicator lights. The lighting system guides aircraft approach safer, especially in adverse situations such as bad weather and night. ILS CAT I AR (authorization required) allows an aircraft to approach until a decision altitude (DA) of 150 feet (45 m) over the ground, within a 0.3 mile of the runway. At DA point, the runway should be visible to the pilot. Otherwise, they should perform a go-around procedure.

On the other hand, RWY33 is not equipped with ILS. Its homologation is to non-precision approaches. To perform this type of approach, it uses VOR/DME and NDB.

Another essential air navigation aid implemented in both runways is PAPI. It is a visual aid that provides visual guidance to help pilots maintain glideslope during approach procedure.

Besides ground-based procedures where allow pilots to perform precision and non-precision approaches, VCP has SID and IAC satellite-based charts in place to both runways.

To understand VCP operations, a brief description of arrivals and departures is necessary. AIP Brasil (DECEA, 2021) brings some recommendations about SBKP Local traffic regulations:

> ***Arrival:*** *Pilots are reminded that high speed taxiways from the landing runway enables ATC to apply minimum spacing on final approach that will achieve maximum runway utilization and will minimize the occurrence of "go-around". All arrivals are to ensure that they are fully vacated before stopping. During the arrival, pilot must select an appropriate and achievable Rapid Exit Taxiway (RET) to ensure MROT; Pilots should clear the runway completely (holding point markings) before decelerating to taxi speed and hold short of the adjacent parallel runway at the holding point allocated by the TWR; The maximum design speed of these RET is 50 kt when exiting the runway.*
>
> ***Departure:*** *Pilots should be ready for departure when reaching the holding point. If not, advice ground control. When cleared to line-up or take-off, pilots shall ensure, considering safety, that they are able to proceed expeditiously. Upon receiving the takeoff clearance, it must be started immediately. (the expected reaction time is up to 10 seconds, for the start of the takeoff); Unless otherwise instructed, Pilots are encouraged to take advantage of "intersection takeoffs" to ensure minimum runway occupancy time. Aircraft category A, B, C and D must be prepared to take off from RWY 15 at intersection with TWY Hotel when required. Distance available 2910 m; Aircraft category A, B and C must be prepared to take off from RWY 33 at intersection with TWY Foxtrot when required. Distance available 2208 m.*

In short, to arrivals and departures operations, VCP recommends to its users to ensure minimum runway occupancy time by selecting appropriate RET upon arrivals and proceed expeditiously once cleared to line-up or take-off. For departures, the airport operations also recommend take-off, when required, from intersections between the runway and taxiways, i.e., take off from RWY33 at the intersection with TWY Foxtrot.

All procedures and recommendations state at AIP Brasil are aligned with the ICAO standards, but achieving more efficiency and making the most implemented infrastructure is necessary to take some actions. The study will explain it later in this document.

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CHAPTER 5 – ANALYSIS OF THE NEEDS

Considering the infrastructure presented in Chapter 4 and its characteristics of being at the same time a cargo and passenger national hub, demanding a well-adjusted operation, VCP airport has been facing some bottlenecks that reflect a lack of efficiency in daily operations.

The constraints listed are the foundation to further analyses in this document.

5.1. Runway Occupancy Time

Serving as Azul Airlines national central hub, VCP handles a mixed aircraft environment, from turboprop aircraft to cargo aircraft, such as Boeing 747. The variety of operating aircraft is pushing the airside infrastructure, specifically the runway. The current procedures can handle operations until a certain level. Azul Airlines has been adding new destinations in its national and international network, and cargo operations increased even more in pandemic times. Runway occupancy time is a latent issue in VCP.

5.2. Approach and Departure procedures

Although VCP has published IFR and GNSS procedures for its approaches and departures complied with ICAO standards, the set of the published procedures itself did not turn VCP as efficient as its global peers.

5.3. Lack of taxiway Lima

As presented in paragraph 4.2.2., Viracopos airport has its operations concentrated on Apron 4 (November) and Apron 5 (Papa). It represents more the 90% of aircraft operations.

Especially to Apron 4 and 5 operations that involve a high demand of ground movement and turn arounds its operations have been degraded due to the current apron access infrastructure, i.e., the taxiway Mike.

The taxiway Lima is projected to be parallel to taxiway Mike. Still, its lack has affected ground operations, driving to an increase in taxi-in and taxi-out times and, consequently, delays.

5.4. Lack of redundant entry point to RWY33 holding point

Even though RWY33 represents only 15% of VCP operations, considering it is a non-precision approach runway that reduces landings efficiency in adverse situations, lack of redundant entry point to RWY 33 causes queues and delays in departure operations, mainly in peak hours.

5.5. Taxiway’s intersection

One of the main issues observed in VCP is related to its taxiway’s layout. There is an intersection between RET Alpha, Bravo, and taxiway Charlie. The current design has created a hotspot harming expeditious operation.

For instance, taxiway Charlie is vital to VCP's daily operations. It connects arrivals from RWY15 to the cargo apron (Apron 3), domestic and international passenger terminal (Apron 4, 5, and 6). Any mitigation action to avoid safety occurrences directly impacts taxi-in, taxi-out, and runway occupancy times, triggering overall operational improvements.

5.6. Restrict use of taxiway Kilo 1

The taxiway Kilo 1 is mainly used for Apron 4 entry due to an infrastructure issue. There is a pavement irregularity between taxiway Golf and apron 4, creating a downhill when the aircraft enters apron 4 via taxiway Kilo 1.

This infrastructure failure made airport operations avoid apron 4 exits via taxiway K1 due to the uphill track necessary to leave the apron. So, if the aircraft leaves apron 4 via Kilo 1, it needs to increase the engine thurst generating undesirable jet blast to the passenger terminal.

5.7. Taxiway Golf infrastructure extension

Taxiway Golf is essential to cargo operation because it is used as entry and exit to cargo apron 3. It is also used to taxi-in when RWY15 is the runway in-use and taxi-out when departures perform from RWY33.

Lack of taxiway Golf extension between apron 3 and taxiway Echo and Echo 1 is an issue to VCP. As Azul Airlines has recently opened its maintenance hangar in front of RWY33, towing activities from and to the hangar are frequent. Thereby, taxiway Charlie occupancy time by towing activities causes a direct impact on departures operations in RWY33 and arrivals from RWY15 that vacates the runway by RET Foxtrot.

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CHAPTER 6 – INTERNATIONAL BENCHMARK

Go in-depth into the study, I realized that it was essential to find a global benchmark to evaluate VCP infrastructure and operations with its pears. In this regard, London Gatwick - LGW, the world's busiest and most efficient single-runway airport, is the best example to study.

This chapter aims to explain the LGW infrastructure and operations to learn the best practices and procedures in place to analyze VCP needs.

6.1. Single runway airport

Perhaps the single most important facility on the airfield's movement area is the runway. After all, without a properly planned and managed runway, desired aircraft would be unable to use the airport. (Young, et al., 2011).

According to Neufville et al. (2013), *several major and many secondary airports have only a single runway. Because of limited land availability at their sites, it is also unlikely that many of these airports will ever add second runway.*

At single-runway airports, the landside facilities are to the side of the runway, with passenger buildings and cargo buildings possibly on opposite sides. However, because of site limitations, the buildings may sometimes be inconveniently located relative to the runway (Neufville et al., 2013)

As part of this study's goal to observe the best worldwide practices in terms of infrastructure and single-runway operations for eventual proposal to implementation in VCP to improve its operations, this study will present the global benchmark, London Gatwick.

6.2. London Gatwick Airport – LGW

The London Gatwick Airport (ICAO code: EGKK and IATA code: LGW), UK's second-largest airport and the world's busiest and most efficient single-runway airport, is situated in Crawley, West Sussex. *The airport is managed by VINCI Airports owning the majority shareholding of 50.01% and the remainder owned by a consortium of investors and managed by Global Infrastructure Partners (GIP), who have operated Gatwick since 2009* (Gatwick Airport, 2021)

London Gatwick airport currently operates in two terminals, the North Terminal with 98,000 m2 and the South Terminal covering 160,000 m2.

London/Gatwick geometric layout is quite simple, as illustrated by Figure 12– EGKK Aerodrome Chart. Although the airport seems to have a pair of close parallel runways, it operates with a single runway at all times because of the proximity of 08L/26R and 08R/26L: the former is normally used as a taxiway for the latter, except at times when 08R/26L is closed down for maintenance and repairs (Neufville, et al., 2013).

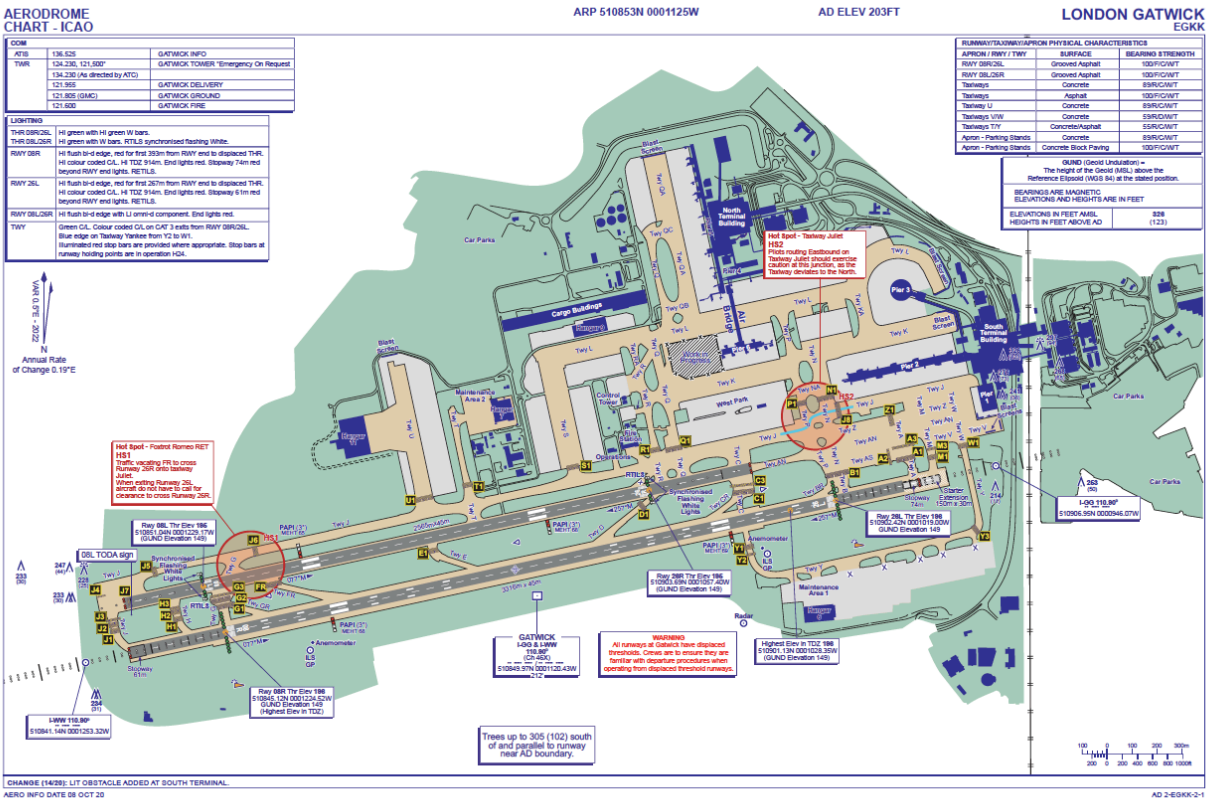

Figure 12 EGKK Aerodrome Chart
Source: (NATS, 2021)

Continuing the explanation about London Gatwick, Neufville et al. (2013) state that *the location of the main passenger building necessitates taxiing distances of about 3,500 m (2.2 miles) for aircraft taking off from 08R, which is the case much of the time. The nature of the traffic that single-runway airports handle is dictated in large part by the length of the runway. Milan/Linate, with a 2700 m (8860-ft) runway, is limited to short and medium-range flights. London/Gatwick and Geneva both have long runways and can accommodate intercontinental, long-range flights.*

Gatwick is the best example that single-runway airports can handle many passengers with sustainable growth, especially if its infrastructure and mix of aircraft enable operating wide-body aircraft.

For instance, in the Gatwick Airport Scheduling Declaration Summer 2021 IATA Calendar, the airport declared they were able and prepared to handle up to 55 movements per hour (Figure 13). A combination of hourly runway efficiency usage and a high percentage of wide-body in the LGW mix of aircraft led to a significant increase of passenger processed.

Gatwick Airport Scheduling Declaration
Summer 2021

Hourly Runway Scheduling Limits

S21 Declaration

Start of UTC Hour	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	15hr (05-19)	17hr (05-21)
Total Limit	29	53	55	52	50	51	55	54	55	54	52	52	55	55	54	48	46	39	29	30	795	880
Arrival Limit	20	20	25	26	23	26	28	28	28	27	26	26	28	28	28	27	25	35	27	25	394	454
Departure Limit	20	37	36	29	30	28	29	29	30	29	29	28	29	30	28	25	22	10	10	10	446	478
Arr-Dep Flex:	11	4	6	3	3	3	2	3	3	2	3	2	2	3	2	4	1	6	8	5	44	51

Changes against previous declaration

Start of UTC Hour	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	15hr (05-19)	17hr (05-21)
Total Limit			1					-1		1	1										2	2
Arrival Limit																		1			0	1
Departure Limit			1								1										2	2

Figure 13 Gatwick Scheduling Declaration Summer 2021
Source: (ACL Airport Coordination Limited Ltd, 2020)

The decrease of aircraft movements in Gatwick at late night and first hours of the day operations is because it has restrictions on the number of aircraft that can take-off and landing between 11:30 pm and 06:00 am, due to noise abatement measures. The number of flights between 11:30 pm and 06:30 am is limited by a quota (seven months) and 3,250 in winter. At night, between the restriction time, the noise limit is 87 dBA. There is also a separate quota system based on noise, with noisy aircraft using more points (UK Department for Transport, 2021).

Even though the nighttime restrictions and considering figures before the COVID19 pandemic caused a massive impact on global aviation, London Gatwick had been performing an ascendant growth curve, handled 46.6 million passengers in 2019 processed 285,000 aircraft movements that year. (Civil Aviation Authority, 2021)

However, in 2020 the airport suffered a 77% drawdown in aircraft movements. In that year, LGW handled 63,136 aircraft, according to UK Civil Aviation Authority (2021).

To understand how London/Gatwick has improved its numbers year over year and became a worldwide benchmark regarding growing with efficiency without taking the eyes off safety, an explanation of some factors about infrastructure and operations is necessary.

6.3. London Gatwick Airport Infrastructure

Even though Gatwick is classified as a single-runway airport, it has two runways. The Northern Runway (08L/26R) is a non-instrument runway and will only be used when Main Runway (08R/26L) is temporarily non-operational because of maintenance or incident. Thus, during routine daily operations, it is used as a taxiway. The operations cannot use both runways simultaneously because of insufficient separation between the two, only 200m apart.

According to The UK Integrated Aeronautical Information Package – IAIP (NATS, 2021), the Main Runway 08R/26L is 3,316 meters long by 45 meters wide, has 06 RET`s (Delta, Charlie Romeo and Bravo Romeo on eastbound operations and Echo, Foxtrot Romeo, and Golf Romeo on westbound). The surface is grooved asphalt, and it is PCN 100/F/C/W/T.

One of the solutions presented at LGW to improve runway operations and reduce runway occupancy time - ROT is Runway Guard Lights. It is installed at all runway/taxiway intersections, comprising alternating flashing amber standard low-level dual traffic lights, operating H24. Taxiway Unavailable Bars (TUBS) contains a line of red stop lights spaced at approximately 3 m centers across the full width of each RET/RAT's mouth adjacent to the main runway running parallel to the runway centerline. *TUBS are installed at Alpha, Bravo, Bravo Romeo, Charlie, Charlie Romeo, Delta, Echo, Foxtrot Romeo, Golf, Golf Romeo, Hotel and Juliet, to prevent incursions onto taxiways that are unavailable due to operational issues such as Work in Progress* (NATS, 2021).

Rapid Exit Taxiway Indicator Lights (RETILs) are installed on the first and second rapid exit taxiways for Runway 08R/26L. They provide a 3-2-1 countdown pattern of amber lights to enable pilots to locate the nearest RET and apply braking action for a more efficient roll-out and runway exit speed. *The lighting of runways 08R and 26L at Gatwick is precision approach Category III.* (NATS, 2021)

Regarding navaids and type of operation, the airport handles precision and non-precision approaches. The main runway 08R/26L is approved for CAT II/III operations, and special aircrew and aircraft certifications are required. The lighting system of its runway is precision approach Category III. It also has precision Approach Path Indicators (PAPI) installed. The northern runway operates non-precision approaches, and it is equipped with air navigation ground aids such as DME. Both runways have GNSS procedures in place, as well as departures and approaches.

The apron system comprises 186 centerlines, which can use a stand flexibly to park up to 186 aircraft. Both South and North Terminal have 31 stands each, while there are 57 remote stands served by coaches (Gatwick Airport, 2021), as illustrated in Figure 14.

To coordinate all the movement in the movement area and maintain the high level of efficiency observed in runway operations, Gatwick Airport is equipped with an advanced surface movement radar utilizing Mode-S transponder, also called Ground Movement Radar (GMR).

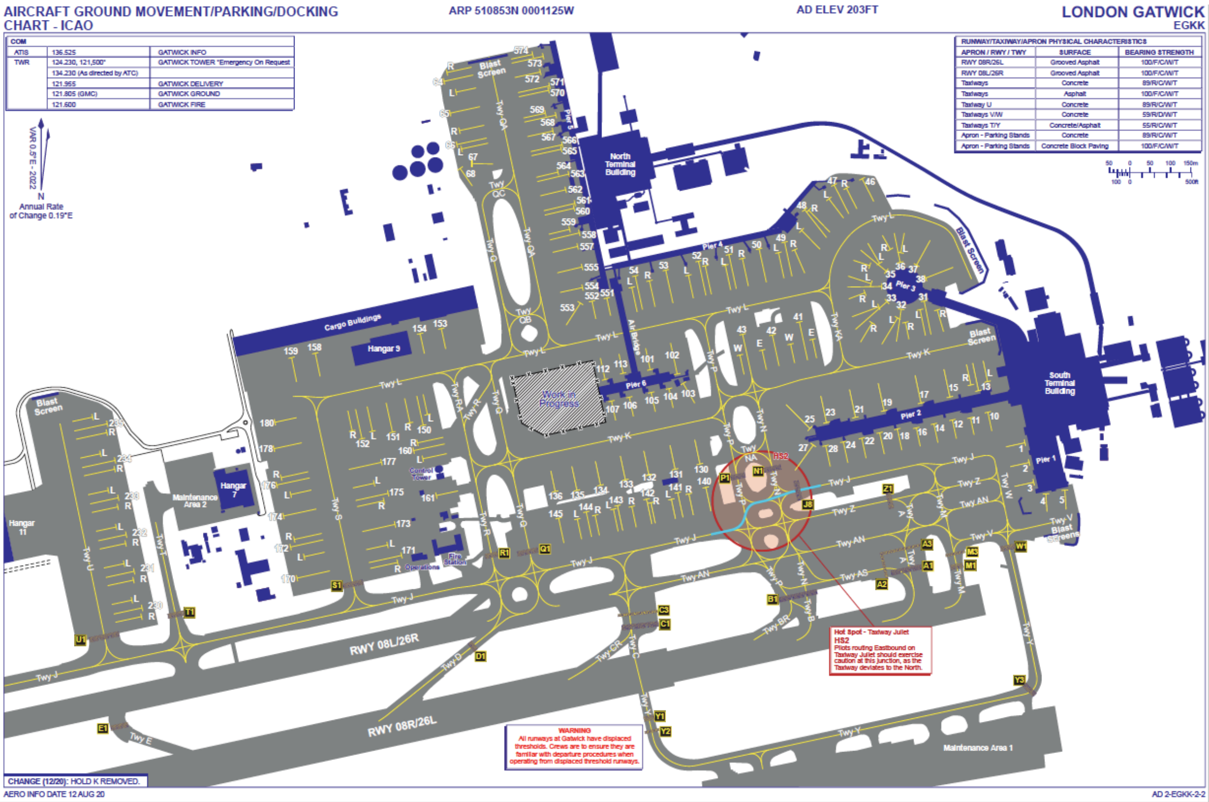

Figure 14 EGKK Aircraft Ground Movement/Parking/Docking Chart

Source: (NATS, 2021)

6.4. London Gatwick Airport Operations

Over the last decade, LGW has been presented continuous growth having solid numbers in its passengers' operations. The airport has the characteristic of being a short and long-haul hub, leading to a large mix of airline operators offering full service, low-cost and charter services, with over 50 currently operating regularly from Gatwick. Around 1 in 5 passengers are now traveling to a long-haul destination since LGW has more than 60 long-haul routes worldwide (Gatwick Airport, 2021).

This study analyzed an academic approach to figure out why Gatwick became the world's busiest and most efficient single-runway airport making the best use of existing infrastructure.

Initially, the scope of analyzes observed a group of procedures for departures and arrivals that together, well-executed and monitored contributes to a robust foundation to Gatwick efficiency and growth. According to AIP UK and LGW charts (2021), several aspects were analyzed by and pointed out by item:

For arrivals:

a) **Speed Restrictions:** this procedure is applied for ATC separation purposes and is mandatory.

- 220 KT from the holding facility during the intermediate approach phase;

- 180 KT on base leg/closing heading to the ILS; and
- between 180 KT and 160 KT when first established on the ILS;

b) **Minimum runway occupancy time:** regarding arrivals, LGW has the necessary infrastructure to apply and benefit from these procedures. In short, the procedure consists of reminding pilots to rapid vacate the runway in an appropriate RET that enables ATC to use the minimum spacing on the final approach that will maximize maximum runway utilization and will minimize the occurrence of go-arounds. Table 2, extract from AIP UK (2021), explains RET's details and its procedures during landing.

Table 2 LGW Rapid Exit Taxiways
Source: (NATS, 2021)

08R	***D***	***CR***	***BR***
Distance from threshold(M)	*1318*	*1739*	*2194*
Design Exit Speed (KT)	*38*	*49*	*52*
Notes: *Landing aircraft are to vacate expeditiously.* *Arrivals are to ensure fully vacated before stopping.* *Traffic vacating at **CR** to await onward clearance before entering taxiway Juliet due to conflicting ground traffic.* *Traffic vacating at **BR** to route TWY Papa and hold before TWY Juliet to ensure tail clear of the runway.* *Tactical requests to extend the landing roll to reduce ground taxi/exit nearer to parking stand are not to be made to ATC.* *Taxiway Echo is not available for vacating Runway 08R.*			
26L	***E***	***FR***	***GR***
Distance from threshold(M)	*1323*	*1773*	*2069*
Design Exit Speed (KT)	*38*	*52*	*49*
Notes: *Landing aircraft are to vacate expeditiously.* *Arrivals are to ensure fully vacated before stopping.* *Traffic vacating at **E** are to turn right on to Runway 08L without stopping on the runway exit.* *Traffic vacating **FR** and **GR** to cross Runway 26R onto Taxiway Juliet. When exiting Runway 26L aircraft do not have to call for clearance to cross Runway 26R as the runways cannot be used simultaneously.* *Pilots of Code F must not stop until the aircraft is established on, or north of, 08L/26R.* *Taxiway Delta is not available for vacating Runway 26L.*			

The preferred exit points for RWY 26L are:

- *Medium/Heavy Aircraft: RET FR (Distance from THR 1773m).*

- *Light/Small Aircraft: RET E (Distance from THR 1323m).*

The preferred exit points for RWY 08R are:

- *Medium/Heavy Aircraft: RET CR (Distance from THR 1739m).*
- *Light/Small Aircraft: RET D (Distance from THR 1318m).*

As shown in Table 2, the landing procedure to vacate the runway, including taxiway crossing and low-frequency occupancy, maximizes runway utilization, reduces ATCO workload, and provides an expeditious flow in landing operations.

c) **"Land After" procedure:** The AIP UK (2021) states: *the spacing provided between aircraft will be designed to achieve maximum runway utilization within the parameters of safe separation minima (including vortex effect) and runway occupancy. It is important to the validity of the separation provided, and to the achievement of optimum runway capacity that runway occupancy time is kept to a minimum consistent with the prevailing conditions.* Usually, only one aircraft is permitted to land or take-off on the RWY-in-use at any one time. However, in LGW, when the traffic sequence is two successive landing aircraft, the second one may be allowed to land before the first one has cleared the RWY-in-use. This sort of procedure is possible in LGW due to the long runway 08R/26L that allows the preceding landing aircraft has landed and has passed a point at least 2500m/1.35 NM from the threshold of the runway; when the second aircraft has been warned; and also, the second aircraft will be able to see the first aircraft clearly and continuously until it is clear of the RWY (Jeppesen, 2020). This procedure is only applied under VMC conditions and during daylight hours.

d) **Taxiway Lighting System***: Rapid Exit Taxiway Indicator Lights (RETILs) and paint markings are provided on Runway 08R/26L to assist pilots in judging distances to RET and enable them to apply braking action for a more efficient roll-out and runway exit speed. RETILs are provided for exit at D and CR on 08R and E and FR on 26L* (NATS, 2021).

e) **Continuous Descent Operations:** in the LGW approach *on receipt of descent clearance the pilot will descend at the rate he judges will be best suited to the achievement of continuous descent, the object being to join the glide path at the appropriate height for the distance without recourse to level flight* (NATS, 2021). According to London Gatwick 2019 Performance Report, in 2019, 90% of arriving aircraft have performed CDO that allows (Gatwick Airport, 2021) predictability in operation and reduces the noise footprint.

For departures:

a) **Taxiway Guidance System to RWY 08L/26R:** this important TWY lighting system allows expeditious flow and accurate aircraft guidance through a complex taxiway infrastructure during RWYs 08L and 26R operations. The system consists of limited selective switching of green centerline lights in conjunction with red STOP BARS at RWY holding points.

b) **Ground Holding Areas:** As part of the A-CDM implemented airport group that means all its aircraft operations (arrival + departures) are predetermined or scheduled by Eurocontrol ATC slots, be on time is a must. So, any delay may be crucial for the airport operations planning and starts an undesired chain reaction. In this context, LGW has adopted an apron buffer solution: departing aircraft not holding an immediate ATC slot may push-back and hold a designated ground holding area (not to be confused with RWY holding points). It is an area on the airport in a self-maneuvering nose-out configuration ready to advance any slot improvement that may become available. It optimizes the use of parking stands, ground resources, and departure slots.

c) **Minimum runway occupancy time:** to reduce runway occupancy time on departures, the airport has implemented a procedure that optimizes the runway usage during departures. *On receipt of line-up clearance pilots should ensure, commensurate with safety and standard operating procedures, that they are able to taxi into the correct position at the hold and line-up on the RWY as soon as the preceding aircraft has commenced its take-off roll or landing run*. Whenever possible, cockpit checks should be completed before the line-up, and any checks requiring completion while on the RWY should be kept to the minimum required. Pilots should ensure that they can commence the take-off roll immediately after take-off clearance is issued (NATS, 2021).

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CHAPTER 7 – CASE STUDY

This chapter presents a case study done by VCP TWR in the context of Agile VCP tasks. It consists of an explanation of assessment of the final approach and runway occupancy time to check the practicability of 5NM separation of one departure between two successive arrivals, aiming to increase runway capacity and efficiency and reduce runway occupancy time.

7.1. Introduction

Since the beginning of this study, during the first Agile VCP meeting, I had some unstructured interviews with experts from different expertise who operate in the airport to understand better airport airside inefficiencies. The runway operations were permanently appointed as a constrain to improve operations efficiency.

I have done extensive academic research in parallel, and I found studies dealing with assessment and benchmarks of airport airside operations. One of those studies was about analyses of Brazilian airport infrastructure's role as a conditioning factor to seventeen airports' capacity that supported the 2014 World Cup. The methodology adopted in the paper was data processing according to a multivariable analysis approach called Data Envelopment Analysis (DEA), which used the tool called Integrated Decision Support System - SIAD (Crespo, 2014).

Viracopos Campinas airport was part of the study scope and had its runway and RET infrastructure efficiency analyzed using the Data Envelopment Analysis (DEA) and benchmarked against Gatwick. Still, according to Crespo (2014), the SIAD tool processed the runway and RET data from each airport and ranked it according to the benchmark efficiency. After that, the study analyzed the minimal infrastructure required to keep, by that time, current capacity and projected what would be the capacity if some operations procedures were applied. Regarding VCP, the study concluded that the runway and RET infrastructure were underutilized, and it was necessary to improve its operational procedures. Moreover, the study brought VCP runway capacity of 28 movements hourly in 2014 and concluded if operational improvements were applied, VCP runway capacity would increase to 40 movements hourly.

According to CGNA 2019 Air Traffic Statistical Yearbook (2020), the aircraft movement in VCP has increased 5.4% over 2018 with a daily average of 322 aircrafts movements. The hourly peak observed in VCP was 31 movements, as we can see in Figure 15. As Figure 15 is in Portuguese to better understand, the figure displays the 2019 VCP daily average hourly (maximum and minimum values), segregate by Monday to Friday (light blue background) and Saturday-Sunday (white background).

Média Diária de Movimentos Hora-Hora de SBKP – 2019 (Segunda-Sexta e Sábado-Domingo)

		0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Seg-Sex	Máx.	23	6	4	4	9	13	26	27	30	31	21	20	25	28	26	17	24	30	29	27	24	30	30	30
	Méd.	**7**	**1**	**1**	**0**	**4**	**8**	**17**	**19**	**22**	**21**	**10**	**10**	**18**	**19**	**17**	**10**	**16**	**20**	**18**	**14**	**15**	**21**	**21**	**21**
	Mín.	0	0	0	0	0	0	0	0	0	4	3	4	8	10	7	3	6	5	1	5	7	3	5	1
Sáb-Dom	Máx.	23	4	4	2	8	12	20	21	26	31	17	21	25	26	22	15	21	27	26	19	26	26	31	28
	Méd.	**4**	**1**	**1**	**1**	**3**	**6**	**13**	**16**	**19**	**17**	**9**	**10**	**15**	**18**	**14**	**10**	**11**	**16**	**14**	**13**	**13**	**17**	**16**	**15**
	Mín.	0	0	0	0	0	1	7	12	13	6	4	4	8	9	7	3	4	5	4	6	9	7	5	3

Figure 15 2019 VCP daily average hourly
Source: (DECEA, 2020)

Even though the massive impact on aviation due to the COVID19 pandemic, in 2020, VCP observed a slight increase in hourly peak, reaching 32 movements, as shown in Figure 16 (DECEA, 2021). As Figure 16 is in Portuguese to better understand, the figure displays the 2019 VCP daily average hourly (maximum and minimum values), segregate by Monday to Friday (light blue background) and Saturday-Sunday (white background).

Média Diária de Movimentos Hora-Hora de SBKP -2020 (Segunda-Sexta e Sábado-Domingo)

		0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
Seg-Sex	Máx.	17	4	4	3	8	11	26	27	27	26	14	24	28	25	26	19	26	29	28	19	25	25	32	27
	Méd.	3	1	0	0	3	4	13	12	15	14	5	10	13	13	11	6	13	12	12	9	13	11	15	10
	Mín.	0	0	0	0	0	0	0	2	1	2	0	0	0	1	0	0	1	0	0	2	1	3	0	0
Sáb-Dom	Máx.	20	5	2	2	6	11	24	22	28	24	12	22	22	24	19	14	23	23	29	23	23	21	27	30
	Méd.	2	1	0	0	2	3	11	10	13	10	4	7	8	9	7	4	7	8	7	8	12	8	12	7
	Mín.	0	0	0	0	0	0	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 16 2020 VCP daily average hourly
Source: (DECEA, 2020)

However, 2020 VCP statistics reported 73,698 aircraft handled in that year (Aeroportos Brasil Viracopos, 2021), representing a 35.61% drawdown over 2019 (Figure 17).

After the VCP concession to a private sector in 2012, increasing the runway capacity is essential for its operational optimization. It is a fact that the construction of a second runway, as expected in the concession contract, will bring this capacity increase. However, since demand triggers foreseen for the second runway are still far from becoming a reality. Given the air traffic trend observed in the last few years and an expectation of recovery in the medium-term due to reduction caused by the COVID19 pandemic, feasibility studies for the adoption of operational procedures that enable a capacity increase is fundamental before the airport infrastructure expansion.

Summary of Airport Movement (SAM)												
Viracopos International Airport Operational Movement: January to December 2020												
2020	**Aircraft** *(Land and Takeoff)*			**Passengers** *(Inbound / Outbound / Connection)*			**Cargo** *(tonnes)*			**Courier Cargo** *(tonnes)*		
	DOM	INT	SUM	DOM	INT	SUM	DOM	INT*	SUM	DOM	INT*	SUM
January	8.626	1.038	**9.664**	859.995	104.797	**964.792**	3.097	11.590	**14.687**	0	421	**421**
February	7.906	1.008	**8.914**	754.823	83.899	**838.722**	3.027	12.890	**15.917**	0	362	**362**
March	5.882	923	**6.805**	523.129	52.349	**575.478**	2.831	15.092	**17.923**	0	449	**449**
April	1.483	607	**2.090**	145.391	5.155	**150.546**	1.133	17.793	**18.926**	0	339	**339**
May	2.360	612	**2.972**	218.545	8.025	**226.570**	3.343	16.572	**19.915**	0	399	**399**
June	3.083	680	**3.763**	294.795	10.674	**305.469**	5.945	15.742	**21.687**	0	477	**477**
July	3.741	667	**4.408**	373.910	9.316	**383.226**	3.777	15.885	**19.662**	0	583	**583**
August	4.470	663	**5.133**	444.494	9.716	**454.210**	5.851	16.253	**22.104**	0	560	**560**
September	5.095	676	**5.771**	553.638	11.115	**564.753**	6.627	16.720	**23.347**	0	549	**549**
October	6.463	788	**7.251**	686.097	15.410	**701.507**	7.331	20.005	**27.336**	0	550	**550**
November	7.452	806	**8.258**	738.838	15.581	**754.419**	7.489	19.616	**27.105**	0	492	**492**
December	7.823	846	**8.669**	769.350	20.019	**789.369**	8.378	19.483	**27.861**	0	563	**563**
SUM	64.384	9.314	**73.698**	6.363.005	346.056	**6.709.061**	58.829	197.641	**256.470**	0	5.744	**5.744**
Sum (same period of 2019)	102.614	11.845	**114.459**	9.607.559	977.459	**10.585.018**	36.299	180.148	**216.447**	0	5.467	**5.467**
Variation (same period 2019)	-37,26%	-21,37%	**-35,61%**	-33,77%	-64,60%	**-36,62%**	62,07%	9,71%	**18,49%**	-	5,07%	**5,07%**

Figure 17 Summary of Airport Movement
Source: (Aeroportos Brasil Viracopos, 2021)

In the Viracopos Airport Infrastructure Capacity Declaration for Summer 2021 IATA Calendar (Aeroportos Brasil Viracopos, 2020), the airport declared its runway capacity in 40 movements per hour (Figure 18).

Capacidade de Pista				
Regra de Desbalanceamento das Operações no Aeroporto de Viracopos *Parecer Técnico: Ofício nº 7/AOM/3236 de 9 de abril de 2020*				
SBKP	**Tipo**	**R60 - Mov/60min**	**R15 - Mov/15min**	**R05 - Mov/05min**
	Capacidade	40	10	4
	Alocação de Pouso	25	8	4
	Alocação de Decolagem	30	8	4

Figure 18 VCP Runway Declared Capacity
Source: (Aeroportos Brasil Viracopos, 2020)

7.2. Final Approach and ROT Assessment

In the Agile VCP working group context, a final approach and runway occupancy time assessment demanded the group to go in-depth in this issue. The goal was to check the practicability of 5NM separation for one departure between two successive arrivals.

First, the VCP TWR headed a data collection to analyze the feasibility of 5MN separation for two consecutive approaches intercalated by one departure. Considering the IAC ILS RWY 15 and IAC RNAV RWY 33 charts, a survey aimed to find out the final approach average time and average runway occupancy time (ROT) was done taking into account the following scenarios:

a) The time between landing aircraft crossing THR 15 and the following aircraft airborne over FAP/FAF KP061 (Figure 19).

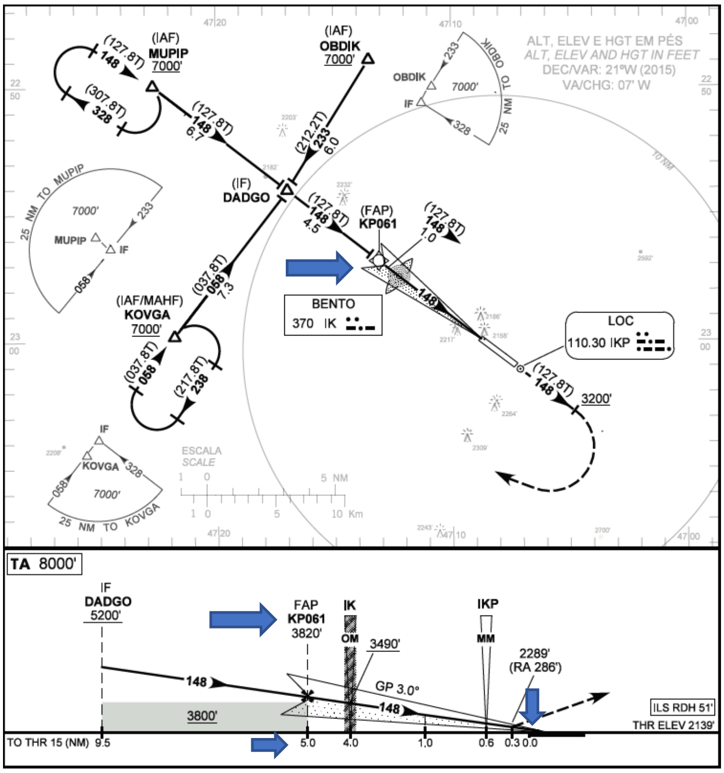

Figure 19 IAC ILS RWY 15
Source: (DECEA, 2021)

b) The time between the leading aircraft crossing THR 33 and the trailing aircraft flying over FAF KP063 (Figure 20).

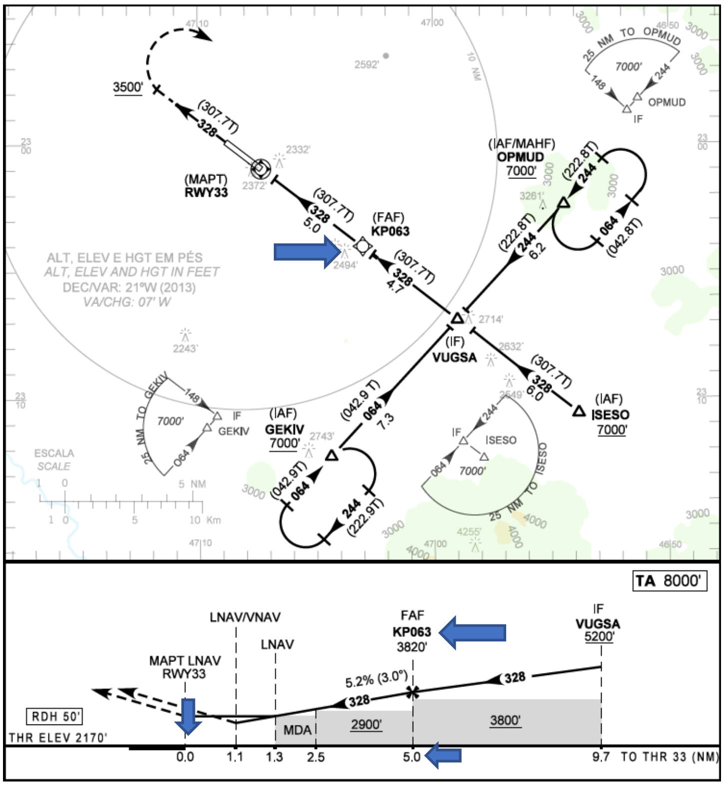

Figure 20 IAC RNAV RWY 33
Source: (DECEA, 2021)

c) Runway occupancy time from THR15 crossing until clear onto TWY Alpha or TWY Foxtrot (Figure 21).

Figure 21 RWY 15 arrival flow
Source: Google Earth

d) Runway occupancy time from THR33 crossing until clear onto TWY Bravo (Figure 22).

Figure 22 RWY 33 arrival flow
Source: Google Earth

e) Departure time from waiting on holding point cleared to line-up and take-off run until crossing the threshold (Figure 23).

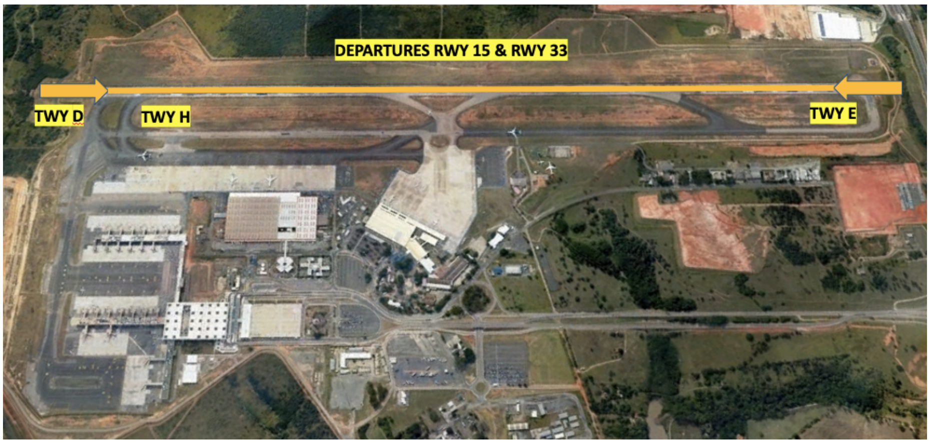

Figure 23 RWY 15/33 departure flow
Source: Google Earth

The survey was carried out by VCP TWR that had got data from daily operations during random days. The scope was to measure operation times between final approach points (FAP) and runway threshold for both runways and measure runway occupancy time in departures and arrivals to eventually evaluate the feasibility of a departure between two successive arrivals within 5NM separation. The survey observed the following outputs considering the type of operations (general or commercial aviation), type of aircraft, and performance. The results are shown in Table 3, Table 4, Table 5, Table 6, and Table 7 below:

Table 3 RWY 15 occupancy time clearing at TWY Alpha

	RWY15 OCCUPANCY TIME - TWY A				
ARR	GEN. AVIATION - TURBOPROP & HELICOP.	GEN. AVIATION - JET	TURBOPROP	JET - CAT C	JET - CAT D/E
TIME	01m06s	00m56s	00m48s	00m50s	01m09s

Table 4 RWY 33 occupancy time clearing at TWY Bravo

	RWY33 OCCUPANCY TIME - TWY B			
ARR	GEN. AVIATION - TURBOPROP & HELICOP.	GEN. AVIATION - JET	TURBOPROP	JET – CAT. C
TIME	NIL	01m06s	00m54s	00m54s

Table 5 RWY 15 final approach time from FAP/FAF KP061 to THR 15

	RWY15 FINAL APPROACH TIME				
ARR	GEN. AVIATION - TURBOPROP & HELICOP.	GEN. AVIATION - JET	TURBOPROP	JET - CAT. C	JET - CAT. D/E
TIME	02m23s	02m12s	02m25s	02m09s	02m01s

Table 6 RWY 33 final approach time from FAF KP063 to THR 33

	RWY33 FINAL APPROACH TIME				
ARR	GEN. AVIATION - TURBOPROP & HELICOP.	GEN. AVIATION - JET	TURBOPROP	JET - CAT. C	JET - CAT. D/E
TIME	02m46s	02m13s	02m37s	02m09s	01m57s

Table 7 Take-off time since waiting on holding point to THR crossing

	TAKE-OFF - HOLDING POINT TO OPPOSITE THR	
DEP	MIN. TIME	MAX. TIME
	01m50s	02m00s

7.3. Data Analyses and Findings

The focus of the assessment was on commercial aviation, which represents 93% of airport aircraft movement. So, some findings were noticed about that:

a) Arrival followed by departure in RWY 15:

- Turboprop operations: considering total runway occupancy time of a leading arrival aircraft vacating onto TWY Alpha and a trailing departure aircraft, since waiting on holding point, cleared to the line-up and take-off run until crossing the threshold, observed average time was 02 minutes and 48 seconds.

- Category C Jet operations: considering total runway occupancy time of a leading arrival aircraft vacating onto TWY Alpha and a trailing departure aircraft, since waiting on holding point, cleared to the line-up and take-off run until crossing the threshold, observed average time was 02 minutes and 50 seconds.
- Category D/E Jet operations: considering total runway occupancy time of a leading arrival aircraft vacating onto TWY Foxtrot and a trailing departure aircraft, since waiting on holding point, cleared to the line-up and take-off run until crossing the threshold, observed average time was 03 minutes and 09 seconds.

b) Arrival followed by departure in RWY33:

- Turboprop operations: considering total runway occupancy time of a leading arrival aircraft vacating onto TWY Bravo and a trailing departure aircraft, since waiting on holding point, cleared to the line-up and take-off run until crossing the threshold, observed average time was 02 minutes and 54 seconds.
- Category C Jet operations: considering total runway occupancy time of a leading arrival aircraft vacating onto TWY Bravo and a trailing departure aircraft, since waiting on holding point, cleared to the line-up and take-off run until crossing the threshold, observed average time was 02 minutes and 54 seconds.

c) Two successive arrivals in RWY 15:

- Turboprop operations: considering total time on final approach (from FAP to runway threshold), the observed average time was 02 minutes and 25 seconds. Thus, when the leading aircraft vacate RWY 15 via TWY Alpha, the trailing aircraft would be 01 minutes and 37 seconds from the runway threshold.
- Category C Jet operations: considering total time on final approach (from FAP to runway threshold), observed average time was 02 minutes and 09 seconds. Thus, when the leading aircraft vacate RWY 15 via TWY Alpha, the trailing aircraft would be 01 minutes and 19 seconds from the runway threshold.
- Category D/E Jet operations: considering total time on final approach (from FAP to runway threshold), observed average time was 02 minutes and 01 seconds. Thus, when the leading aircraft vacate RWY 15 via TWY Foxtrot, the trailing aircraft would be 52 seconds from the runway threshold.

d) Two successive arrivals in RWY 33:

- Turboprop operations: considering total time on final approach (from FAF to runway threshold), the observed average time was 02 minutes and 25 seconds. Thus, when the leading aircraft vacate RWY 15 via TWY Bravo, the trailing aircraft would be 01 minutes and 31 seconds from the runway threshold.

- Category C Jet operations: considering total time on final approach (from FAF to runway threshold), observed average time was 02 minutes and 09 seconds. Thus, when the leading aircraft vacate RWY 15 via TWY Bravo, the trailing aircraft would be 01 minutes and 15 seconds from the runway threshold.

Knowing the runway occupancy time and final approach time for each situation presented on the assessment, the results observed for one departure between two successive arrivals within 5NM separation are:

a) RWY 15:
   - Turboprop operations: the total average time noticed in the survey to one landing succeeding by one take-off was 168 seconds. Once the leading aircraft vacated the runway via TWY Alpha, the trailing aircraft will be 97 seconds to cross the runway threshold. The average observed rate of descent is 695 ft/min. The departure procedure took at least 120 seconds to perform. Thus, 97 seconds won't be sufficient for a turboprop aircraft to take off between two successive arrivals within 5NM separation, considering current VCP procedures.
   - Category C Jet operations: the total average time noticed in the survey to one landing succeeding by one take-off was 170 seconds. Once the leading aircraft vacated the runway via TWY Alpha, the trailing aircraft will be 79 seconds to cross the runway threshold. The average observed rate of descent is 792 ft/min. The departure procedure took at least 120 seconds to perform. Thus, 79 seconds won't be sufficient for a category C jet aircraft to take off between two successive arrivals within 5NM separation, considering current VCP procedures.
   - Category D/E Jet operations: the total average time noticed in the survey to one landing succeeding by one take-off was 189 seconds. Once the leading aircraft vacated the runway via TWY Foxtrot, the trailing aircraft will be 52 seconds to cross the runway threshold. The average observed rate of descent is 833 ft/min. The departure procedure took at least 120 seconds to perform. Thus, 52 seconds won't be sufficient for a category D/E jet aircraft to take off between two successive arrivals within 5NM separation, considering current VCP procedures.
b) RWY 33:
   - Turboprop operations: the total average time noticed in the survey to one landing succeeding by one take-off was 174 seconds. Once the leading aircraft vacated the runway

via TWY Bravo, the trailing aircraft will be 91 seconds to cross the runway threshold. The average observed rate of descent is 630 ft/min. The departure procedure took at least 120 seconds to perform. Thus, 91 seconds won't be sufficient for a turboprop aircraft to take off between two successive arrivals within 5NM separation, considering current VCP procedures.

- Category C Jet operations: the total average time noticed in the survey to one landing succeeding by one take-off was 174 seconds. Once the leading aircraft vacated the runway via TWY Bravo, the trailing aircraft will be 75 seconds to cross the runway threshold. The average observed rate of descent is 767 ft/min. The departure procedure took at least 120 seconds to perform. Thus, 75 seconds won't be sufficient for a category C jet aircraft to take off between two successive arrivals within 5NM separation, considering current VCP procedures.

7.4. Assessment Conclusion

Based on database analyses, calculation of arrival times, runway occupancy time, and all departure procedure time, the study concluded that 5NM separation for successive arrivals with an intercalated departure would not be feasible under current operating conditions. The assessment also pointed out the need for operational procedure adjustments in VCP, which could allow the implementation of intended 5NM separation for one departure between two successive arrivals, taking into account the possible solutions already implemented in airports around the world, as follow:

a) Speed restrictions in the final approach.
b) Pilots alert ATC (APP or TWR) when it is not feasible to clear the runway at the expected TWY, for instance, narrowbodies on TWY Alpha and widebodies on TWY Foxtrot.
c) Use of immediate curves after departures, performing SID omnidirectional.
d) Reduce Runway Separation Minima – RRSM.

To propose improvements in runway capacity and efficiency, based on best practices studied in the global benchmark to single-runway operations, my presented study working along with the Agile VCP working group. In this sense, I have brought in the next chapter a possible solution to increase runway capacity.

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CHAPTER 8 – PRESENTATION OF POSSIBLE SOLUTION

This chapter explains the possible solutions to VCP operations improvement I have studied and performed during this Advanced Master final project among the Agile VCP working group.

8.1. Speed Restrictions

As explained in Chapter 7 about the single-runway international benchmark, London Gatwick is placed in one of the world's busiest and congested air traffic environments and surrounded by high competitiveness airports market in Europe. Such inherent characteristics pushed LGW to seek continuous improvement in its operations to increase its market share.

Bearing in mind the scenario described, a synchronized well-managed, and structured operation is mandatory to succeed, and LGW has been doing its homework. Every procedure itself is essential to the whole landing process, but everything begins at the STAR procedure. This phase is critical to sequence aircraft with proper separation to have a predictable landing sequence and organized and expeditious aircraft flow.

To get high runway efficiency, LGW has implemented speed restrictions in its approach's procedures. This sort of procedure is applied for ATC separation purposes and is mandatory. The speed is decreasing gradually to equalize all approaches performances maintain the separation, regardless of aircraft category. The speed restrictions consist in:

1. *220 KT from the holding facility during the intermediate approach phase.*
2. *180 KT on base leg/closing heading to the ILS.*
3. *Between 180 KT and 160 KT when first established on the ILS.*

   (Jeppesen, 2020)

Also, the Jeppesen LGW Airport Briefing chart (Jeppesen, 2020) describes the whole speed restrictions arrival procedure:

> *2.1. SPEED RESTRICTIONS*
> *During intermediate approach (after leaving the hold until approximately 6NM before turning onto the ILS intercept heading), ACFT will be instructed to fly in the speed range 210-220 KT as required. Thereafter and until established on final approach, the highest possible speed within the band is 160-180 KT. Inbound ACFT must be established at 160 KT, on a stable approach at not less than 7NM from touchdown. For ACFT that are unable to maintain 160 KT to 4NM from touchdown, TC Gatwick will ascertain the final approach speed and inform the air controller. These procedures do not apply during SRA. TC Gatwick may transfer high speed traffic to air without prior co-ordination provided that the pilot is instructed to report speed on initial contact. However, TC Gatwick must effect prior co-ordination if separation from a following ACFT is dependent on the leading ACFT maintaining a speed higher than 160 KT.*

During my research and unstructured interviews with pilots and ATCO, they raised a speed restriction issue for Brazilian procedures. As I noticed in LGW and other international airports, the speed restriction procedure published in STAR and IAC charts is broadly used internationally but is not really in Brazil yet. This lack of published information allows aircraft to approach at different speeds and performances, creating an undesirable chain reaction to APP and ACC sequencing and airport operations. This sort of situation causes degradation in ATC services, bringing a loss of predictability on arrivals, increasing ATCO workload due to a significant rise of radar vectoring.

Thus, it impacts the airport operations and its capacity to generate more revenues because of a decrease in runway capacity, leading to airline service degradation through delays and inefficiency of slots allocation.

So, the speed restrictions procedure is the first step to equalize the approach flow bring predictability to the ATC system and airport operations.

8.2. Omnidirectional Standard Instrument Departure

In order to join the take-off phase to the en-route stage through a standard ATS route, an instrument procedure called SID (Standard Instrument Departure Route) implemented in IFR airports to aircraft perform after take-off.

The advantages of SID implementation go since the ATCO workload reduction, radiofrequency occupancy decrease until predictability in tracks performed by aircraft that bring safe and efficiency and operations.

In this context, to avoid multiple departure patterns for each runway, the omnidirectional departure concept was created to allow departures in any direction. This procedure is described in DOC 8168 - Procedures of Air Navigation Services- Flight Procedures, Volume I, as followed:

> *“2.5 Omnidirectional departures*
> *2.5.1 At many aerodromes, a departure route is not required for air traffic control (ATC) purposes or to avoid particular obstacles. Nevertheless, there may be obstacles in the vicinity of the aerodrome which affect departures. An* ***omnidirectional departure procedure is a convenient and flexible method of ensuring obstacle clearance. In cases where no track guidance is provided****, departure procedures are designed using the omnidirectional method.”*
> (ICAO, 2018)

Omnidirectional departures, called SID OMNI or OMNI DEPARTURE, is an instrument procedure that allows aircraft to curve in any direction during the take-off phase after it reaches a certain altitude. The OMNI SIDs differ from conventional SID in terms of not have pre-defined flight paths and do not need navigation aids to provide navigation guidance.

This kind of procedure allows greater flexibility for planning and performing the flight plan, supporting the pilot free navigation to the en-route entry waypoint/fixed, besides there are no lateral and vertical restrictions.

Another benefit of SID OMNI implementation is related to the increase of runway throughput to departments. As long as a leading aircraft take-off and reach an altitude that can turn to any direction, the leading airborne aircraft will head a divergent track from the trailing departure reducing the wake turbulence effect and, consequently, time separation to departures. Omnidirectional departure procedure brings efficiency to runway throughput when applied in a mixed aircraft environment, such as VCP. For instance, the turboprop take-off phase is longer than a jet due to its inherent lower performance on departure comparing to jet aircraft operations. So, turboprop or other low-performance aircraft performing SID OMNI preceding a jet departure may turn after the take-off and head to a divergent track reducing the necessary separation time to following departure aircraft.

Therefore, the SID OMNI provides an alternative to conventional SID. The SID OMNI mitigates instrument departure issues associated with navigation aids inoperability. It also allows a rationalization of published SID procedures.

The VCP airport has a SID OMNI procedure published in AIP Brasil (DECEA, 2021). The procedure consists of maintaining the heading indicated in the chart, climbing until 4,500 feet before turning, continuing climb below 8,000 feet, and expect further ATC instructions, as shown in Figure 24.

It is worth mentioning this procedure is also used in the USA, which provides obstacle clearance allowing turn after departure when the aircraft reaches 400 feet after take-off. It is called Obstacle Departure Procedures (ODP). The FAA states:

> *ODPs provide obstruction clearance via the least onerous route from the terminal area to the appropriate en route structure. ODPs are recommended for obstruction clearance and may be flown without ATC clearance unless an alternate departure procedure (SID or radar vector) has been specifically assigned by ATC. Graphic ODPs will have (OBSTACLE) printed in the procedure title; for example, GEYSR THREE DEPARTURE (OBSTACLE), or, CROWN ONE DEPARTURE (RNAV) (OBSTACLE).*
> *(...)*
> *Unless specified otherwise, required obstacle clearance for all departures, including diverse, is based on the pilot crossing the departure end of the runway at least 35 feet above the departure end of runway elevation, climbing to 400 feet above the departure end of runway elevation before making the initial turn, and maintaining a minimum climb gradient of 200 feet per nautical mile (FPNM), unless required to level off by a crossing restriction, until the minimum IFR altitude. A greater climb gradient may be specified in the DP to clear obstacles or to achieve an ATC crossing restriction. If an initial turn higher than 400 feet above the departure end of runway elevation is specified in the DP, the turn should be commenced at the higher altitude. If a turn is specified at a fix, the turn must be made at that fix. Fixes may have minimum and/or maximum crossing altitudes that must be adhered to prior to passing the fix. In rare*

instances, obstacles that exist on the extended runway centerline may make an "early turn" more desirable than proceeding straight ahead. In these cases, the published departure instructions will include the language "turn left(right) as soon as practicable." These departures will also include a ceiling and visibility minimum of at least 300
(FAA, 2020)

Thus, a precise and expeditious ATC performance should contribute to SID OMNI operations' success, which may reflect in runway increase capacity.

Unless observed obstacles risk, it is recommended that DECEA review the 4,500 feet minima height in VCP SID OMNI. The minima reduction to the initial turn will allow an efficiency gain in runway throughput for departures, as long as VCP stands as Azul Airlines national hub and its line-up fleet is composed of lower performance aircraft, such as turboprop ATR.

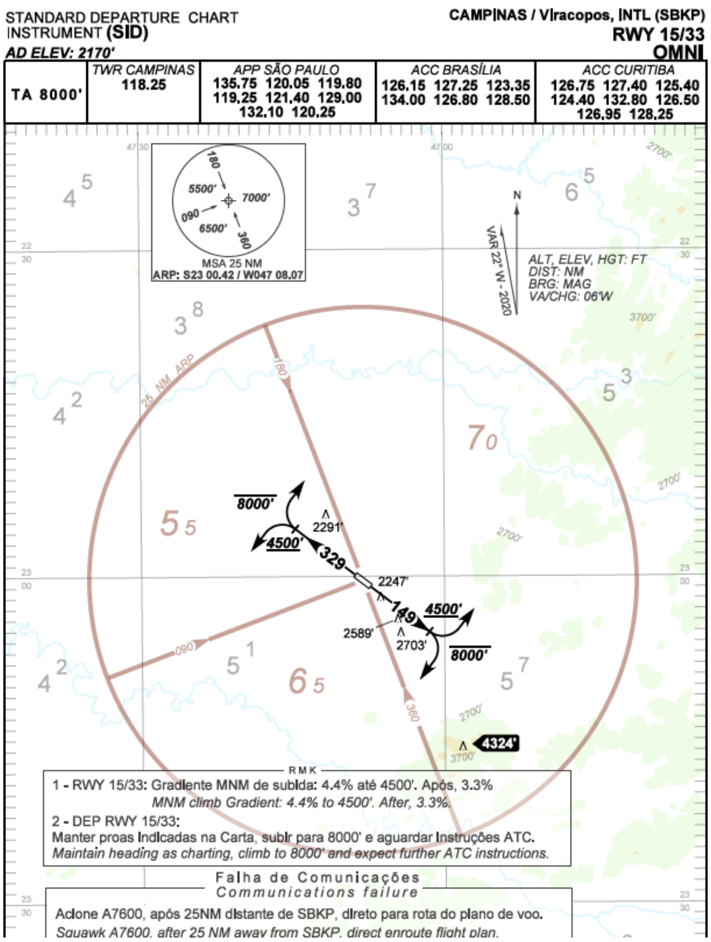

Figure 24 VCP SID OMNI RWY 15/33 chart
Source: (DECEA, 2021)

8.3. Reduce Runway Separation Minima – RRSM

Before the consequences brought by the COVID-19 pandemic, VCP was experiencing a growth in passenger handled and aircraft movements. Follow the trend of global airports facing capacity constraint issues, an increased capacity for runway throughput is necessary to deal with growing traffic.

In this context, ICAO Doc 4444 PANS-ATM describes a procedure to enhance runway throughput and ATC operational efficiency and flexibility, called Reduced Runway Separation Minima - RRSM. In short, it consists of lower separation minima during the hours of daylight from 30 minutes after local sunrise to 30 minutes before local sunset, under the two traffic situations:

a) between two successive arrivals; or
b) between a departure and a succeeding arrival.

According to ICAO DOC 4444 PANS-ATM, to apply the RRSM procedure is necessary to fulfill the following conditions:

> *7.11.6 Reduced runway separation minima shall be subject to the following conditions:*
> *a) wake turbulence separation minima shall be applied;*
> *b) visibility shall be at least 5 km and ceiling shall not be lower than 300 m (1 000 ft);*
> *c) tailwind component shall not exceed 5 kt;*
> *d) there shall be available means, such as suitable landmarks, to assist the controller in assessing the distances between aircraft. A surface surveillance system that provides the air traffic controller with position information on aircraft may be utilized, provided that approval for operational use of such equipment includes a safety assessment to ensure that all requisite operational and performance requirements are met;*
> *e) minimum separation continues to exist between two departing aircraft immediately after take-off of the second aircraft;*
> *f) traffic information shall be provided to the flight crew of the succeeding aircraft concerned; and*
> *g) the braking action shall not be adversely affected by runway contaminants such as ice, slush, snow and water.*
> (ICAO, 2016)

RRSM procedure also established some conditions for arrivals and departures:

> *7.11.7 Reduced runway separation minima which may be applied at an aerodrome shall be determined for each separate runway. The separation to be applied shall in no case be less than the following minima:*
> *a)* ***landing aircraft:***
> *1) a* ***succeeding landing Category 1 aircraft may cross the runway threshold when the preceding aircraft is a Category 1 or 2 aircraft*** *which either:*
> *i) has landed and has passed a point* ***at least 600 m from the threshold*** *of the runway,* ***is in motion and will vacate the runway without backtracking****; or*
> *ii) is airborne and has passed a point at least 600 m from the threshold of the runway;*

*2) a **succeeding landing Category 2 aircraft may cross the runway threshold when the preceding aircraft is a Category 1 or 2 aircraft** which either:*

*i) has landed and has passed a point **at least 1 500 m from the threshold** of the runway, **is in motion and will vacate the runway without backtracking**; or*

ii) is airborne and has passed a point at least 1 500 m from the threshold of the runway;

*3) a **succeeding landing aircraft may cross the runway threshold when a preceding Category 3 aircraft**:*

*i) has landed and has passed a point **at least 2 400 m from the threshold** of the runway, **is in motion and will vacate the runway without backtracking**; or*

ii) is airborne and has passed a point at least 2 400 m from the threshold of the runway;

*b) **departing aircraft:***

1) a Category 1 aircraft may be cleared for take-off when the preceding departing aircraft is a Category 1 or 2 aircraft which is airborne and has passed a point at least 600 m from the position of the succeeding aircraft;

2) a Category 2 aircraft may be cleared for take-off when the preceding departing aircraft is a Category 1 or 2 aircraft which is airborne and has passed a point at least 1 500 m from the position of the succeeding aircraft; and

*3) an **aircraft** may be **cleared for take-off** when a **preceding departing Category 3** aircraft **is airborne and has passed a point at least 2 400 m** from the position of the **succeeding aircraft**.*

(ICAO, 2016)

Knowing the RRSM technical requirements and considering the VCP airside infrastructure, precisely runway length, and existing rapid exit taxiway, the airport can have RRSM implementation.

Nevertheless, according to ICAO Doc 4444 PANS-ATM, a safety assessment shall be performed for each runway that the reduced minima are intended, considering factors such as runway length, aerodrome layout, and types/categories of aircraft involved.

7.11.1 Provided that an appropriate, documented safety assessment has shown that an acceptable level of safety can be met, lower minima than those in 7.9.2 and 7.10.1 may be prescribed by the appropriate ATS authority, after consultation with the operators. The safety assessment shall be carried out for each runway for which the reduced minima are intended, taking into account factors such as:

a) runway length;

b) aerodrome layout; and

c) types/categories of aircraft involved.

(ICAO, 2016)

As mentioned in Chapter 6, LGW airport already uses the same procedure called “land-after”. The LGW Jeppesen chart describes this procedure:

2.5.2. SPECIAL LANDING PROCEDURES

Special landing procedures may be in force in conditions hereunder, when the use will be as follows:

- When the RWY-in-use is temporarily occupied by other traffic, landing clearance will be issued to an arriving ACFT provided that at the time the ACFT crosses the THR of the RWY-in-use the following separation distances will exist:

*- **Landing following landing** - The preceding landing ACFT will be clear of the RWY-in-use or will be at least 2500m/1.35NM from the THR of the RWY-in-use.*

*- **Landing following departure** - The departing ACFT will be airborne and at least 2000m/1.1NM from the THR of the RWY-in-use, or if not airborne, will be at least 2500m/1.35NM from the THR of the RWY-in-use.*

- Reduced separation distances as follows will be used where both the preceding and succeeding landing ACFT or both the landing and departing ACFT are propeller driven and have a maximum total weight authorized not exceeding 5700kg:

*- **Landing following landing** - The preceding ACFT will be clear of the RWY-in-use or will be at least 1500m/0.8NM from the THR of the RWY-inuse.*

*- **Landing following departure** - The departing ACFT will be airborne or will be at least 1500m/0.8NM from the THR of the RWY-in-use.*

- Conditions of Use
*The procedures will be used by **DAY only** under the following conditions:*
- When 26L/08R is in use;
- When the controller is satisfied that the pilot of the next arriving ACFT will be able to observe the relevant traffic clearly and continuously;
- When the pilot of the following ACFT is warned;
- When there is no evidence that the braking action may be adversely affected;
- When the controller is able to assess separation visually or by radar derived information.
When issuing a landing clearance following the application of these procedures
ATC will issue the second ACFT with the following instructions:
...... (call sign) after landing/departing
...... (ACFT Type) cleared to land
RWY ..... (designator).
(Jeppesen, 2020)

Since 2020, due to an initiative of DECEA, GRU Airport, INFRAERO, ABEAR, IATA, ANAC, and Azul Airlines, Brazil has been experiencing the implementation of RRSM in São Paulo Guarulhos International Airport (ICAO code: SBGR and IATA code: GRU) for 3NM separation in the final approach. The RRSM procedure is published in AIP Brasil (DECEA, 2021) to GRU airport operations, as followed:

4 Aircraft separation
a. The minimum ATS surveillance minima at the approach final will be of 3NM.
b. Application of reduced runway separation minima at SBGRRRSM may be applied between departing aircraft and a subsequent landing aircraft, between two departing aircraft on the same runway or between two landing aircraft on the same runway, provided that:
I) During daylight, starting 30 minutes after sunrise and up to 30 minutes before sunset.
II) Wake turbulence separation shall be applied;
III) Visibility shall be at least 5 km and ceiling shall not be lower than 300 m (1000 ft);
IV) Tailwind component shall not exceed 5 kt;
V) Minimum separation continues to exist between two departing aircraft, immediately after take-off of the second aircraft;

VI) The braking action shall not be adversely affected by runway contaminants such as ice slush, snow and water; and
VII) RRSM application information shall be included in the ATIS message.
The RRSM will be applied when the runway in use is still occupied by other traffic, provided that there is reasonable certainty that the following separation distances will exist.
1. RWY 09R/27L
LANDING AFTER LANDING: The preceding aircraft has passed a point at least 2400 m from the runway threshold (TWY CC entrance for RWY 09R or TWY G entrance for RWY 27L), and it is in motion and clears the runway without backtracking.
LANDING AFTER DEPARTURE: The preceding aircraft passed a point at least 2400 m from the runway threshold (has passed TWY CC for RWY 09R or TWY G for RWY 27L).
DEPARTURE AFTER DEPARTURE: The preceding aircraft passed a point at least 2400 m from the runway threshold (has passed TWY CC for RWY 09R or TWY G for RWY 27L).

To summarize, when an aircraft is performing an approach procedure in good meteorologic conditions, during the hand-over phase, approach control (APP) transfers the traffic to the tower (TWR), a natural loss of separation minima occurs in the final approach. Due to landing aircraft deacceleration, ATCO may issue a go-around procedure to succeeding aircraft. This sort of operation increases the pilots and ATCO`s workload and reduces ATC and airport efficiency.
However, whenever RRSM has activated, the tolerance to loss of separation minima is higher, allowing the succeeding aircraft landing to improve the approach and departure flow in the airport maintain a high level of safety in compliance with ICAO standards.
In this context, RRSM is aligned with this final study's goal to enhance operations efficiency in VCP itself and turn in an additional revenue source to ATC, airlines, and the airport. Even though it seems to be a simple procedure when it is properly working, there are many requirements, technologies, time training, and safety assessments to be done before its full implementation.

8.4. Taxiways

As mentioned in Chapter 4, VCP has a vast taxiway system to serve cargo and commercial aviation operations. This infrastructure is essential to a smooth airport operation, connecting the runway to the aprons.
Therefore, a well-designed and implemented taxiway system saves taxiing time for arrivals and departures, allows an expeditious aircraft flow, and as a consequence, reduces CO_2 emissions avoiding unnecessary fuel burn. It represents economic savings in OPEX and an increase of operating leverage to the airport operator and the airlines.
For better comprehension, Neufville et al. (2013) state:

To appreciate the magnitude of the economic quantities involved, consider the taxiing time that aircraft experience in traveling between aprons and runways at a busy airport handling, for example, 300,000 movements and 25 million passengers in a year. A design improvement that reduces taxiing time by 1 minute, on average, translates to savings of 5000 aircraft-hours and over 400,000 passenger-hours per year. If the average direct operating cost for taxiing aircraft at this airport is $2000 per aircraft-hour, saving a minute of average taxi times saves about $10 million per year in direct airline costs alone—the equivalent of about $100 million in capital investment. The value of this saving in taxi time could more than double if savings in passenger time at $40 per hour saved (typical for such analyses in the United States) were also taken into consideration. In practice, airport planners unfortunately often fail to take a systems view of the design and, in this case, focus on the capital costs incurred by the airport and not the system benefits received by the users, the airlines and passengers. Airports need to recognize, however, their potential to recover costs through user charges, and to strive to maximize the overall productivity of the system.

During my in-depth study about VCP, taxiway constraints were identified in some important operational spots in the movement area. Chapter 6 identified and listed those constraints:

a) Lack of taxiway L.
b) Lack of redundant entry point to the RWY33 holding point.
c) Taxiway's intersection.
d) Restrict use of taxiway K1.
e) Taxiway G infrastructure expansion.

As we can see, some VCP taxiway issues were raised with a demand for better infrastructure due to cargo and growing commercial traffic and by network expansion of Azul Airlines. The IATA Airport Development Reference Manual -ADRM, considered the industry's most important guide for airport planning and development, states about taxiways requirements:

3.2.7.2.8 Taxiway Requirements

The principal function of taxiways is to provide access for aircraft moving between runways and passenger terminal areas, cargo areas and maintenance hangars. Taxiways should be arranged so that arriving aircraft do not obstruct and delay departing aircraft.

The extent of taxiway layouts is determined by the volume and frequency of traffic to be handled in the peak hour and the expected aircraft taxi routings to support planned runway use. Exhibit 3.2.7.2.8 summarizes the capacity of various configurations of parallel taxiways serving a runway. Should peak hour movements not require a full parallel taxiway, then a partial parallel layout can be used to minimize construction costs. The partial parallel taxiway can be extended to a full parallel as traffic demand warrants.

Exhibit 3.2.7.2.8: Capacity of Parallel Taxiways

Number of taxiways	***Taxiway capacity (mvts/hr)***	***Notes***

0	*0-15*	*Backtracking required on the runway*
1	*16-20*	
2		*Runway capacity will be the limiting factor*
Landing only	*50-55*	
Takeoff only	*30*	

(IATA, 2014)

Given IATA ADRM guidance, It noticed the airport alignment with IATA manual recommendations regarding the number of parallel taxiways to serve the runway. As cited in chapter 7, the VCP declared runway capacity is 40 movements per hour. It has a direct correlation to taxiway capacity, according to IATA ADRM.

Even though VCP is following IATA ADRM, the taxiway Golf is still a partial parallel taxiway (Figure 25), causing some operations constraints, especially in taxiway Charlie, due to some observed operational occurrences:

a) Once a given aircraft vacate the RWY15 via RET Foxtrot performing taxi-in to cargo or the terminal aprons via taxiway Charlie and another plane taxiing or towing in the opposite direction towards Azul hangar, an increased taxi time was noticed, generating delays and degrading the taxiway Charlie hourly capacity.
b) Once the runway in-use is RWY33, it creates a conflict taxiing between departure aircraft and towing aircraft from Azul Hangar to the apron in taxiway Charlie, increasing taxi-out times for departures.
c) Departures from RWY33 are less expeditious than RWY15 due to lack of redundant entry points, generating undesirables queues in peak hours, reflecting in taxi-out time growth.

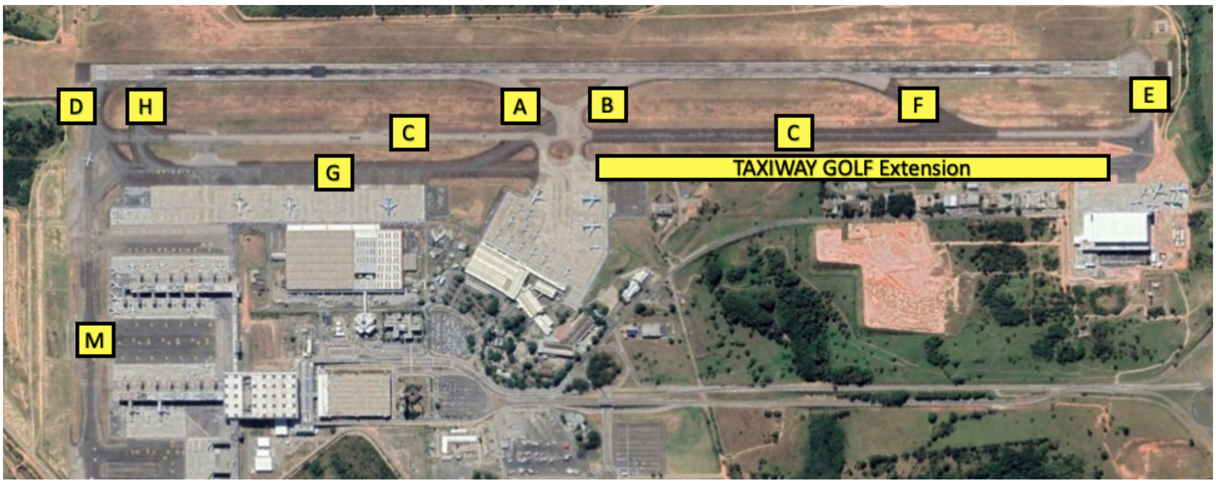

Figure 25 Taxiway Golf Extension
Source: Google Earth

Thus, a lack of taxiway Golf infrastructure expansion and the lack of redundant entry point to RWY33 holding point lead to a series of unwilling consequences to all stakeholders, such as

a) flight delays,
b) boost of taxi-in and taxi-out times jeopardizing airlines operational cost,
c) loss of potential revenues due to inefficient slot allocation, and
d) increase of fuel consumption and CO2 emissions.

Short-term mitigation to a redundant entry point to RWY33 would be allowing departures from RET Foxtrot. However, the solid solution still is an implementation of a new taxiway adjacent to taxiway Echo.

However, according to Neufville et al. (2013), the airport administration needs to plan before building a one-off robust and completed taxiway system to get economic efficiency, evaluating to do so in phases, taking into account growing traffic to make investments.

> *Another common mistake is overbuilding in the early stages. Runways that are not used intensively during the early years of an airport's operation can usually be adequately supported, depending on the airport's geometry, by a single taxiway running parallel to the entire length of the runway ("full-length taxiway"). Even when a second parallel taxiway may be needed to ensure smooth circulation of airport surface traffic under all circumstances, that second taxiway need not be full-length. It may be sufficient in most cases to build that second parallel taxiway for only part of the length of the runway. Unfortunately, airport designers often tend to emphasize the symmetry. Almost reflexively sometimes, they design taxiway systems with two full-length parallel taxiways per runway and then build the entire taxiway system in a single step. The key to economic efficiency is to design carefully a flexible taxiway system and then build it up in phases over the years as traffic grows.*

In this regard, the COVID19 pandemic and its second-order effects, in general, forced airport operators throughout the world to postpone investments overall. Usually, airside planned investments are triggered by either number of passengers or aircraft movements handled by year. In 2020, VCP suffered a massive downturn in passenger and aircrafts movements, directly impacting the capacity to generate non-aeronautical and aeronautical revenues. As a consequence, the airport investment capacity reduces.

However, the VCP statistics noticed a paradoxical situation last year. However, the verified passenger downturn, a slight increase in aircraft movements in peak hours was perceived. It occurs due to the overall network and frequency reduction lead to flight concentration in peak hours.

In this sense, airside infrastructure is pushed too, even in crisis times. Regarding VCP, apron 4 and 5 are responsible for more de 90% of ground operations. The taxiway Mike is the only way in and out to apron 5 and 6. Thus, a bottleneck created diminishing turn-around efficiency, impacting taxi-in and taxi-out times directly and eventually runway capacity.

Since the short-term investments' perspectives are low, mitigation action to maximize expeditious ground operations are needed. In this context, the Agile VCP working group recommended a homologation of new taxiway Mike 1, between apron 4 and 5, parallel to taxiway Mike and Terminal Pier, as shown in Figure 26. Nonetheless, to homologate taxiway Mike 1 is necessary a slope correction to comply with national regulations, which means infrastructure investment.

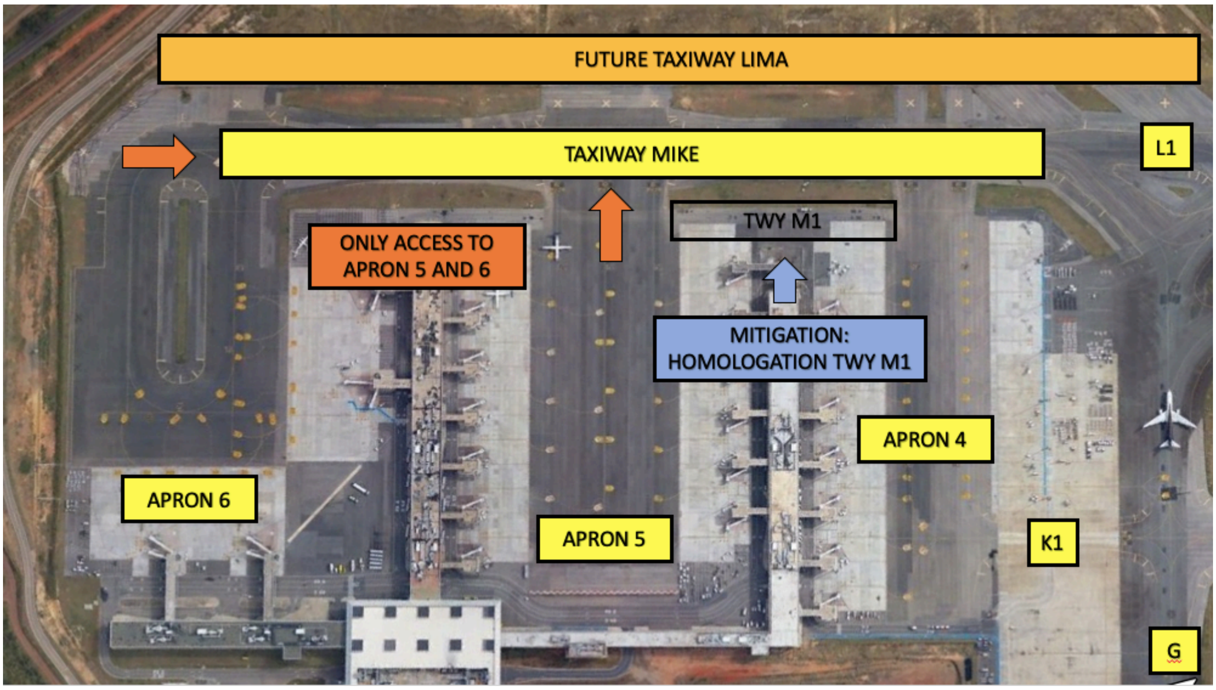

Figure 26 Taxiway Mike 1
Source: Google Earth

Last but not least, the taxiway Charlie plays a vital role in VCP airside operations. It the only full-length taxiway in VCP, serving as the essential and primary link between runway and aprons. However, the current layout has created a hotspot due to an intersection between RET Alpha, Bravo, and taxiway Charlie, leading to a potential safety event.

In this regard, Agile VCP pointed out mitigation to avoid a further safety event. The solution is to create taxiway holding points in taxiway Charlie and Golf to increase situational awareness about the intersection hotspot.

Another important aspect related to taxiway Charlie is its use as a backup runway. As mentioned in the international benchmark chapter, London Gatwick has a backup runway used as a taxiway mainly and as a runway when the main runway is closed to maintenance or for another operational reason.

This sort of infrastructure mitigates a temporary airport close down due to a hypothetical runway shutdown.

In 2012, VCP had faced a big issue when an MD-11 cargo aircraft broke down its landing gear on the runway after the landing procedure (G1, 2012). The airport had its departures and arrivals operations shut down for 45 hours until the aircraft removal. As a consequence, more than 495 flights were canceled, generating an approximate loss of R$ 20 million (US$ 3.54 million) by that time to Azul Airlines.

However, from the date of incident related to the current days, VCP still did not homologate taxiway Charlie to use as a backup runway, elevating the risk of an eventually temporary airport close down if a runway shutdown event repeats. To homologate a taxiway to departures and arrival operations is a complex process and takes time. It is necessary for some infrastructure improvements, such as surface, marking, lighting system, and navigation aids besides safety and obstacles assessments.

So, it is recommended to VCP airport make a robust assessment trading off the necessary cost and time expenditure to homologate taxiway Charlie as a backup runway and the risk and potential loss in eventually runway shutdown.

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CHAPTER 9 – ACHIEVEMENTS OF THE INTERNSHIP

9.1. Findings

As a civil servant and a policymaker at Civil Aviation Secretariat (SAC), pursuing continuous improvements, studying, and applying best worldwide practices to Brazilian aviation is part of my daily activities and goals. This vision is aligned with the Infrastructure Ministry's purpose, which is to become the Latin America leader in infrastructure quality. Maybe that`s why a chose to study increase efficiency in single-runway airports, more specifically about Viracopos Campinas that was part of SAC policy to concede to the private sector.

During the ABV internship, being part of the Agile VCP working group was crucial in developing my internship goal. It was about finding procedures, best practices to improve the airport operations efficiency.

In this context, I have studied and identified VCP constraints, such as:

a. Runway Occupancy Time;
b. Approach and Departure procedures;
c. Lack of taxiway Lima;
d. Lack of redundant entry point to RWY33 holding point;
e. Taxiway's intersection;
f. Taxiway Golf infrastructure extension; and
g. Lack of backup runway (taxiway Charlie).

It allowed me to seek best practices throughout the world, understand them and figure out a possible implementation in VCP.

9.2. Difficulties

Without a doubt, the most significant difficulty was performing an internship and the final study during the period of the COVID19 pandemic. It has been a challenging time in all aspects. Due to social distance and lockdown, conciliate a boost of SAC daily activities, internship activities, and homeschooling greatly impacted my schedule and forced me to delay some deliverables.

Even though I performed the internship on-line, the meetings went better than I expect.

At the beginning of 2020, the expectations about the internship were high. However, the COVID19 pandemic collapsed the intended in loco performance.

9.3. What is still to be done?

The study aimed to clarify the VCP constraints and issues, then identified and studied the international benchmark to understand the why and what procedures made LGW airport the efficient and finally propose implementation to VCP.

As the Agile VCP working group shared my study's same goals, I define “work to be done” as a continuous project follow-up. Some of the measures to be taken are complex to implement and the necessary time expenditure to plan, to assess, to implement, to change regulation if necessary, and to training goes beyond the internship period. For instance, to implement RRSM in a Brazilian airport, a planning background is necessary to perform GAP analyses, Safety assessment, ATCO training, amendment airport charts and publish it in AIP Brasil. In general, it takes more than one year, considering all stakeholders involved.

So, my study will contribute actions or foundations to further decisions that eventually will be taken in the Agile VCP.

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CHAPTER 10 – CONCLUSION

10.1. Technical conclusion

After the beginning of the airport concession policy back in 2011, the private airports made massive investments in outdated Brazilian airports. Landside and airside infrastructures were built, expanded, or completed renewed. As one of the consequences, overall airport OPEX costs rise to maintain the new infrastructures and keep an acceptable service quality.

However, in 2015, the most significant economic crises so far struck Brazil, generating a massive downturn in the whole services sector, including aviation. So, the airports had their financial margins pushed by the reductions of revenues, extending the investment payback.

In this context, Brazilian airports started to seek improvements in their operations. An action in this direction was the creation of the AGILE project, which is an initiative of the Brazilian aviation industry to provide a particular and detailed view of a given airport or airspace, with the strategic objective of increasing the efficiency of approach, landing, and take-off operations, improving performance and operational flow. So far, the project is being carried out for the São Paulo International Airport in Guarulhos (Project AGILE GRU), for the Rio de Janeiro Terminal Control Area (Project AGILE RIO), and the Viracopos Campinas International Airport (Project AGILE VCP).

The ABV economic runway capacity assessment was essential in going in-depth on studies to improve Viracopos Campinas International Airport operations efficiency. Each additional movement on runway capacity would represent a potential airport revenue of R$ 4.32 million, around US$ 759 thousand.

Since the beginning of my research, London Gatwick always came in academic literature and expert evaluations as the principal global benchmarking to single-runway operation. Before going in-depth in LGW operations, I had an idea that to handle up to 55 aircraft movements per hour, a lot of cutting-edge technology was necessary. But as I developed my research became clear that the reason for a high level of efficiency observed in LGW. It is not about cutting-edge technology but a series of well-design and well-performed procedures with continuous monitoring by ATC and LGW airport.

The procedures adopted by LGW comply with ICAO standards, and according to my study, there is a feasibility to implement some procedures and operational practices from London Gatwick airport. This study will be an important source for the following steps to the Agile VCP activities. It is recommended that VCP adopt the measures detailed in this document to increase airport efficiency, which may turn into growing revenue. Further, VCP may become the national benchmark since most Brazilian airports operate with a single runway.

Considering the COVID19 pandemic effects brought to the aviation industry, more than ever, all the stakeholders need to unify to pursue new ways to do business, and a deep look into efficient operations is mandatory.

10.2. Personal conclusion

For sure, attending the ENAC Advanced Master in Air Navigation Management - MS ANM18 class was one of the biggest challenges in my life. Developing the study and an internship during a pandemic season was not any different.

I have faced tough times during my internship due to the COVID19 pandemic. The social distance and lockdown policies direct affected the study development.

Although all restrictions I have faced during my internship due to the COVID19 pandemic, I could attend all the Agile VPC online meetings. It added a lot to my study, even though the online contact with experts from different expertise improved my skills and was an excellent opportunity to exercise all the knowledge that I got during MS ANM18 classes.

I have already had 10-year experience in aviation, half of my time at DECEA ANSP (Amazon Area Control Center) as a telecommunications engineer, and another half of my time as a policymaker at the Civil Aviation Secretariat (SAC). I would say that those 2-years classes and the internship broadened my mind and took me to another level regarding knowledge and skill acquired.

Additionally, I had the opportunity to make an immersion in airport operations and meet extraordinary professionals. The internship task made me feel helpful ongoing Agile VCP activities and the ones to come. I hope to give back the knowledge and experience gained in other national projects and eventually see the results and recommendations of this study applied in other Brazilian airports.

10.3. Recommendation

From day one, my study was about studying and finding possible solutions to improve Viracopos Campinas International Airport through extensive research of London Gatwick operations. As explained in this document, the reason to enhance airside operations is a potential gain in airport revenues by increasing runway capacity. However, increase runway capacity is not an easy task. It involves procedures, proper infrastructure, and training. The case study, which assessed the final approach separation and runway occupancy time, proved that some current VCP procedures need to be review and improved.

In this context, based on best practices observed and described in this study and considering the verified slight increase of aircraft movement in peak hours, the recommendations to Viracopos operator (ABV) and Agile VCP working group are:

1. Review current STAR charts regarding the adoption of speed restriction on approach procedure to equalize separation and aircraft performance during arrivals.
2. Implementation of the RRSM procedure increases the tolerance to loss of separation minima in the final approach, allowing a better flow to approach and departure and increasing runway throughput.
3. Encourage the ATC to use SID OMNI more frequently, using the turn and vectoring technique to reduce separation time and wake turbulence effect for departure.
4. Unless observed obstacles risk, it is recommended that DECEA review the 4,500 feet minima height in VCP SID OMNI. The minima reduction to the initial turn will allow an efficiency gain in runway throughput for departures, especially for mixed operations such as VCP, where turboprop and jets coexist.
5. It is recommended to ABV implement a taxiway Golf extension to expedite the taxi-in and taxi-out flow.
6. For the short-term, it is recommended to ABV make necessary infrastructure adjustments to homologate taxiway Mike 1 to create redundant access to apron 5.
7. For mid-term, it is recommended to ABV build taxiway Lima to improve taxiway flow to access apron 4, 5, and 6.
8. It is recommended to homologate taxiway Charlie as a backup runway to avoid operations close down due to an eventual runway shutdown.

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