11-2022

Ramping Up for Cost and Performance Improvements

Arthur Zucchetti Lechmann

Guilherme Henrique Lima

João Paulo Lucchi

Paulo Henrique Azevedo Santana

Pedro Kamikihara

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Arthur Zucchetti Lechmann
Guilherme Henrique Lima
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Pedro Kamikihara

A Capstone Project Submitted to Embry-Riddle Aeronautical University in Partial Fulfillment of the Requirements for the Aviation Management Certificate Program

Embry-Riddle Aeronautical University
Sao Paulo, Brazil
November 2022

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This Capstone Project was prepared and approved under the direction of the
Group's Capstone Project Chair, Dr. Leila Halawi
It was submitted to Embry-Riddle Aeronautical
University in partial fulfillment of the requirements
for the Aviation Management
Certificate Program

Capstone Project Committee:

____

Dr. Peter O'Reilly
Capstone Project Chair

November 2022

Acknowledgements

This part shares our challenges encountered throughout the project construction, each member of the group was determinated to deliver his best, therefore, passing through each step at time, learning with the difficulties and acquiring new skills along the way. We would like to express our gratitude to Dr. Peter O'Reilly, also known as Dr. Pepsi, who pushed us mentally and instructed us technically to reach the finish line. Dr. Pepsi, certainly impacted positively on our work, stimulating us to think in different ways, developing new skills to all of us. In addition, we would like to thank the Capstone Project Committee for validating our project. Furthermore, we would like to place our thanks to Israel, Letícia, Pedro and all ERAU staff based in Sao Paulo, who let our in-class experiences thought the project much more comfortable and unique. Moreover, we would like to thank all our previous Professors based in Daytona, who were part of this great process and supported us along the way. Additionally, our families, spouses and coworkers must be remembered and thanked for their help simply by understating our absences and required hours dedicated to studies throughout the project.

Finally, we want to thank Azul, Azul Conecta and Gol for offering us this priceless opportunity.

Abstract

Group: Lechmann, Arthur Zucchetti
Lima, Guilherme Henrique
Lucchi, João Paulo
Santana, Paulo Henrique Azevedo
Kamikihara, Pedro
Title: Ramping Up for Cost and Performance Improvements
Institution: Embry-Riddle Aeronautical University – Worldwide Campus
Year: 2022

The objective of this Research Project was to study the possible benefits of developing an improved Metering Control System. This study identified potential cost savings and reduced emissions through the greater use of a Metering Control System. The results of this research have indicated an annual cost reduction of $720,000 in fuel burn and a significant delay time reduction caused by accumulated ground traffic. In addition, during peak hours, it was concluded that savings could be potentially higher. Therefore, by optimizing the ground movement, it is also expected a lower level of CO2 emissions, an increased safety level due to more organized apron movements, and finally, an improved customer experience.

The data presented in this research is in line with current Brazilian regulations, focused on reducing or minimizing airline ground delays. The selected airport sample is a main

hub of an airline, concentrating 95% of its operation. Also, the airport is classified as the fourth busiest in terms of operation in Brazil.

An inefficient apron management is responsible for causing a variety of disruptions in terms of on-time performance, fuel consumption and customer satisfaction. Some events may be reduced or even eliminated by applying simple practices, therefore, increasing efficiency without compromising safety.

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Chapter I

Introduction

As the time goes by, and with the technology evolving so fast, the airline industry is at a nonstop search to optimize the airport ground movements of aircraft. The current scenario shows that fuel prices continuously raising. In addition, customers are seeking the lowest possible ticket prices with on time operations. Concerning this last point, the airlines and aviation authorities are able to measure the On-Time Performance (OTP) that is directly impacted by the issues that will be exposed in this research.

Being aware of that if an airline can have a better view of the ground operations at the main hub, the right actions could be taken to maintain the critical flights on time. Such actions can further reduce the delays of flights with IROPS (irregular operations), as well as to achieve the least fuel burn.

Project Definition

The main focus of this research was to establish a method that could set an accurate time for the aircrafts to start the pushback for taxi-out. Naturally, it was expected that every departure could be accomplished on time, but adverse factors such as weather, traffic or maintenance can disrupt the network.

When the disruptions are faced, the company needs to act promptly in order to reduce the harm on the OTP and the flight cancellations. Based on the status of the various data available (aircraft status, weather status, airport status) the company will have means to reestablish the new departure time for every flight at this base. That is called metering control, a method to define the departure time following heavy traffic, adverse weather, maintenance, or any other disruption scenario at the company's hub. In order to find reasonable solutions for these aforementioned issues, one possible resource for this action, is a metering control at the hub ramp. By metering, we mean to be aware of the current arrival and departure flow, so that the aircraft does not have to stand with the engines running for a long time.

Problem Statement

The major American airports are facing issues such as (National Academies of Sciences, Engineering, and Medicine. 2015. Guidebook for Advancing Collaborative Decision Making (CDM) at Airports. Washington, DC: The National Academies Press):

- Poor management of airport resources: During situations when the airlines were diverting their flights to their hub, the airport management had difficulties in allocating gates for these additional flights. As a result, the ground traffic movements were severely impacted.
- Adverse Weather: When the hub airport is under an adverse weather situation (low visibility, icing, snow, etc.) not having a resource that can re-sequence the departure times, aircraft will be negatively impacted by delays, harm to the crew's legality issues, and reduce the throughput of the airport.
- Congestion: When the airlines were already aware of a departure delay, this information was not always shared with the airport management. This generally results in higher traffic demands later. Additionally, such poor communications can create a virtual queue, thus holding aircrafts at the gate instead of having all aircraft competing for runway access.

- Lack of flexibility and predictability: Without data sharing and improved coordination, airlines, ATC services, and airport operators cannot have any flexibility to prioritize and re-sequence flights based on business needs or other concerns.

Since the previously mentioned issues could represent actual threats for the airport and airline operations at any hub airport, this research project had focused on explore the most suitable methods to achieve a harmless and organized operation. Minimize any predictable fact has been a priority by this study.

Project Goals and Scope

The purpose of this study was to identify the best opportunities to improve OTP, NPS, fuel consumption, and to reduce delays, in order to implement a tool called metering. Some of the proposed improvements would include the following:

- To position the connecting flights aircraft close to each other, in order to avoid the critical connecting pax to walk for a long time in the terminal.
- To provide a target pushback time for the critical flights (anticipate or delay) so that delayed flights, or time critical flights (curfew, slots) depart within the optimal flight departure window.

At the end, our research project identified both financial benefits and improved customer service through a better company ramp control system.

Contributions Expected from the Study/Importance of Topic

By introducing airport metering control and airline metering control systems, the following processes could be performed:

- Compare fuel consumption due to absorbing delays at gates instead of during taxi.

- Estimate maximizing the airport resources - quick management of gates allocation for higher demands.

- Explain increased flexibility - ability to prioritize and re-sequence flights based on business needs or other concerns.

- Evaluate increased predictability – to achieve, hopefully, improved precision and accuracy of departure times. The more data is gathered, the more ability to predict future events and set new departure times the company will have.

- Assess optimized scheduling of flight dispatchers, improving time-on-duty.

- Estimate the value of sharing of information, improved situational awareness, and more decisions that are efficient during IROPS and winter operations.

Finally, with these implemented methods, this study expects to achieve the following outcomes:

- Increase the Net Promotion Score rate since the customer will face less delays situations.

- Determine improved safety measures: less exposure to ground safety events, since there will be less traffic allocated on ground.

- Fuel consumption reduction.

- Recommend improved schedule compliance.

- Determine more suitable flight time departures.

Definitions of Terms

ANAC	Brazilian national aviation authority.
HUB	An airport serving as a transfer point to get passengers to their final destination.
Metering	Method to control the release of aircraft from an airport, often for purposes of managing en-route or arrival congestion issues.
OTP	Index that measures the capability of an airline to depart flights on time.
Multilateration	A localization technique based on measuring the difference of the distances between the robot and landmarks.

List of Acronyms

ABEAR	Brazilian Association of Airlines
ACARS	Aircraft Communication Adressing and Reporting System
ACDM	Airport Collaborative Decision Making
ADS-B	Automatic Dependent Surveillance–Broadcast
AIBT	Actual In-Block Time
ALDT	Actual Landing Time
AOBT	Actual Off-Block Time
AOC	Airline Operations Center
AOCnet	Airline Operations Center network
ASDE	Airport Surface Detection System
ASDE-X	Airport Surface Detection System Model X
ATC	Air Traffic Control

ATD-2	Airspace Technology Demonstration 2
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATOT	Actual Take-Off Time
AVGTouT	Average Taxi Out Time
CDM	Collaborative Decision Making
CLT	Charlotte Douglas International Airport
CO2	Carbon dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DECEA	Departamento do Controle do Espaço Aéreo
EOBT	Estimated Off-Block Time
EPTA	Estação Prestadora de Serviço de Telecomunicações e de Tráfego Aéreo (Telecommunications and Air Traffic Service Provider Station)
ERAU	Embry Riddle Aviation University
ESPT	Estimated Safety Performance Targets
ETOT	Estimated Take-Off Time
EWR	Liberty International Airport, Newark
FAA	Federal Aviation Administration
FB	Liter Consumption Per Hour In Taxi In
FCFr	Fuel conversion factor
FCOM	Flight Crew Operating Manual

FedEx	Federal Express
FIDs	Flight Information Displays
GND Control	Ground Control
HCC	Hub Control Center
HOC	Hub Operational Control
IADS	Integrated Arrival, Departure, and Surface
IOBT	Initial Off-Block Time
IROPS	Irregular Operations
JFK	John F. Kennedy International Airport
MREDTFB	Mass of Jet fuel Burn
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NOTAM	Notice to Airmen or Notice to Air Missions
NPS	Net Promotion Score
NPS	Net Promoter Score
OAG	Official Airline Guide
OOOI	Aircraft OUT of the gate, wheels OFF the runway into the air, wheels ON the runway, and aircraft IN the gate.
OPS	Operation Quantity
ORD	Chicago's O'Hare International Airport
OTP	On-time Performance
PANYNJ	Port Authority of New York and New Jersey

PDRC	Precision Departure Release Capability
RedPercentage	Percentage reduction
REDTFB	Total Fuel Reduced
ROI	Return on Investment
S-CDM	Surface Collaborative Decision Making
SMP	Surface Metering Programs
SOBT	Scheduled off Block Time
TFB	Total Fuel Burn
TMAT	Target Movement Area entry Time
TNAP	Transportation Network and Airfield Pavement
TOS	Time On Station
TWR-KP	Viracopos Control Tower
VCP	Viracopos International Airport

WIP – Work In Progress

Plan of Study

To the completion of this project, the following topics have been covered:

Chapter Two – Literature Review, where the research plans to revisit the literature of metering and airport traffic best solutions around the world. This part also supported the analysis of the current literature utilized by air traffic management system and aviation authorities regarding this topic.

Chapter Three – Research Methodology, where this study has addressed data collection techniques and current data from main hub airports, with an applicable conclusion that aim to testify the efficiency of metering the traffic and achieve reasonable metrics to safety, NPS and OTP.

Chapter Four – Outcomes, where this project had demonstrated the efficiency and robustness of simple and complex practices regarding metering on hub airports. It is intended to present significant results based on practical applications of improved ground movements.

Chapter Five - Recommendations and Lessons Learned, where the research has been included directed suggestions for further studies about continuity of optimize airport and airline operations, deepening the concerns that will be explored by the study. In this chapter, the purpose of the project was achieved.

Chapter II

Review of the Relevant Literature

Flight cancellations and delays represent some of the biggest problems for consumers of scheduled air transport services today. They directly affect the object of the contracted service, which is the transportation from one point to another, on a date and time pre-established (ANAC, 2009).

Flight cancellations and delays, in particular, also negatively impact the efficiency of the civil aviation system in providing air transport service, since air carriers operate in a network structure (ANAC, 2009).

The Brazilian Association of Airlines (ABEAR) clarifies what are the most common causes that cause flight delays: weather problems, balloons, drones, birds, runway incidents, technical failures, unscheduled maintenance, and any cascade effect (ABEAR, 2019).

All these adversities usually cause the so-called cascading effect when a problem at one airport triggers delays throughout the airline network. This happens because an aircraft that should be at Airport B but is still on the ground at Airport A due to the presence, for example, of a drone preventing it from taking off (ABEAR, 2019).

Our research has proposed the implementation of the surface Collaborative Decision Making (CDM) to act on this last described problem, the cascading effect. We explored and identified ways to reduce cases of delay, thus improving the level of customer satisfaction and reducing fuel consumption, by reducing taxi time, as an example.

Collaborative Decision Making (CDM) is a joint government/industry initiative aimed at improving air traffic flow management through increased information exchange among aviation community stakeholders. CDM is comprised of representatives from government, general aviation, airlines, private industry and academia who work together to create technological and procedural solutions to the Air Traffic Flow Management (ATFM) challenges faced by the National Airspace System (NAS). (FAA, 2022).

CDM is an operating paradigm where ATFM decisions are based on a shared, common view of the NAS and an awareness of the consequences these decisions may have on the system and its stakeholders. There are two central tenets to CDM: that better information will lead to better decision-making, and tools and procedures need to be in place to enable air navigation service providers and the flight operators to respond more easily to changing conditions. By sharing information, values and preferences, stakeholders learn from each other and build a common pool of knowledge, resulting in ATM decisions and actions that are most valuable to the system (FAA, 2022).

Collaborative Decision Making

In the mid-1990s, the FAA and flight operators understood that there had to be a more efficient way of conducting air operations. Missing or incorrect information about flights was being used for decision making. For example, the FAA was using the Official Airline Guide (OAG) to forecast daily demand while the flight operators were using internal real-time data to adjust the schedules causing significant deviations from the OAG (FAA, 2017).

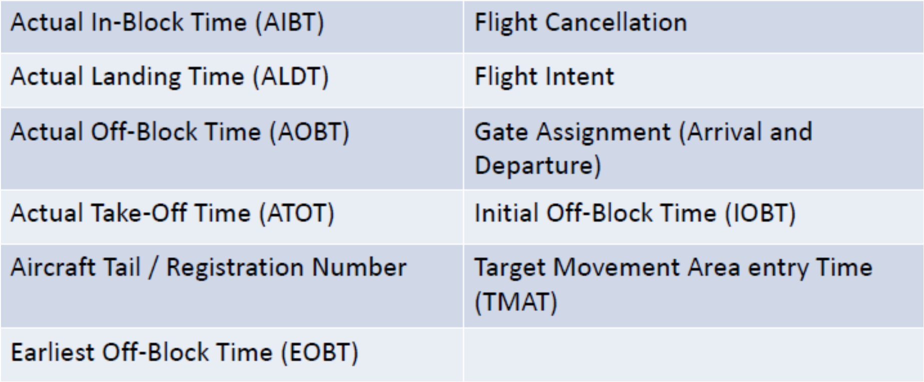
In 1995, the FAA/Industry CDM Program was officially initiated (FAA, 2017). In 1996, the FAA and industry developed graphical displays of air traffic demand that greatly facilitated collaboration such as, expected airport demand in time increments as small as 15 minutes, status of the demand, degree of demand over or under capacity, degree of demand that did not become active as scheduled, the amount of delayed demand and the impact of delaying that demand, and ability to illustrate the impact of demand vs various capacity scenarios (FAA, 2017). In 1997, a common AOC (Airline Operations Center) network (AOCnet) was established to facilitate distribution of demand and delay data between not only the FAA and AOCs, but also between AOCs (TNAP, 2015).

The benefits of collaboration were immediate because, for the first time, decision-makers understood what was occurring in the entire NAS, not just in their segment. From that point on, collaboration and participation increased. Tools were developed not only to facilitate collaboration but to allow the users to substitute delays between flights in order to enact business preferences. CDM became a philosophy of operations (TNAP, 2015).

Surface Collaborative Decision Making

According to the FAA, for an effective Surface-CDM, some fundamentals are necessary, such as access to airport aircraft surface surveillance data, electronic flight data automation, accurate and timely operational data, ability to share operational data among airport operators, flight operators, pilots, and other stakeholders (FAA, 2017). Below is Table 1, which contains some initial data listed by the FAA as essential for such an implementation.

Table 1 - Initial Surface CDM Data Elements



Actual In-Block Time (AIBT)	Flight Cancellation
Actual Landing Time (ALDT)	Flight Intent
Actual Off-Block Time (AOBT)	Gate Assignment (Arrival and Departure)
Actual Take-Off Time (ATOT)	Initial Off-Block Time (IOBT)
Aircraft Tail / Registration Number	Target Movement Area entry Time (TMAT)
Earliest Off-Block Time (EOBT)	

(FAA, 2017)

Also, according to FAA (FAA, 2017), some differences between Surface-CDM and ACDM are:

- Incoming leg information not used in calculations**.**
- Metered time begins at the taxi entry point (TMAT).
- Substitutions will be allowed with S-CDM.
- Departure slot will be the property of the airline.
- Each airline will be allowed to swap their own flights.
- Departure slots for cancelled flights will be used in substitution or made available for others (FAA, 2017),

ACDM Operations Today

No airport in the United States has fully deployed and thus, totally optimized all surface air traffic movements via the ACDM process. There have been several individual airport one-of-a-kind trials and decision support tool tests to partly enable or facilitate ACDM. These trial and decision support tool tests can be divided into three categories (TNAP, 2015).

Actual ACDM Technology Tool Deployment

In the United States there is the ground departure-metering tool employed at JFK International Airport, initiated by the Port Authority of New York and New Jersey (PANYNJ). It is operated and staffed under a contract with the PANYNJ (see Appendix C for details). The focus of this ground departure-metering tool is to control/limit the number of departing aircraft queued on an active taxiway at any one time (TNAP, 2015).

The effectiveness of this departure metering operation is inhibited by the lack of real-time ATC movement restrictions impacting departures (TNAP, 2015). Thus, the ground departure metering function is metering flights without consideration of ATC traffic management restrictions (TNAP, 2015).

Commercial Tools Leased/Purchased by the Airport or a Specific Operator

These commercial tools are generally used to improve situational awareness applications. Their specific usage varies from airport to airport. Examples of this tool include:

- Utilizing privately installed multilateration: ***(Multilateration is a localization technique based on measuring the difference of the distances between the robot and landmarks.)*** antennas and flight matching capabilities.
- Generating a real-time display of aircraft movements on or around the airport, which allows the user to gauge real-time positioning of flights for gate and ramp management.
- An airborne tracking of flights using a slightly delayed feed from the FAA Aircraft Situation Display feed or real-time positioning via ADS-B generated information.

- Airborne tracking of flights’ decision support tool that provides alerts for such activities as entering holding, diversion, or change of destination (TNAP, 2015).

Tools Not Intended for ACDM Technology but Sometimes Utilized as Such

Many airports have Flight Information Displays (FIDs). There are several types of FIDs. In addition to passenger information displays, these systems are utilized to relay parking position information to various vendors operating on the airport ramp areas (TNAP, 2015).

Many operators display countdown parameters at each gate. These parameters display flight numbers, destinations, countdowns to departure, etc. They are used to collaborate ramp activities toward on-time departure readiness. Such systems could be used to gauge an Estimated Off Block Time (EOBT), but such information is usually held internally by airports. **(**TNAP, 2015).

Around the world, there are some examples of ACDM applications, initiated for reasons such as reducing operation taxi time, fuel burn reduction, and CO2 emission. Some of these examples are listed below.

Europe

Paris’ Charles de Gaulle Airport enacted an ACDM effort where some, but not all, users are provided with a means for data entry to display maintenance delays and other factors involved in departure readiness. Additionally, the same users receive data such as departure runway and queue length. This effort originally only involved two airlines (Air France and FedEx) for test purposes. However, it is being expanded as lessons are learned and systems and techniques are refined (TNAP, 2015).

Some gains reported from this are, reducing average taxi time outbound by 2 minutes, 44 tons of CO2 per day, 14 ton of fuel per day (TNAP, 2015).

China

China has instituted Airport CDM programs at most major airports. This was a result of growing ATC flight departure delays. This ACDM program did not significantly reduce delays but did emphasize the fact that delays from major Chinese airports resulted from airspace constraints and limitations on airspace availability to commercial aviation usage (TNAP, 2015).

Japan

ACDM in Japan concentrates on environmental issues such as reduced emissions from taxiing aircraft due to emphasis on conformance to the Kyoto Protocol. The effort is in an organizational stage with workshops and educational programs being initiated beginning in Fall 2013. Specific system-wide procedures for all Japanese airports have not yet been initiated (TNAP, 2015).

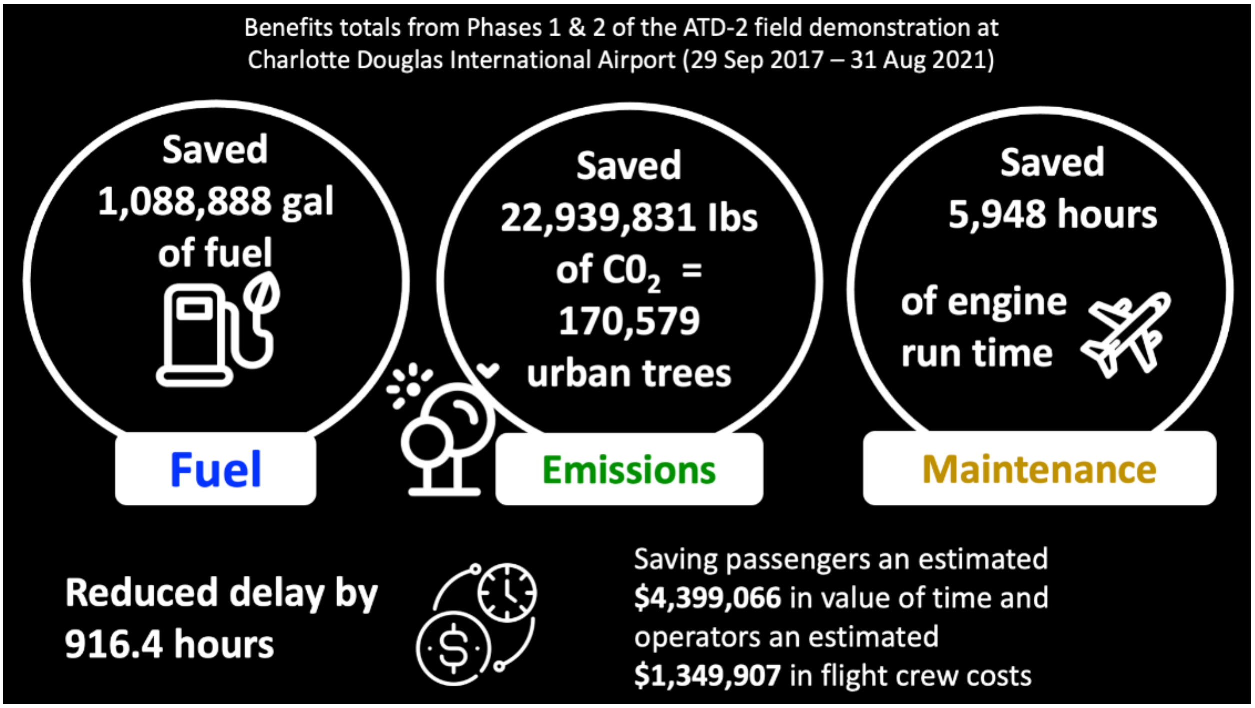
Charlotte Douglas International Airport

NASA is developing and testing a suite of decision support capabilities for integrated arrival, departure, and surface (IADS) operations. The effort consists of three phases, under NASA’s Airspace Technology Demonstration 2 (ATD-2) sub-project, through a close partnership with the Federal Aviation Administration (FAA), National Air Traffic Controllers Association (NATCA), air carriers, airport, and general aviation community (TNAP, 2015).

The Phase 1 and 2 IADS capabilities provide enhanced operational efficiency. They generate predictability of flight operations through data exchange and integration, surface metering, and automated coordination of release time of controlled flights for overhead stream insertion. Phases 1 and 2 have been demonstrated at Charlotte Douglas International Airport (CLT) starting in 2017 (NASA).

Field demonstration results of departure metering from Phase 1 and Phase 2 thus far (September 29, 2017, through August 31, 2021) suggest that the ATD-2 IADS System saves fuel and emissions, reduces congestion on taxiways, and improves compliance with scheduled takeoff times for managing overhead stream insertion (NASA).

Figure 1Benefits totals of the ATD-2 field demonstration at Charlotte Douglas International Airport from Phases 1 and 2 thus far.



Benefits totals from Phases 1 & 2 of the ATD-2 field demonstration at Charlotte Douglas International Airport (29 Sep 2017 – 31 Aug 2021)

Saved 1,088,888 gal of fuel

Saved 22,939,831 lbs of CO_2 = 170,579 urban trees

Saved 5,948 hours of engine run time

Reduced delay by 916.4 hours

Saving passengers an estimated **$4,399,066** in value of time and operators an estimated **$1,349,907** in flight crew costs

(September 29, 2017 - August 31, 2021) (NASA).

On February 3, 2021, NASA’s Airspace Technology Demonstration 2 (ATD-2) team deployed a new version of the Phase 3 Integrated Arrival, Departure, and Surface (IADS) system. ATD-2 Phase 3 is focused on developing and demonstrating technology for collaborative rerouting of departure flights to reduce delays and improve operational efficiency (NASA). The collaborative rerouting is enabled by the digital exchange of candidate routes (called Trajectory Option Sets or TOSs) between airline flight operators and Air Traffic Controllers (ATC) (NASA).

Two key enhancements in this software release include the first time that the ATD-2 system provides field demo partners with gate-to-gate predictions for a set of routes. In particular, new data elements provide estimates of a flight’s arrival delay at the destination airport for both the flight’s filed route and alternate routing options (TOS) (NASA).

Required Data and Sources

As presented throughout this Chapter, one of the essential factors was the ability for a collaborative effort by various stakeholders to share information, monitoring, reading, and decision making.

For this, the transportation research board's guidebook lists the following Table 2 as a guideline describing the relevant information that needs to be shared, and who is responsible for providing it.

Table 2 Data Point Elements and Sources

		Sources					
		ANAC	**Airline Ops Center**	**DRC**	**Airport Ramp Tower**	**Airline Ops Center**	**DECEA**
Data Element	**AOBT**		■			■	■
	ASDE-X	■					
	EOBT		■		■	■	
	ESPT	■					■
	ETOT			■	■		■
	SOBT		■			■	
	OOOI	■	■			■	
	PDRC	■		■			■
	TMAT	■		■	■		■

(TNAP, 2015)

Summary

As it is clearly evidenced, CDM (Collaborative Decision Making) all over the hubs spread worldwide came to be a positive project in order to reduce delays, saving fuel, and optimizing the air traffic flow. With the ability of gathering every data required to start this project in Brazil, the local industry will perceive the gains from this practice, as well as the Brazilian passengers, who will face lower time delays and possibly a reduction in the tickets, which will come from the savings.

Chapter III

Methodology

In this chapter, the data sources will be presented. This study aimed to introduce a hub ramp control which will give the companies full autonomy to better regulate their ground movement and operations at the hubs. Our research considered any Brazilian airline's operation at its hub, and how it can achieve the best results by having the ability to fully manage the aspects described above.

In addition, the study assessed how American companies conducted their hub ramp controls. We studied how this could be replicated in Brazil. It is of general knowledge that this concept is successfully implemented in a number of large airports such as JFK (multiple airlines with hub ramp control), EWR (United) and ORD (United).

Experimental Design

The need of developing a method to implement a Hub Ramp Control in Brazil was identified mainly as the outcome of higher fuel prices. The idea being thinking on how much could be saved if the disruptions could be better managed. It was claimed that American companies largely use the Hub Ramp Control (metering) at major airports. This can give airlines the ability of modifying their schedules and reducing delays and fuel expenses. (Guidebook for Advancing Collaborative Decision Making (CDM) at Airports (2015).

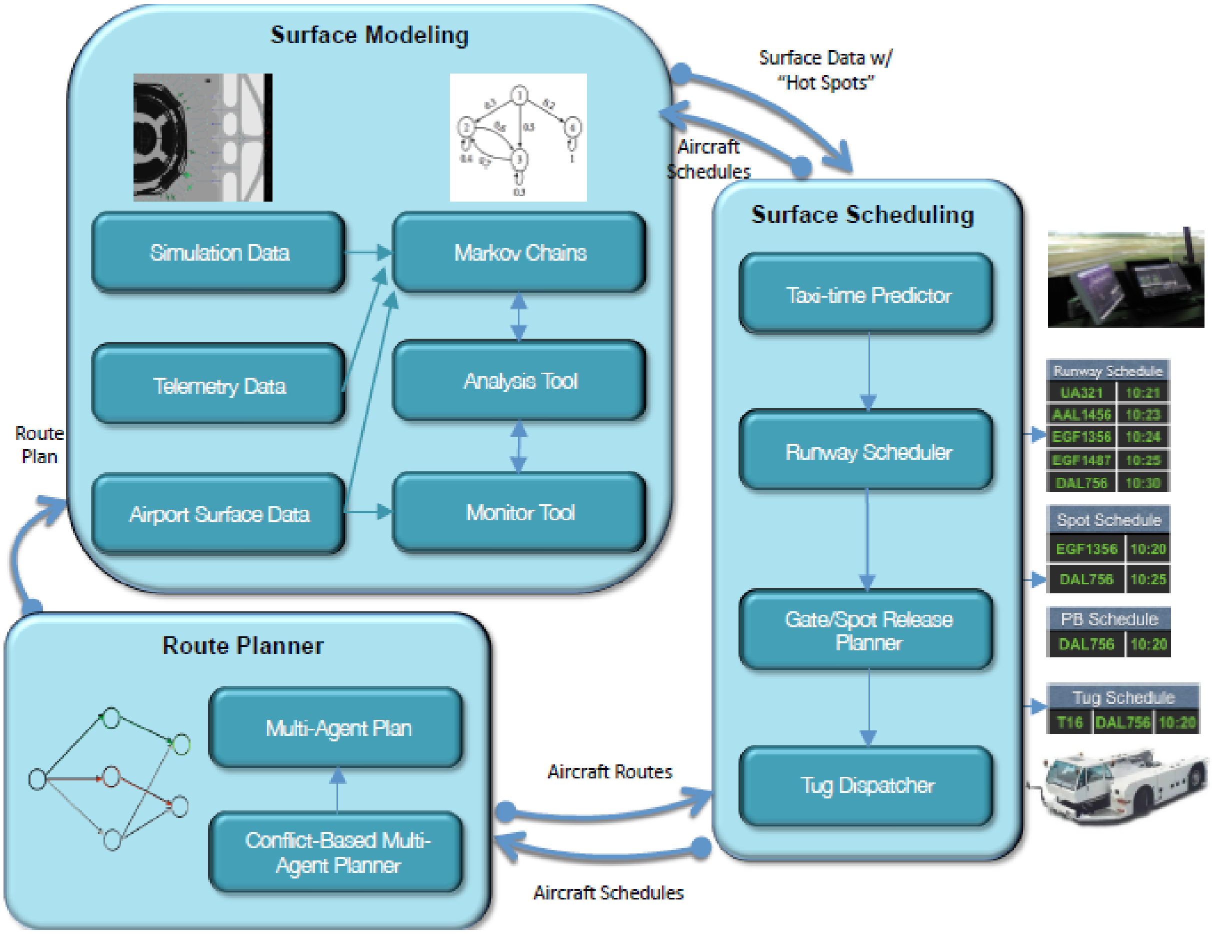
Data Source(s), Collection, and Analysis

For this research, six data sources were taken into consideration:

1. The first one is entitled as "Scheduling and Airport Taxiway Path Planning under Uncertainty", which describes how the schedules which goes into disruption can be recovered. This study goes through a simulation and provides several scenarios which permits to reschedule the ground operations again.

2. The second one is named “Planning, Scheduling and Monitoring for Airport Surface Operations”. This data source understands better how a surface modelling can help on developing the resources to put the operations back on track, as per Figure 3.1 below.

Figure 2 Surface-Modelling



Reference: Planning, Scheduling and Monitoring for Airport Surface Operations

3. The third source is the “Guidebook for Developing Ramp Control Facilities”. Since the main goal of this work is to continuously sequence the departing aircrafts in order to keep the network as close to the planned as it can, counting with a Ramp Control is key. This is why this reference is useful to start this project.

4. The fourth source is the “Analysis of Airport Surface Schedulers Using Fast-time Simulation”. This resource gathers data regarding the times required for every moves during ground operations, since the pushback time until being ready for takeoff at the runway. This timeline analysis makes it possible to predict the schedules along the operation day. It is essential that the operator can assess each aircraft model, since some might take longer to taxi, as the airport infrastructure will require specific taxiways to be used due to length and wingspan of the airplane.
5. The fifth source is the “Strategic Surface Metering at Charlotte Douglas International Airport” article. At this airport, it was identified that during peak hours of the day, there is the need of strategic surface movements. This is what they call SMP (Surface Metering Programs), a program that predicts long taxi times, based on the current network. Once it is identified that longer than usual taxi times will generate delays, target pushback times are provided for every flight to reduce the predicted delays.
6. The sixth source is the “Guidebook for Advancing Collaborative Decision Making (CDM) at Airports”. One of its Appendix describes the CDM implementation at JFK, which made it possible to reduce taxi out times by 14,800–21,000 hours; reducing fuel burn by 3.26–4.98 million gallons of fuel; and reducing CO2 emissions by 32,000–47,800 metric tons.

All these data sources are secondary, meaning, they were extracted from pre-existent databases, therefore not being collected by the research.

The analysis of each source was done aiming to adapt the experiences for the Brazilian reality.

Methodology Illustration

To implement this project at a hub in Brazil, the following is to be considered:

- The current Brazilian aviation rules state that the DECEA (Departamento do Controle do Espaço Aéreo) has the power to execute air and ground space control activities, so that no private or any other state enforcement can provide this kind of service;
- The only exception about the statement above is the Class B EPTA (Estação Prestadora de Serviço de Telecomunicações e de Tráfego Aéreo), which CAN be used in some airports in Brazil, such as GIG and VCP. (ICA 63-10)
- It is also necessary to state that a ramp control CANNOT be understood as a ground service control activity but as a facility at which the DECEA does not have autonomy on;
- To achieve the ramp control autonomy at a determined ramp, the company has to directly coordinate with the Ground Control, the Tower Control and the Approach Control. For this to happen, mechanisms such letters of agreement should be firmed with these organs and with the airport administrator;
- The company at stake has to represent at least 90% of the operation in the ramp where the metering control is to implemented. This is to justify the autonomy provided for this operator;
- To be possible for the operator to control the ground movements at the ramp, there will be additional taxes. With a financial study, this research aimed to prove that the costs involving a ramp control would pay off, since substantial direct cost reductions with fuel burn and crew hours, as well as indirect costs such as processes by the customers and customer satisfaction are to be faced.

Examples:

Currently, Airport ABC (hypothetical) in Brazil at which a company operates as its main hub, has only one terminal. At this airport, there is one company which represents 95% of the ground movements;

Naturally, many delay reasons occur for this company at this airport, and with all of the processes described previously in this chapter, it is possible to put the operations back in the schedule, or at least to reduce the amount of delay minutes;

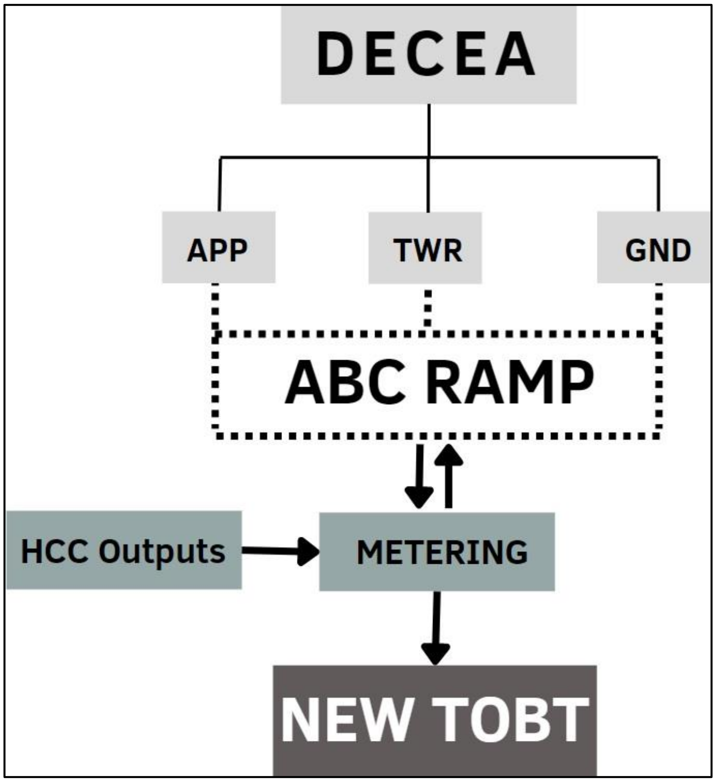
In addition, when disruption events such as adverse weather, maintenance, traffic, etc. happens, the most critical flights can be repositioned to the front line to reduce all of the drawbacks attached to it.

- Missing contents: Numbers: delay statistics at the hub; reasons for delay; expenses attached to the delay; mathematic models for delay amounts; daily number of ground movements; decision making.

Figure 3 Dynamics involved in the Metering Activation

The image above shows an airport at which a Ramp Control is incorporated. As depicted in the image, the boundaries for the Ramp jurisdiction (blue area) end at the taxiway that allows access to runway or main taxiway, where the GND control jurisdiction starts.

Figure 4 Describes the dynamics involved for the Metering to be deployed. Reference: image created by the group.



ABC Ramp, which is a communication organ that does not provide Ground Control, is designed to provide movement instructions at the Ramp area. Nevertheless, this entity has to communicate directly with the control organs, such as GND, TWR and APP, because it is essential for the Ramp to be aware of the expected movements all along the airport moving area (taxiways and runways).

Regarding the HCC:

- HCC is a branch of the OCC. It executes very similar activities in comparison to the OCC, but focused at the HUB;
- The HCC is the assigned company entity to deploy the Metering;
- By being aware of the delays and disruptions, the HCC rebuilds the schedule, and assigns updated TOBTs for the affected flights, in order to reduce the operational harms caused by the disruptions;
- These adjustments are created based on the estimated times provided by the teams who are in charge of correcting the disruption. For instance: a pilot feels sick and will drop off from the next flight. The execution roster will inform how long it will take the new pilot to enter the next flight, and based on this data, the HCC will provide an updated TOBT.

Regarding the Metering:

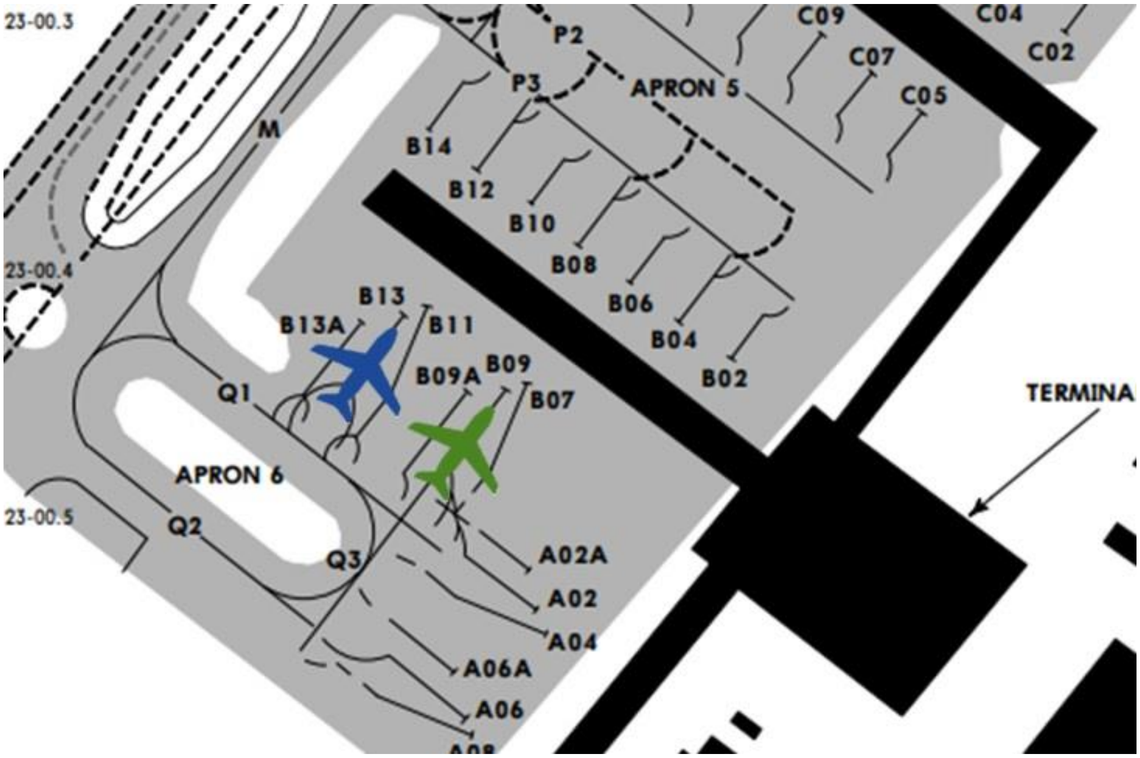
- It is deployed during peak hours or when it is identified that the Metering has to be in force (e.g.: several disruptions);
- The HCC defines when the Metering is in force;
- The pilots are aware that the Metering is in force through ATIS information;

- While the Metering is in force, it does not mean that every flight will receive an updated TOBT. Just those that are impacted or could affect the network schedule are given a new TOBT. All of the remaining flights shall start the pushback at the standard assigned time, and shall keep the track as close to the original as it can.

Practical example 1:

- Flight ABC123 is assigned an EOBT at 17:45 at gate 5. When the pilot in charge of external inspection goes checking the aircraft, he/she realizes that one tire is flat. The maintenance is warned, and they claim a 30 minute period to replace the tire and leave the aircraft ready for departure. The airport states it takes another 30 minutes to reboard the aircraft. Hence, the HCC assigns an updated TOBT to 18:45 for ABC123.
- By 18:45, flight ABC456 is supposed to pushback at gate 4. If both ABC123 and ABC456 start the pushback at the same time, ABC456, will cause an additional delay for ABC123, because it will taxi and takeoff first;
- Being aware of this, the HCC has to come up with a strategy to avoid this additional delay, hence, the Metering is activated;
- The HCC is informed that everything is set for ABC456 to pushback on time. That way, the Metering sends an ACARS message to ABC456 informing that its new TOBT is 18:40. This will guarantee that ABC456 departs on time, and that this flight does not cause any further issue for ABC123, which is already late.

Figure 5 Airport ramp scheme.



PRACTICAL EXAMPLE 2: Multiple airports closed in the South region. Many flights rescheduled for later.

- Six flights are parked in APRON 5 at ABC airport. Flights ABC 111, ABC 222, ABC 333, ABC 444, ABC 555 and ABC 666.
- All of these flights are retained because their destinations and/or alternate airports are closed due to an extensive fog all over the South region;
- The meteorology team claimed approximately a 45 minutes delay for these flights to depart, because the weather is predicted to improve within this time;
- Being aware of this, the HCC activates the Metering, and the new TOBTs are issued for each flight, as demonstrated by the table below:

Table 3 Standard EOBT and New TOBT.

FLIGHT	STANDARD EOBT	NEW TOBT
111	07:00	07:45
222	07:05	07:45
333	06:55	07:46
444	07:00	07:47
555	07:05	07:44
666	07:10	07:50

- The flights above are serving different destinations, and for each one of those a new TOBT is assigned by the Metering, according to a priority;
- The priority logic in terms of earlier departures is designed as the following:

I. Connecting passengers at the next base;
II. Crew duty limits;
III. Operating time of the destination and alternate airports; (WIP NOTAMs, etc)
IV. Fuel burn during taxi;
V. Any other reason.

NOTE: The Metering can override the sequence above in case it is necessary.

Because Flight ABC 555 was the most critical one regarding passenger connections, this flight was assigned the earliest TOBT. In case any other flight requests pushback prior to ABC 555, the ABC Ramp Control will not allow this flight to push in case it precludes ABC 555 to push ahead of 07:44.

- **Estimated costs attached to delays**

  Considering an operation in South America, the average costs involving an aircraft parked at the gate due to any disruption would be represented by the following table:

Table 4 Average cost by range of time.

Time (minutes)	15	30	45	60	75	90	120	180	240	300	360
Average cost (U$)	1967	3167	4567	6067	6300	8033	11400	17400	21700	24167	26133

The costs involved for these figures are fuel consumption (APU running at the gate); airport and navigation taxes (taxes for exceeding the estimated parking times); crew payment (in case the crew exceeds the duties, it will be necessary to replace the crew members, generating additional costs); passengers services (meal and legal rights); passengers reassignments (transferring passengers to other companies); Handling services (extra tug and tools use).

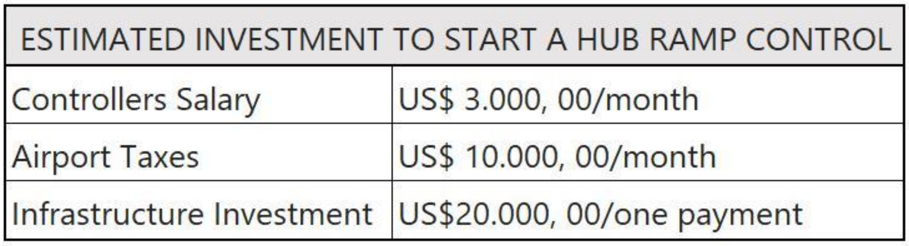
(Source: Team F AVM V).

Estimated Costs Attached to Administer the Ramp Control.

Since the company that administrates the airport will grant ABC Airline the permission to manage the ground movements at the ramp, it is supposed that the administration company will create an additional tax for this benefit.

Furthermore, additional investment will be necessary regarding infrastructure and ramp controllers. Both of these items are further explored in the following topics of this chapter.

Table 5 Investiment to start a Hub Ramp Control.



ESTIMATED INVESTMENT TO START A HUB RAMP CONTROL	
Controllers Salary	US$ 3.000, 00/month
Airport Taxes	US$ 10.000, 00/month
Infrastructure Investment	US$20.000, 00/one payment

Estimated investment to start a hub ramp control

Controllers Salary | US$ 3.000, 00/month

Airport Taxes | US$ 10.000, 00/month

Infrastructure Investment | US$20.000, 00 /one payment

Estimated time for ROI

Supposed that this project permits a daily reduction of 15 minutes delay, and considering the values provided in table 3.2, it would be possible to save close to US$ 2.000, 00 per day.

That way, the ROI would be perceived in the first month of implementation, granting a monthly US$ 60.000, 00 cost reduction due to disruptions.

Letter of agreement and relationship with other companies.

Letter of Agreement

VIRACOPOS INTERNATIONAL AIRPORT

LETTER OF AGREEMENT

Effective date: September 25, 2022

SUBJECT: Agreement for responsibilities and movement management of Viracopos Aprons 4,5 and 6**.**

1. OBJECTIVE

1. The purpose of this letter of agreement is to constitute an alliance among ABC Airlines, ABV Airport Operator and Viracopos Control Tower with respect of controlling aircraft movement on aprons 4, 5 and 6.

2. SCOPE

2.1 Although it is known that there is no apron management control in Viracopos Airport. ABV Airport Operator has stablished rules as well as guidelines in order to provide a safe ground movement operation. The ground control tower works closely with ABV, by communicating to pilots the assigned gates and rules to push back and move around the aprons. As ABC's main hub is set at Viracopos Airport, it is expected that daily flights achieve 200 operations, so. Therefore, in recent months ABC established a Hub Control Center, located on Pier C, in order to sustain and study more operational solutions to continuously provide a more efficient and safer operation. Wherefore, ABC Airlines understands that it is ready to assume ground control of the ramp 4,5 and 6 operations.

3. ORGANIZATIONS

1. The organizations referred to this letter of agreement are:

I. ABC Airlines Ltd.
II. ABV Airport Operator Authority
III. Brazilian Civil Aviation Agency (ANAC)
IV. Brazilian Airspace Department (DECEA)
V. Viracopos Control Tower (TWR-KP)
VI. Swissport Ground Handling Operator

4. ROLE OF EACH ORGANIZATION

1. ABC Airlines Ltd.

The airline will be responsible for managing and coordinating arrivals as well as departures, considering gale allocation of aprons 4,5 and 6. In order to guarantee a fair operation, all aircraft operator within the referred aprons will be served equally, therefore, eliminating all kinds of bias or specific privileges. In addition, ABC Airline will be responsible to stablish a VHF frequency to operate on aprons 4,5 and 6, in order to mitigate possible controlling interferences with aprons 1,2 and 3. ABC Airlines will observe the airport operating hours or any restriction imposed by Notice to Air Missions (NOTAM) in order to comply with. Finally, ABC Airlines will strictly follow and respect the apron pushback rules and limitations established by ABV. Any procedure change will require an analysis of the Airport Safety Department.

2. **ABV Airport Authority**

The referred Authority will recognize that ABC Airlines Ltd. will have jurisdiction over controlling Aprons 4,5 and 6, considering gate allocation as well as pushback clearances and taxi-in and taxi-out up to access these aprons, these changes will be stated in Viracopos Aeronautical information Publication (AIP) and will be responsibility of ABV to request the manual update. In addition, gate management allocation program of aprons 4,5 and 6 will also be handed and live image cameras of the aprons will also be provided, thus being responsibility of ABC Airlines. Finally, ABV Authority will provide training and monitor operations for the duration of this agreement.

4.3 Brazilian Airspace Department (DECEA)

The Brazilian Airspace Department will be responsible to update any Aeronautical Publications, such as; Charts, AIP and whatever may be applicable, with respect of bringing up the new Ramp control configuration for Viracopos Airport.

4. **Brazilian Civil Aviation Authority (ANAC)**

ANAC will acknowledge this letter of agreement and if so, manifest any concern. It is suggested to share the content with other carriers.

5. **Viracopos Control Tower (TWR-KP)**

TWK-KP will hand over the communications and control of aprons 4,5 and 6. In addition, Tower will ensure the Automatic Terminal Information Service (ATIS) will mention "Metering in force", thus guarantying all aircraft receive the current information.

6. Swissport Ground Handling Operator

Swissport will continue to assist on ground handling operations and follow and comply strictly with the ground operation procedures established by ABV Airport Operator.

5. OPERATIONAL PROCEDURES

1. Gate Assignment, Parking and Apron Movement

Aircraft parking positions as well as pushback and taxi clearances will be assigned by ABC Airlines on aprons 4,5 and 6 with a non-discriminatory purpose, therefore, clarifying that all carriers will have equal rights of access. Although, application of practices that will promote efficiency in operations and optimize passenger levels of service will be considered based on the non-discriminatory principle. Apron movement rules, such as pushback, jet blast and taxi lane restrictions are set to be followed the current Ground Movement and Guidelines Manual, provided by ABV Airport.

5.2 Hand off during departure and arrivals

The jurisdiction of ABC Ramp control will be as shown in the image below:

During departures, ABC Ramp Control will hand off to the Viracopos Ground Control the aircraft after taxiway “M”, those aircrafts parked on positions 107, 108 and 109 on apron 4 will be handed off after reaching TWYs “M” or “K1”. During arrivals, Viracopos Ground Control will hand the aircrafts determined to park on aprons 4,5 and 6 before reaching taxiways “M” or “K1”. All changes regarding to ground movement rules must be communicated to all stakeholders listed in this letter of agreement.

1. **CANCELATION OR AMMENDMENT**
2. This letter of agreement represents an agreement directly to ABC Airlines, ABV Airport Authority and TWR-KP, however, all stakeholders listed in this document are free to express any concern by September 23, through the e-mail aproncontrol@sbkp.com.br.

REPRESENTING ABC AIRLINES

Name:

Signature:

Date:

REPRESENTING ABV AIRPORT OPERATOR

Name:

Signature:

Date:

REPRESENTING VIRACOPOS TOWER

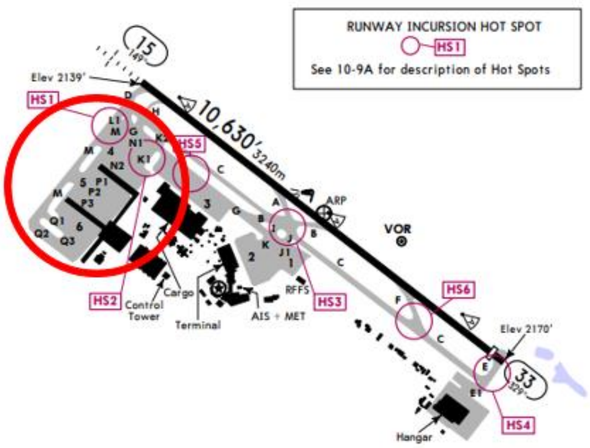
Name:

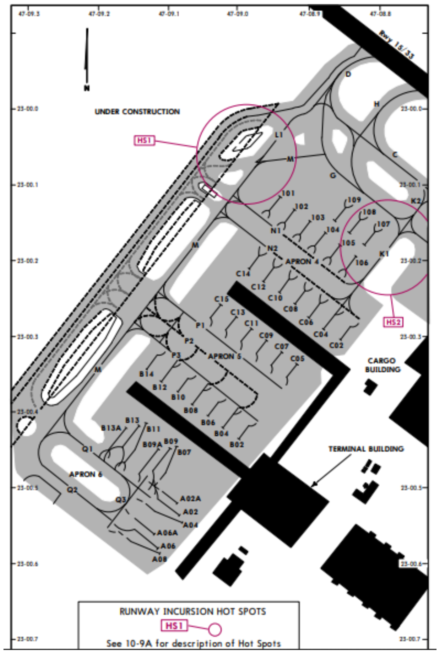
Signature:

Date:

Challenges regarding Airport infrastructure

At this hypothetical airport we have three aprons (4, 5 and 6) controlled by a Ground Control. In order to access these aprons, the airlines have just taxiway M as below:





In reason of this, sometimes the aircraft ground traffic becomes stuck. This TWY M is a two-way (⇄), allowing all the aircraft to arrive in this aprons and to depart as well.

The airline ramp control would allow a better controlling of aircraft flow on these aprons. In order to make this possible, the Ramp Control must have access to the cameras of the three aprons (4, 5 and 6). If not, many cameras for this purpose would be installed in the terminal side, but also next to the taxiways on ground control area. Moreover, the

Ramp Control needs to be equipped with Radar Repeater of ATC (ground) and to access the respective live communication. In addition, there is a stopped project of a new taxiway behind the M. Our project suggests restarting the construction of this adjacent taxiway, in order to make the two-way traffic easier and smoother.

Experimental Design

For statistical studies and to measure the possible gains and impacts of the project implementation, the team collected data from the 3 airlines in Brazil. According to ANAC 2021 data, the 3 companies represent 92.2% of total domestic operations in 2021.

The data provided were: Taxi out fuel burn per hour per equipment, Origin, Destination, Number of takeoffs and average taxi out time.

Based on the consumption per hour for each equipment, the total fuel consumed for the taxi out operation at an airport was calculated. Through this it is also possible to calculate the amount of fuel consumption reduction after the implementation of the project, which foresees a percentage reduction in consumption, according to the history of other airports where similar initiative has been implemented.

Another relevant point of the study, besides the reduction of fuel consumption and consequent financial reduction, is the reduction of CO2 emissions. This project may contribute to airlines being able to meet the regulations set in the CORSIA, an ICAO initiative, which aims to establish the maximum CO2 emissions for airlines in order to reduce environmental impacts.

Part One – Total Fuel Burn from taxiing operation.

It is important to understand that each equipment has a specific fuel consumption, and therefore it is necessary to quantify the operations for each equipment, so that you can calculate the total consumption for an airport.

Another important point is that in the taxi out stage, the zero fuel weight (the weight of the aircraft before fueling) does not affect the fuel consumption of the aircraft, different for the climb and cruise stages, for example, which generate weight stress and makes the aircraft need more forces to maintain its lift forces, and therefore consume more fuel. This increase in consumption by weight is presented in Cos of Weight studies.

The equation used for this calculation is:

$$
\begin{aligned}
TFB = {} & 700.(FB.OPS.AVGTouT) + 800(FB.OPS.AVGTouT) \\
& + MAX(FB.OPS.AVGTouT) + 320(FB.OPS.AVGTouT) \\
& + 319(FB.OPS.AVGTouT) + 321(FB.OPS.AVGTouT) \\
& + 19SE1(FB.OPS.AVGTouT) + 19SE2(FB.OPS.AVGTouT) \\
& + ATR(FB.OPS.AVGTouT) + 330NEO(FB.OPS.AVGTouT) \\
& + 330SEO(FB.OPS.AVGTouT
\end{aligned}
$$

TFB = total fuel burn (liter);

OPS = operation quantity (integer);

AVGTouT = average taxi out time (hours);

FB = liter consumption per hour in taxi in (l/h).

The consumption per hour and the average taxi in time were obtained by the airlines, and the operation quantity by ANAC data.

Part Two – Reduction in Total fuel Burn.

For this calculation we used the average reduction of taxi time presented in studies done in airports in Europe, the United States and Guarulhos. With the reduction percentage, we can multiply the TFB by this number, which will result in the total avoided fuel.

The equation, therefore, is as follows:

$$REDTFB = RedPercentage.TFB$$

TFB = total fuel burn (liter);

REDTFB = total fuel reduced (liter);

RedPercentage = Percentage reduction (%).

Part Three - Total amount of carbon avoided

To calculate the carbon emission reduction, the amount of fuel avoided was used and multiplied by the CO2 emission coefficient for each kg of fuel, or the FCFr.

$$CO_2 = MREDTFB.FCFr$$

CO2= Total CO2 emission (in tons);

FCFr = Fuel conversion factor equal to 3.16 (in kg CO2/kg Jet fuel);

MREDTFB = Mass of Jet fuel Burn (in tons).

The FCFr factor of 3.16 is presented in a 2018 ICAO study. This number determines the ratio of the amount of each ton of CO2 for each ton and Jet Fuel consumed.

Chapter IV

Conclusions

This research project aimed to develop what is called “Metering”, a resource that can optimize the time management when facing disruptions or during peak hours at the hub. This project aimed to improve airport operations. Initially, one airport was considered, due to its characteristics. Only one runway is available for landings and takeoffs. Taxiways are used in both ways. In addition, a large company operates in several at the same schedule. Nevertheless, this is not an exclusive issue. The Metering benefits can be extended to many airports worldwide, by assisting the operations, bringing optimization, agility, efficiency, and economy.

Conclusion One – The Metering- An annual cost reduction of $720,000 in fuel and decreased taxiing delayed time could be achieved through the implementation of the Metering concept. This cost reduction will come in several different forms, such as reduction of taxi time, which includes operational expenses such as fuel burn, flight hour payments for crew members, aircraft leasing, and others.

Data gathering

During peak hours or during operational disruptions, creating a logic line that follows the variables already presented such as, passenger connection at the next base, crew duty limits, operating time at the destination and alternate airport, fuel burn during cab, parking position among others can create an optimized line reducing the amount of taxi time. This would decrease the fuel burn for this part of the flight. Indirectly, cost reduction can also be involved with a reduced crew payment and avoiding duty hours issues, as well as less use of engine (maintenance and lease costs). This cost was measured considering the average expense of a 15-minute delay on ground at Latin America airports.

Results

Financial wise, a significant monthly reduction can be realized. In a hypothetical scenario, where 15 minutes are saved in a day, the initial investment would be returned within a month, being aware that 15 minutes represent US$ 2,000. Hence, if this value can be reduced daily, the previously mentioned total of US$ 720,000 can be potentially saved annually, at a single airport.

Conclusion

Implementing of the Metering process can possibly give the airline a significant financial cost reduction.

See Recommendation 1 in Chapter Five.

Conclusion Two – New Taxiway- Add a second taxiway would save an additional US$ 730,000 per year on this airport.

Data gathering

A study through airports that lack taxiways to have the traffics taxiing both ways demonstrates that the taxi time increases significantly.

Results

For a hypothetical situation where every day there is an additional amount of 15 minutes taxi for the whole ground movements due to taxiways being used in both hands, an additional US$ 2,000 a day or US$730,000 annually is to be added to the operational costs at this hub.

Conclusion

Counting with additional taxiways to enter and exit the apron is key to optimize the Metering tool proposal.

See Recommendation 2 in Chapter Five.

Conclusion Three – NPS (Net Promotion Score)- Metering should give opportunities for the airline to keep or increase the NPS rates.

Data gathering

Each US airline loses up to US$1.4 billion in annual revenue due to the NPS. Hence, NPS can be monetized. Much of this rate comes from the on-time performance the airlines can keep. This index allows the companies to input higher charges on the tickets.

Results

If 30 minutes of delay - general operations - can be reduced daily, the NPS rates will not decrease significantly. A NPS evaluation from the customer experience with the flight and the company overall can be as low as 0 and as high as 10. If the Metering can avoid a delay, or at least reduce the delay amount, the NPS score given by the customer will be higher than if no additional measures to fight this delay were not taken.

Conclusion

Implementing the Metering is an additional resource for the positive customer experience and an opportunity to keep the fares at higher prices.

See Recommendation 3 in Chapter Five.

Conclusion Four – No Additional Training- Implementing the Metering should not require additional training.

Data Gathering

Sometimes, implementing new procedures require additional training. For example: new types of approach procedures, new software introduced into an aircraft, etc.

Results

Training is always a high investment. For this scenario, no additional training would be needed to implement a resource that can reduce the operational costs. With the annualized US $720,000 potentially cost reduction, this value should be redirected to other investments within the airline.

Conclusion

Since the standard procedures for the personnel involved (HCC employees, pilots, ground controllers, airport operators) would not change significantly with the Metering, no investment with training shall be necessary.

See Recommendation 4 in Chapter Five.

Conclusions Text and Support Material

Conclusion One: This conclusion was achieved by considering the Metering use at hubs and the expenses attached to fuel, maintenance, and general operational disruptions. The saving estimate is given with the data thought in the reality of an airport and its operational characteristics. The data and values were based, besides the previously mentioned references, preferably on the Capstone *The Impact Of Unscheduled Maintenance To An Airline's On Time Performance* (2021).

There are also associated expenses that we are unable to account for, which can be incurred due to excessive delay, such as customer dissatisfaction due to missed appointments, missed connections, and anxiety about arriving at the destination soon. These situations can cause the company to not only suffer legal or juridical losses due to lawsuits that can be filed against the airline, but also the customers may never want to fly with that company again and make negative advertisements, and this damage is impossible to quantify. The application of this proposed process in additional airports could result in significant savings of more than $10 million dollars.

Conclusion Two: This conclusion was achieved by understanding how much time can be saved when there are dedicated taxiways to enter and exit the apron. The supporting data presented here are in agreement with estimates of average fuel burn of worldwide fleets, as well as with mathematical models and experience gained during years of operation and experience.

Conclusion Three: Based on research and theses about the importance of NPS we have this well-founded conclusion. We have no way of defining how much we would have to save at this airport and the airlines that serve this particular airport before it is actually implemented, but we can use lessons learned from other airlines to have a basis for how beneficial our proposal can be not only in reducing consumption, manpower and operating expenses, but also in customer satisfaction and service promotion.

Conclusion Four: This conclusion was achieved by understanding the challenges of introducing the Metering regarding the knowledge required to the personnel involved (HCC, pilots, ground controllers and airport operators). Field research, meeting with operators that already use this tool, as well as official data such as the JetBlue JFK Airport Briefing provide the basis for these conclusions.

Jointly Generated Savings - If we add up the savings from the implementation of metering as well as the construction of this additional taxiway, the annual value can reach up to $1,450 billion dollars. This value can be increased even more if we can quantify the value of the gains generated by the NPS.

Chapter V

Recommendations, Limitations of Study, Future Research, and Lessons Learned

This research project's purpose was to demonstrate the impacts and possible financial returns that the implementation of Metering Control could obtain at a Brazilian Airport in which the conditions described in Chapter III are followed. It was demonstrated through the estimates of fuel cost reduction, by the costs from taxiing delayed time, and valuing the costs necessary to implement such a project. The Metering Control could be supported with investment for an airline to start the HUB ramp control and of possible investment in the airport infrastructure, with the creation of more taxiways.

Based on the conclusion of the research, some recommendations become important to support solutions for companies to implement this control at an airport.

Finally, it was possible to conclude that in addition to the direct savings that can be obtained by implementing such control, there is a great opportunity to increase the revenue of airlines due to the reduction of flight delays, and a better NPS, which could be translated in an increase of the potential for capturing new customers and maintaining current ones.

Recommendation 1- By metering, an annual cost reduction of $720,000 in fuel and decreased taxiing delayed time could be achieved considering VCP airport scenario. Our recommendation has been that such a change should be discussed with the airport stakeholders, with a common agreement.

Recommendation 2 - Considering 15 minutes taxiing delay at VCP airport as a mean, the study demonstrated saving of U$ 730,000 per year through investment in add a second taxiway to enter or exit the apron in the airport. Our recommendation is to investment in infrastructure such as construction of new taxiways be financially possible by airport administration.

Recommendation 3 - Delays affect NPS of airlines significantly and could be improved also by metering control implementation. Therefore, our recommendation is that airlines be motivated to implement this tool in order to improve their NPS and passengers' attraction.

Recommendation 4- Once that training would not be required for the metering control implementation, airline and airport companies need to do networking with experienced partners. Our recommendation is that stakeholders involved in this project shall exchange information with GRU airport and JetBlue due to their experience in metering control.

Recommendations Supporting Material

Recommendation 1

As shown in the study, every year there is a relevant cost for airlines due to delays in their operations, which sometimes were not caused by them but by external factors, such as weather. With the application of control based on data and enabling the airline to make decisions to define ramp operations, could reduce this cost with a low investment and with return even in the first month.

Recommendation 2

Although investing in infrastructure at an airport is not something simple, which demands a high value, execution time, and uncertainties in the financial return, the research could fund the return of this investment, by taxiing delay reduction and optimization of ground operations. It is necessary to focus on such investment because it is a vital point for the success of “Metering” and in correcting disruptions, bringing financial, operational, and security benefits.

Recommendation 3

In the NPS characteristics, in which the customer has a basic question about whether or not he recommends the airline, we saw that the punctuality factor is the main factor in the customer's evaluation. Given this, through the metering implementation, airlines could reduce their costs of implementing new products, such as the provision of snacks on their short flights, and focus their investment on tools, employee and processes that optimize their operations to be the most punctual in the market. Therefore, maintaining their competitiveness and even being able to maintain a higher price on their tickets.

Recommendation 4

The main point of the project is to have a tool and system integrations where information between all parties can be shared and analyzed. In addition, to implement metering control, training should not be required for pilots or ground personnel. For this reason, a consultation could be done with the CDM group of other companies or airports where there is already an exchange of information among stakeholders and system integrations, in order to have a first proposal of functionality for sharing this data according to the Brazilian reality.

Limitations of Study

- The study was complex, since the Brazilian aviation market is not yet as mature as the American and European ones, where there are already clearances for airlines to be responsible for the organization of the ramp operation.
- The implementation of the project in airports where the company represents practically the totality of the ramp operation is extremely complicated, since in principle each company would focus its actions on what will bring the best result for them.
- The research group collected data from the three main airlines in the country, however, not in detail about equipment and operation, as was initially proposed. This difficulty is due to the confidentiality of the information. Therefore, the operation data used was obtained from past studies and from the companies FCOM.
- Modeling an equation that guides companies in an automated way which and how to organize their operation is something extremely difficult. We saw that there is still nothing solid being practiced within the companies in the country.
- Even if the project proves to be positive for all the airport stakeholders, there is still a great difficulty to obtaining an alignment to share data, given the sensitivity and confidentiality of the information.

Future Research

- Brazilian public policies and regulations do not encourage airlines and airports to work with ramp control by metering. Therefore, it is necessary to make them more flexible in order to allow airports in the country to start to work with this type of tool.

- After the implementation of “Metering” it will be interesting to validate the project and to identify improvements measuring and comparing the on-time performance of airlines regarding previous years.
- It was found that metering control could reduce fuel burn and reduce CO2 emission, therefore. In this way, research could be developed in order to measuring the impact on the reduction of CO2 emissions from the decreasing of taxi time and verify the possibility of using it to generate carbon credits in the Corsica program.

Lesson Learned

- The study showed that the investment will not only bring a saving to the operation, but also a possibility to position the airline more strategically in the market, and that the project can also improve the operation safety.
- Implementation of a metering control needs to be a cooperative project, which all the stakeholders must be well aligned. All the parts develop important tasks that can affect each other.

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