FINAL PROJECT – TI 184833

RESCHEDULING AIRCRAFT ROUTES IN IRREGULAR OPERATION AMIDST PANDEMIC SITUATIONS

RISANG ARKAAN JAUZA
NRP. 02411640000073

SUPERVISOR:
Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.
NIP. 196811091995031003

DEPARTMENT OF INDUSTRIAL SYSTEM AND ENGINEERING
FACULTY OF INDUSTRIAL TECHNOLOGY AND SYSTEMS ENGINEERING
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

FINAL PROJECT – TI 184833

RESCHEDULING AIRCRAFT ROUTES IN IRREGULAR OPERATION AMIDST PANDEMIC SITUATIONS

RISANG ARKAAN JAUZA
NRP. 02411640000073

Supervisor:
Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.
NIP. 196811091995031003

DEPARTMENT OF INDUSTRIAL SYSTEM AND ENGINEERING
Faculty of Industrial Technology and Systems Engineering
Institut Teknologi Sepuluh Nopember
Surabaya
2020

APPROVAL SHEET

RESCHEDULING AIRCRAFT ROUTES IN IRREGULAR OPERATION AMIDST PANDEMIC SITUATIONS

FINAL PROJECT

Submitted to Qualify the Requirement of Bachelor Degree

Industrial and Systems Engineering Department

Faculty of Industrial Technology and Systems Engineering

Institut Teknologi Sepuluh Nopember

Surabaya, Indonesia

Author:

RISANG ARKAAN JAUZA

NRP 02411640000073

Approved by:

Supervisor

Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.

NIP. 196811091995031003

SURABAYA, AUGUST 2020

DISCLAIMER

This research entitled “Rescheduling Aircraft Routes In Irregular Operation Amidst Pandemic Situations” is an unpublished research document. Any kinds of referencing activities involving this research must not be done before permissions from corresponding researcher and researcher’s supervisor are granted. Permission proposal is able to be sent via email to arusdian@ie.its.ac.id. If any publication (seminar, national or international journal) uses this research, thus a reference should be properly shown in the publication.

RESCHEDULING AIRCRAFT ROUTES IN IRREGULAR OPERATION AMIDST PANDEMIC SITUATIONS

Name : Risang Arkaan Jauza
Student ID : 02411640000073
Department : Industrial and System Engineering ITS
Supervisor : Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.

ABSTRACT

Pandemic situation has brought a serious impact on airline industry. The unprecedented steep dive in passenger demand have crippled the business as the mainstream of revenue collapse. As for now, airlines have limited control over their revenue stream. The most appropriate approach to cope with this challenge is to minimize their cost. In desperate effort to keep the finance flow, airline should reinvent their operations to adapt with current situation. Airlines are reducing their traffics and ground fraction of their fleet, this condition calls for irregular operation. Definition of irregular operation should be leveraged into planning phase as planned aircraft shortage is desired. Thus, developing a tool to support decision making process regarding aircraft dispatching is required. In this research, a decision support tool is developed with the aim to simulate aircraft routing under different routing and cost parameter. This tool takes form of VBA model that process scheduled route regarding valid routing constraint and giving corresponding cost regarding the input. The model incorporates routing algorithm that allows the identification of cancelled, delayed, or earlier flight. In addition, the model will generate network representation of the valid routing in two-dimensional time-space network. The model can simulate the different dispatching decision. The results then used to compare different dispatching decision to find the good result heuristically and further understanding of the problem. Several aspect surrounding the model do play important role in the model result. The initial routing as well as the network type affecting the flexibility of route rescheduling.

Keyword: Irregular Operation, Aircraft Routing, Aircraft Dispatching

(This page is intentionally left blank)

ACKNOWLEDGEMENT

Praise to Allah Subhanahu Wa Ta'ala. Only with his will, grace, and guidance, the author can complete this research entitled "Rescheduling Aircraft Routes in Irregular Operation Amidst Pandemic Situation". This report is made as one of the requirements to complete bachelor's degree at Department of Industrial and System Engineering, Institut Teknologi Sepuluh Nopember.

The author would like to give highest gratitude and appreciation to all parties that involve in the making of this research by constantly giving support, feedback, motivation, and guidance. All thanks addressed to:

1. Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD., as this research supervisor, who give feedback, ideas, guidance, and help during the completion of this final project.
2. Prof. Dr. Ir. Suparno, MSIE., Ph.D., Prof. Ir. I Nyoman Pujawan, M. Eng., Ph.D., and Mr. Stefanus Eko Wiratno, S.T., M.T. as proposal seminar examiners who gave valuable feedback for the development of this final project.
3. Mr. Dody Hartanto, S.T., M.T. and Mr. Yudha Andrian Saputra, S.T., M.B.A. as examiner on final project presentation who gave insightful feedback and advice for the completion of this research.
4. Author beloved parents, Mr. Eko Sri Haryanto, Mrs. Ririn Amperarini, and the rest of author's family who gave trust, support, and motivation to complete this report.
5. All lecturers and staffs of Industrial and System Engineering Department that help the author to progress through the completion of this report.
6. All friends from Industrial and System Engineering Department batch 2016 for providing moral support during the completion of this report
7. All colleague in Logistics and Supply Chain Management Laboratory that giving support to the completion of this report
8. All parties who have supported and help the preparation up to the completion of this research that are not mentioned above.

The author realize that this report still has many drawbacks. The authors are delighted and open for any critics and suggestion for this research. The author hope that this report can give insight to the airline problem regarding irregular operation amidst pandemic situation, particularly in aircraft routing.

Jakarta, August 2020

Author

LIST OF CONTENT

LIST OF FIGURES

(This page is intentionally left blank)

LIST OF TABLES

CHAPTER 1
INTRODUCTION

The introduction of this research includes the background of the problem, problem formulation, objectives, benefit, limitation and assumption, and report outline in general.

1.1 Background of the Problem

Covid-19 pandemic has led global economy to an unprecedented recession. An once health crisis has brought spillover implications into major sectors of the global economy. There are two main reasons on how this outbreak crippled economy and carried out a global economic crisis. First, the exponential rate of virus spreading heightened uncertainty about how bad the situation was. And second, the virus spread has encouraged social distancing which led to the shutdown to financial markets, corporate office, industries, businesses, and events (Ozili & Arun, 2020). With increasing number of cases day by day across the globe, immediate actions were taken by authorities around the world to restrict the spread of the virus.

Countries started to impose travel restriction for non-essential travel as people are asked to remain at home. This shapes up people perspective of the new normal lifestyle during this pandemic situation. The transmissibility of the virus has caught people awareness as people together hand in hand try to do their part in the global effort to restrict the virus spread. Offices run from home, schools are carried out through online classes, and travel demand have come to near zero. The severity of this condition was felt tremendously by several economic sectors especially travel industry. Airline business as part of travel industry have known to take the biggest hit.

Air transportation has been a major channel for rapid spread and dissemination of communicable diseases. Given the increasing number of travelers and air cargo, the risk of infectious disease transmission during air travel is a significant concern (Mangili et al., 2015). Aside from travel restriction and social distancing regulation, governmental and federal agencies enforced set of regulations specifically addressed for air travel to further control the spread of the virus. In

Indonesia for instance, central government established Coronavirus Disease Mitigation Acceleration Task Force that are mandated to make regulations regarding public health and human control. One of them is SE No.4 2020 that puts strict exception and requirement for people intended to travel regionally and internationally only limited to government officials, patients in need of immediate health services, and Indonesian citizen repatriation flight. Additionally, according to Indonesia Ministry of Transportation regulation No. 18, 2020, on article 14, several controls are applied over air transport activities including the reduction of airport slots, aircraft maximum capacity limitation, and surcharge adjustment. In addition, regulation No.25, 2020 article 24 impose that due to temporary travel ban, airlines are obligated to perform refund, rescheduling or reroutes of booked tickets prior to the pandemic situation.

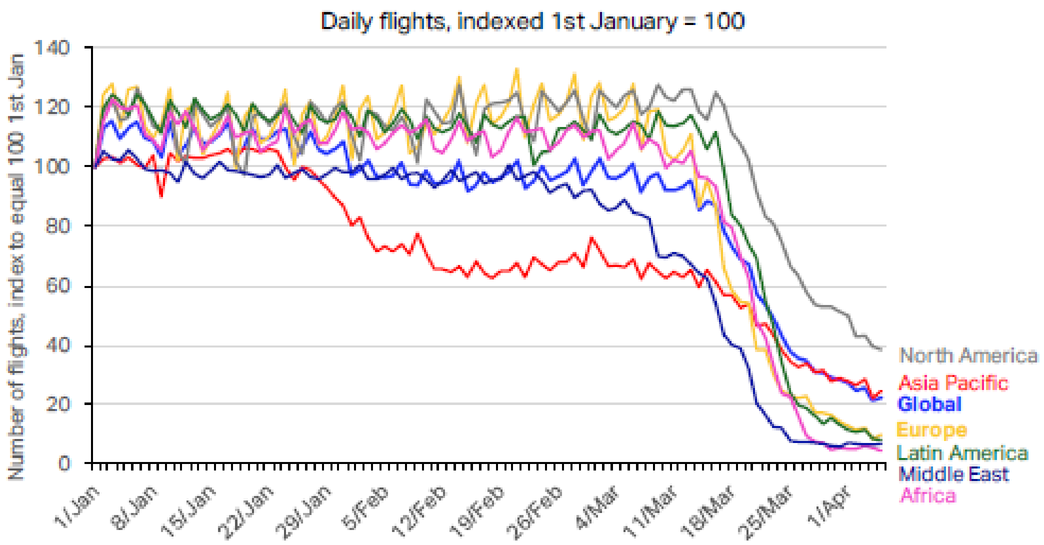


Figure 1.1 The drop of daily flight frequency since beginning of 2020
Source: IATA, 2020

Airlines with capital-intensive business nature are struggling as their mainstream of revenue collapsed. Travel restrictions have cut down dreadful amount of travel demand both in regional and international. According to data compiled by the International Air Transport Association (IATA) in Mach 2020, global flight has been plumped and loss of revenue are expected to reach 113 billion US dollar globally. During this trying time, every operation in airlines industry is bloody operation. To compensate the reduction of maximum capacity and demand loss, airlines around the world have reduced their flight frequency. The initial capacity inherent on the volume of aircrafts on the fleets are way to high compared to the current market demand. This condition led to the grounding of aircrafts due to reduced flight traffics. The mass grounding of aircrafts further impacted the financial health of airline industry as their high value assets are idling and generated only depreciations and maintenance cost.

Figure 1.2 Delta airline fleet being mass grounded in Victorville, USA
Source: John Kilmer, 2020 (Airteamimage.com)

Aircraft in general are complex machinery that required continuous care and maintenance. Idling position such grounding would affect the reliability of the aircraft that may reduce the airworthiness. According to Kotoky et al. (2020) on the media report published by Time, grounded planes are subjected to various threats such as internal component depreciation. In addition, external factors such as dust, moist, and bird nesting need proper and periodic maintenance and monitoring. Some planes need constant towing to keep the wheels rotating, additional of silica moisture to keep engine dry and prevent corrosion, and periodic component check such as avionics, flight control, and cabin interior. Those condition incurred costs under operational basis to properly maintain aircraft airworthiness through their out of service time.

As for now, airlines currently have limited control over their revenue stream. Management must put great concern on the liquidity of the business. The most appropriate approach to cope with this challenge is to minimize their cost. Every operation should be planed and execute accordingly. With all the stated conditions, it safe to say that airline which operates during this pandemic situation are running under irregular operations. According to Bazargan (2010), irregular operation defined as activities that are not pre-planned and occur only when there is a distribution. Airlines remain in service should adapt this definition and leverage it up to planning phase. This is important as the current operation are dominated with unscheduled flight consist of chartered, cargo, and repatriation flights. In addition, airlines are forced to ground substantial amount of their aircrafts to preserve cash following the reduction of flight traffic due to steep dive in passenger demand. The unprecedented downfall of the demand makes the number of aircraft higher than the required capacity to operates the scheduled flight. The problem dimensions got more complex as the management should minimize cost while keep the grounded plane properly maintained and preserved to keep the aircraft airworthy for future times. Additional cost incurred during those operations should also consider. Aircraft that still operated amidst this pandemic outbreak will needs constant cleaning and sanitizing to ensure proper hygiene standard. Additional labor hour of maintenance and aircraft cleaning will be necessary to manage grounded aircraft and the operating aircraft properly. Lastly, the planning should also meet the regulations and protocol requirement to be in service.

Proper management of irregular operations under this condition is critical. As the solution to the problem, the writer proposed a decision support tool in form of a model to simulate best scenario of aircraft dispatching under irregular operations. The model will provide a result regarding aircraft dispatching decision with respect to general routing constraints and give corresponding total cost of simulated condition. The model incorporates cost model based on time band approximation developed by Argüello et al. (1998) and adapted by Bazargan (2010) in the aircraft routing under irregular operation. The logic and algorithm of the model will be converted into computer model which allow further analysis on the scenario of variable changes. The computer model will be aided by Excel Visual

Basic for Application as the platform and used to generate result from different scenario. The result of the simulation aimed to help writer to understand the nature of the problem through experimental analysis of the used variables and give the best recommendation toward the problem.

1.2 Problem Formulation

The main problem of this research is how to manage aircraft route in irregular operation to minimize potential cost by proper aircraft dispatching to given set of routes.

1.3 Objectives

The objectives of this research are listed below.

1. Create a decision support tool capable of simulating aircraft dispatch decision.
2. Generating optimal aircraft routing under irregular operation which yield minimum cost.
3. Study the parameters affecting the model outcomes.

1.4 Benefits

The benefits of this research are listed below.

1. The result of the simulation can be used as a basis for aircraft dispatching decision.
2. The analysis of simulation result can help management to understand the problem inherent by irregular operations.

1.5 Limitation and Assumption

The limitation and assumption applied on this research are listed below.

1.5.1 Limitation

1. The model is decision support tool that is used only to simulate numerical experiment without optimization on total cost.
2. The model only covers rerouting feasibility from aircraft availability.
3. The cost included in the model are operational cost, grounded cost, delay

cost, and cancellation cost.
4. The model uses predefined cost and route based on the user as inputs.
5. The set of option for rearranging flight are limited to flight delay and flight cancellation.

1.5.2 Assumption

1. The aircraft on the fleet are homogeneous.
2. Any aircraft is available and capable to service any given route.
3. The flight curfew is 12 o'clock at midnight.
4. The stations in the network are always available to receive incoming flight.
5. The cost of operating an aircraft for a whole day is same across the fleet and network.
6. The cost of aircraft grounded for a whole day is same across the fleet.
7. The grounded aircrafts are out of service for a whole day and can't replace the operating aircraft on duty.

1.6 Report Outline

In this sub chapter, the brief explanation of every chapter of this report is presented.

1.6.1 CHAPTER 1 INTRODUCTION

This chapter give general information about the overall report. This chapter begin with the background of the research that appoint the main problem to be discuss. The brief explanation of the writer intention and solution proposed are also presented. This chapter also consist of problem formulation, objectives of the research, benefits of the research, as well as limitation and assumption used in this research.

1.6.2 CHAPTER 2 LITERATURE REVIEW

This chapter present the main references the author uses throughout this research. The reference consists of topics from existing literature and credible source of update information regarding the topic discussed. The literature review will give brief explanation about airline operation in general, airline irregular operation, airline cost structure, and time band approximation network and model.

1.6.3 CHAPTER 3 RESEARCH METHODOLOGY

This chapter will discuss the methodology of this research. The methodology will be presented in graphical form of flowchart, followed by brief explanation of each process.

1.6.4 CHAPTER 4 MODEL DEVELOPMENT

This chapter present the flow of model development as well as its supporting parameters and inputs. The chapter start with the introduction of the model in brief description. The development discuss in this chapter includes model description, scope and equation, data inputs, and model algorithm.

1.6.5 CHAPTER 5 NUMERICAL EXPERIMENT AND ANALYSIS

This chapter consist of numerical experiment followed by analysis of the result. The chapter started with model validation that are performed by basic and simple numerical experiment. The numerical experiment performed mainly emphasis on the scenario in which the number of dispatched aircraft will be varied. The numerical experiment will be aided by the model developed in previous chapter.

1.6.6 CHAPTER 6 CONCLUSION AND SUGGESTION

In this chapter, finding of this study will be presented in accordance with the initial objective of this research. Suggestion toward extensive study on this research and airline management as whom this research address will also presented in this chapter.

(This page is intentionally left blank)

CHAPTER 2
LITERATURE REVIEW

This chapter consist of all references based on existing literature and updated information of current aviation condition from reliable sources.

2.1 General Airline Operations

Airline operations defined as all activities that support airline's continuity in service that covers planning and operations optimization. Airline planning optimization covers network flows, flight scheduling, fleet assignment, aircraft routing, screw scheduling, and manpower planning. While the operational optimization covers subject such as revenue management, fuel management system, airline irregular operation, gate assignment, and aircraft boarding strategy.

The planning horizon may take form in weeks, months, or years' time-bucket. This part gives a guideline and set objectives that airline want to achieve on course of its operation phase. The first strategic step in planning phase is generating flight schedule. This part involves long range planning with market evaluation, while also considering schedule issues and its optimization. Parameter that are used during this operation such as load factor and frequency. The next step is to conduct fleet assignment in case of airline that operates different type of aircraft fleet on their network. This is important as different type of aircraft caries different economic parameter such as revenue per available seat miles (RASM) and cost per available seat mile (CASM). Those parameters will yield different operational cost and expected revenue to the scheduled route. After assigning certain type of aircraft to particular route, the airline needs to conduct aircraft routing in which the work cycle of aircraft should involve maintenance opportunity at home base. Aircraft routing mainly concern on valid routing of all aircraft fleet to be able to serve all given route with accordance to maintenance constraint and general routing constraint. Beside managing the aircraft fleet, airline should also consider the manpower and crew to provide the service and essentially run the route. Careful planning on crew rostering and routing will ensure flight availability and feasibility.

After optimizing planning. The airline then executes the planning in operational horizon. In this phase, operational optimization plays a critical role. The major step in operational phase is to keep track on the inflow of money in form of revenue. The revenue management focused on optimizing revenue based on every possible change to the operation such as marginal revenue and the flight network itself. Fuel management is also taking a critical role as fuel price take a major role in airline cost structure. Other optimization are irregular operations, gate assignment, and boarding strategy. The airline irregular operation covers the response to any disturbance along the operational related to aircraft availability. The more detailed operational optimization takes form of gate assignment and boarding strategy. Both of this optimization mainly aims to increase customer satisfaction and reduce operation time. According to Bazaragan (2016), the hierarchy of aircraft operation can be illustrated by the graph below.

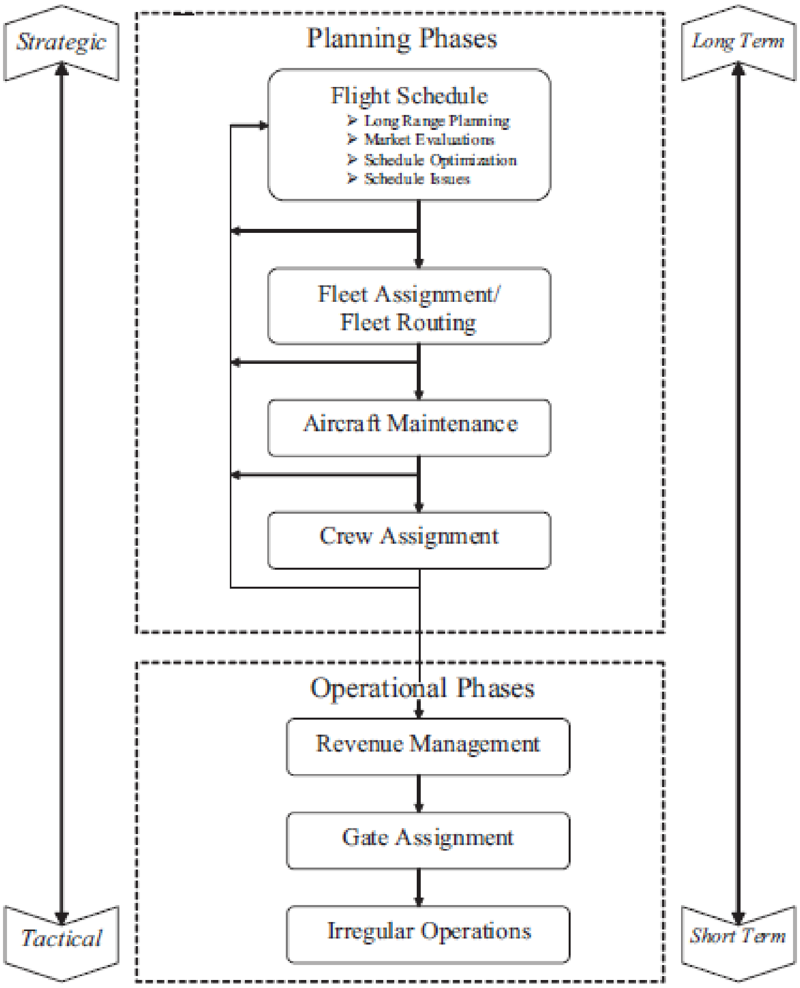


Figure 2.1 The scope of airline operation
Source: Bazargan, 2010

According to the hierarchy, planning phase involve strategic decision making for a long-term horizon of action. While operational phase involves more tactical decision and deals with short-term horizon of action. These two phases encompass all operation within airline locus of control. Thus, the operations previously mention are concerned on internal management. In practice, airline business run in contact with several external parties such as aviation agency, air traffic operators, airports management, and related governmental parties. Airline can’t solely run a flight and conduct its operation by themselves. Airline operators should also consider operation associated with external parties as it is essential for the airline to be able to run a flight. Such operation related with external parties may include airworthiness certification by official agency and slots management with airport authorities.

2.2 Airline Cost Structure

Each airline has its own focus on cost control, it all depends on the strategy set up by the management. Though airlines have unique set of management that distinct their self from other, generally aircraft strategy classified into two main group, low-cost carrier and full service or legacy carrier. Low cost business model based on simplicity and easily help the carrier to be cost leader on the market. While full-service carrier response toward low-cost carrier competition have been observed. According to Martín and Román (2010), full-service carrier has been implementing several strategies such as focusing on costs and productivity, network reconfiguration, yield management, and no-frills service.

Despite the different strategy across airline, generally cost that are broken down into functional categories relatively similar. Indeed, cost are derivative of several factor surrounding airline operation, But regardless the degree of control or management to each factor, the cost structure mainly generic throughout air carrier. International aviation agencies have been collecting data regarding this topic. They generally collect data from several airlines and construct a representable approximation cost for airline operation. According to the International Civil Aviation Organization (ICAO) publication in 2017, the functional cost categories of airline can be observed in the table presented as follow.

Table 2.1 Functional cost category of airline business

Functional Cost	Description	Activity Driver	Cost Breakdown
Aircraft operating cost	Expenses associated with flying aircraft (direct operating cost)	Per block hour	44%
Aircraft service cost	Expenses of handling aircraft on the ground, including landing fees	Per Aircraft Departure	7%
Traffic service cost	Expenses of processing passenger baggage, and cargo at airports	Per Enplaned Passenger	11%
Passenger service cost	Expenses on meals, flight attendants, and in-flight services	Per RPM	11%
Reservation and sales cost	Airline reservations and ticket offices, travel agency commissions	% of Total Revenue	14%
Overhead cost	Advertising and publicity expense, general and administrative expense	% of Total Expense	13%

Source: (ICAO, 2017)

The numbers on the table above are obtained from US major airline total operating cost. The numbers are surely representing the cost structure of airline business in regular operation. With arising concern of disruptive environment brought by Covid-19 pandemic, the cost structure may be changed. According to IATA (2020), the shift in airline cost structure can be observed following rapid cash burn by airlines. Revenue are expected to fall by 68%. On the other side, variable cost is expected to drop sharply roughly 65% to 70% as the price of jet fuel are also fallen. In addition, fixed and semi-fixed cost are expected to be reduced as airline cutting and preserve their workforce.

The shift in airline in this pandemic situation is driven by the additional constraint or irregular operations performed by the airline as it serves essentials service. Referring to the background of the problem, there are several additional operations required to keep airline running during the pandemic situation. One of them being additional labor hour of cleaning process at the end of working cycle.

The cleaning process will be performed to currently used aircraft that remain overnight at the base. This process in necessary to maintain passenger hygiene and mitigate the spread of the virus. Other activity invoked by this pandemic situation is additional check points on the airport that are imposed by authorities to validate the traveler meet all the requirement to travel. This may affect the way of airline scheduled flight, as time for passenger prior to the boarding time will be longer than usual. The changes also give additional cost of equipment used to counteract the virus spread.

The most prominent cost that arise during the pandemic situation is the grounded cost. As airlines navigates through the steep decline in passenger demand, route traffics are reduced. The reduction in traffics affect the reduction of airline capacity which result in reduction of fleet size. The grounded aircraft in fact need a proper maintenance. There are a lot of costs associated with the preservation and handling a grounded aircraft for substantial amount of time. There are a lot of things to be performed to the aircraft individually to maintain the airworthiness for future time. The most notable cost increase is the additional labor hour of maintenance that become busier than ever. During the grounded period, aircrafts are exposed to foreign objects and environmental changes. To keep the airline secure, airline perform series of task that incurred cost along the way. To prevent the contamination of foreign objects, any inlets to the aircraft system should be tightly closed. This include engines, pitot tubes, and any sensors on external part of aircrafts. Accumulation of foreign objects such as water and dust might catalyze internal part corrosion.

Other internal parts of aircraft also need a proper maintenance and monitoring. In the fuel system, routine check on jet fuel required to ensure the idling fuel are free of impurities such as water that may grow microbes. Other internal parts that cannot be missed is the cabin and cockpit of the aircraft. As aircraft shut closed during grounded period, air circulating inside the cabin are not changing. With the rising humidity, this can lead to the accumulation of moisture that may cause damage such as corrosion to the aircraft parts. Therefore, airlines are using with silica packs to absorb any moisture. This method needs a constant monitoring as the packs should be changed periodically.

2.3 Airline Irregular Operation

Airline irregular operation defined as any activity regarding the operation of aircraft that are not pre-planned and occur only when there is disruption in the schedule (Bazargan, 2010). The disruption takes in various form ranging from internal problem such as mechanical problems, up to external problem such as severe weather. Airlines implement combination of tactics to manage those disruption. Among them are delaying flight, flight cancelation, aircraft substitution, ferry flight, and aircraft diversion. In practice, those tactics should incorporate several aspects such as aircraft availability and crew reassignment. But according to in many cases, the aircraft recovery and crew reassignment are handled separately. Upon disruption, the first step airline do is develop a feasible flight rerouting by using tactics previously mentioned. The feasible solution then checked for crew feasibility. This two-layer process continue until feasible solution is found. In irregular operation, airlines faced with unplanned-undesired aircraft shortage. According to Bazargan (2010), one of the most conventional way to deal with irregular operation is by using time-band approximation model. This method allow airline to map aircraft position in corresponding station and specific time band

In this report, irregular operation is translated into any disruption along the regular airline operation. Additional protocol as explained on previous chapter have brought new challenges for airlines. Managing minimum baseline flight with low revenue expectation, high maintenance cost of idling fleet, and additional labor hour on cleaning process that incurred more cost are just some of the challenges. The outbreak may be the most disruptive aspect in irregular operation history. As for now, airlines will continue its essential service in lot of strain. Based on the studied condition, airlines are facing massive drop in revenue stream. This force airlines to readjust their flight capacity by means of proper aircraft dispatching on their scheduled or predefined route. Initially airline irregular operation will take control over the reduction in number of aircraft dispatch in response to disturbance in aircraft availability.

The action horizon of airline irregular operation is at operational phase and take effect directly by altering scheduled flight to cover the unserved flights in aim to minimize total potential cost. This means, initial airline irregular operation take only covers the unplanned aircraft shortage during operational phase. Thus, in this research, the writer proposes a redefine airline irregular operation in which the case leverage into planning horizon. In this case, airline intentionally reduce their aircraft on the network while maintaining just enough to serve predefined flight schedule. This means, if an aircraft decided to be grounded, the route that was served by the grounded aircraft will be reassigned to other operated aircrafts with whole routing recalibration. The total routing recalibration allow airlines to complete reassign aircraft for their routes in correspond to routing feasibility and cost minimization.

2.4 Airline Operations during Pandemic Situation

Airline exposed to a new set of rules during pandemic by the governments and authorities have imposed several guidelines considering the virus spread. For airlines, the main party accountable for the regulation are based on IATA (International Air Transport Association) and WHO (World Health Organization) as general terms. Beside those, local government regulations also play important role in guide lining the airline operation. As a global standard, the following guideline refer to the publication from International Air Transport Association (IATA) in April 2020. The regulation takes effect on current time but subject to constant review corresponds to government regulations. The guideline set up standard for all ground handling services. The services cover in this guideline include passenger check-in, transfer, and date handling, baggage ad cargo handling, ramp handling, aircraft cleaning, and catering handling.

The current situation has put a lot of concern on the survivability of airline businesses. Airlines are running under a lot of strain with a very limited options as a lot of problems encountered are out of their locus of control. Airlines across the globe are forced to take actions to work their way around the problem. The great liabilities carried by the business pushed airline to keep operation in this trying time to keep the cash flow running and offset some losses. As an effort to keep the demand present, airlines are seeking for chartered flights and repatriation flights for their passenger revenue stream. As for majority of airlines, the focus has been shifted to converting their passenger fleet into cargo carrier. This approach appears to be effective with surge in demand for air cargo related to the outbreak relieve effort and goods distribution holding up relatively well. Passenger aircrafts are capable of holding substantial amount of air cargo on their belly-freight. Yet, some airlines have completely switched their business to transporting cargo by utilizing both belly-freight cargo and the passenger cabin as cargo holds. Some airlines even take further step by converting passenger cabin entirely into cargo spaces. Air Canada for instance, has modified three of their Boeing 777-300 ER, the largest in their fleet, to transport cargo in the passenger cabin which doubling the initial cargo capacity.

Beside altering the business operation, airlines are seeking external funding such as governmental grants and loans as well as financial injection from investors. In US for example, government signed a bailout bill which totaling 50 billion US dollar taxpayer-funded aid. Half of it takes form of grants aimed to help airlines on their employee payrolls and prevent widespread layoff. While the other half takes form of low-interest loan. In return, airlines who take the grants or loans are required to flying in a certain baseline amount of flight on their existing network. According to US Department of Transportation, this requirement designed to maintain airlines essentials service, especially to remote and desolate area.

As mention previously, airlines are also busy managing their grounded fleets. The unpresented scale of capacity reduction left airline with yet another difficult task. The grounded aircraft are high-value assets which required a proper maintenance and preservation for a long-term storing. Keeping a single aircraft on ground might be as difficult as keeping the aircraft on the sky, or even worse. The logistical problem related to the parking location, preservation, and routine maintenance and monitoring have become new big task for airlines in this pandemic situation. Airlines across the globe have found this problem as a momentum to early retired their aging and less fuel-efficient aircrafts. Those aircrafts that are currently in storage might not be flown again in the future time as air travel demand resumption still uncertain.

2.5 Time Band Approximation Network and Model

The time band approximation model was developed by Argüello, et al. (1998) to present the aircraft routing network into time-space network. The model provides the graphical representation of aircraft with each designated route in corresponding location or node and time. Bazargan (2010) present this mode with modification on the time column in which the activities within 30 minutes time block are aggregated. The network consists of node and arc.

The node representing the departure and arrival point of a certain scheduled flight. While the arch represents the flight itself, designated with unique flight number. The nodes are divided into transshipment node and sink node. The transshipment nodes are point in which aircraft arrived to and depart respectively at the same working cycle. While the sink node defined as the final node that an aircraft arrived to at the end of working cycle. The sink nodes are the location in which the plane is remain overnight and expected to be ready in service on the morning in the following working cycle.

Time band approximation model in form of mathematical model developed by Arguello is used to minimized total cost. The cost structure for this model consist of delay cost and cancellation cost of certain flight. The input of this model is the number of aircraft currently in service with their respective initial routes. The result should be the least deviation of rescheduling decision apart from the initial schedule. The optimal solution will yield minimum cost for flight cancellation and delay. The mathematical model is presented as follow.

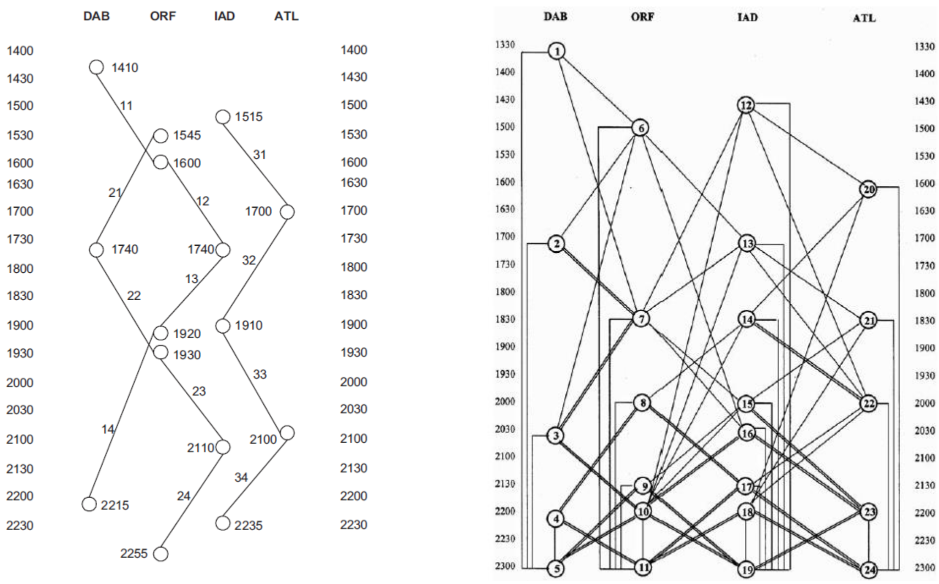


Figure 2.2 Network representation and transformation in time-band network
Source: (Bazargan, 2010)

Index:

i, j	=	Node indices
k	=	Flight index

Sets:

F	=	set of flight
$G(i)$	=	set of flight originating at station-time node *i*
$H(k,i)$	=	set of destination nodes for flight k originating at station-node *i*
I	=	set of station-time nodes
J	=	set of station-sink nodes
$L(i)$	=	set of flights terminating at node *i*
$M(k,i)$	=	set of origination station-time nodes for flight *k* terminating at node at node *i*
$P(k)$	=	set of station-time nodes from which flight *k* originates
$Q(i)$	=	set of station-time nodes at airport containing station-sink i

Parameters:

a_i	=	Number of aircraft available at station-time node *i*
c_k	=	Cost of canceling flight *k*
$d_{i,j}^{k}$	=	Delay cost of flight *k* from station-node *i* to node *j*
h_i	=	Number of aircraft required to terminate at station-sink node *j*

Decision Variables:

$x_{i,j}^{k} = \begin{cases} 1 & \text{if flight } k \text{ occurs through station time node } i \text{ to } j \\ 0 & \text{otherwise} \end{cases}$

$yk = \begin{cases} 1 & \text{if flight } k \text{ is cancelled} \\ 0 & \text{otherwise} \end{cases}$

$Z_i =$ integer number of aircraft terminated at station time node *I* to station sink node at the airport

Objective Function

Min $\sum_{k \in F} \sum_{i \in P} \sum_{j \in H} d_{i,j}^{k} x_{i,j}^{k} + \sum_{k \in F} c_k y_k$

Minimizing total cost of delay and cancellation of flight(s)

Constraints

Flight cover constraint

$\sum_{i \in P(k)} \sum_{j \in H(k,i)} x_{i,j}^{k} + y_k = 1$ for all $k \in F$ (1)

Station-time node flow

$\sum_{k \in G(i)} \sum_{j \in H(k,i)} x_{i,j}^{k} - \sum_{k \in L(i)} + Z_i = a_i$ for all $i \in I$ (2)

Station-sink node flow

$\sum_{k \in L(i)} \sum_{j \in M(k,i)} x_{i,j}^{k} - \sum_{j \in Q(i)} Z_j = h_i$ for all $i \in J$ (3)

Binary aircraft flow

$x_{i,j}^{k} \in \{0,1\}$ for all $k \in F$, $i \in P(i)$, and $j \in H(k,i)$ (4)

Binary cancellation flow

$y_k \in \{0,1\}$ for all $k \in F$ (5)

Integer termination arc flow

$Z_i \in Z^{+} = \{0,1,2,\dots\}$ for all $i \in I$ (6)

The objective function of this model is a cost minimization of total delayed cost and cancellation cost incurred by generated irregular operation schedule. The irregular operation schedule is set of tactics in from of flight cancellation and delay to cover all predetermined route in response to sudden unplanned aircraft shortage. The decision is subject to several constrains. These constrains will ensure the rerouting to be feasible and align with the objective. Constraint (1) ensure that all the flight will be either flown or cancelled. The flown flight might be on schedule or delay. This leave no room for other option for each flight and enforce that no flight is neglected. Constraint (2) enforce the aircraft flow on a station-time node in which an aircraft arrived to and then leave from it. This ensure the continuity of aircraft flow and aircraft utilization. Constraint (3) enforce an aircraft balance in which the number of terminating aircraft at station-sink node at the end of recovery period should be enough to run the schedule flight in the following day. The binary constraint (4) and (5) enforce that each flight can't be partially flown or cancelled. Constraint (6) refers to the termination aircraft from each available node. This constraint prevents a fractional termination of aircraft on each station-time node in the network.

The result of this model is the accumulated cost involving the delay and cancellation cost incurred by the set of flight cancellation and delay in the network. The total cost is supposed to be the minimum or optimal value as the objective function inherent the cost minimization.

CHAPTER 3

RESEARCH METODHOLOGY

This chapter will explain the overall research methodology used throughout the research. Brief explanation of each stage will also be presented in this chapter.

3.1. Research Methodology Flowchart

The research methodology used in this research is presented in the following flowchart.

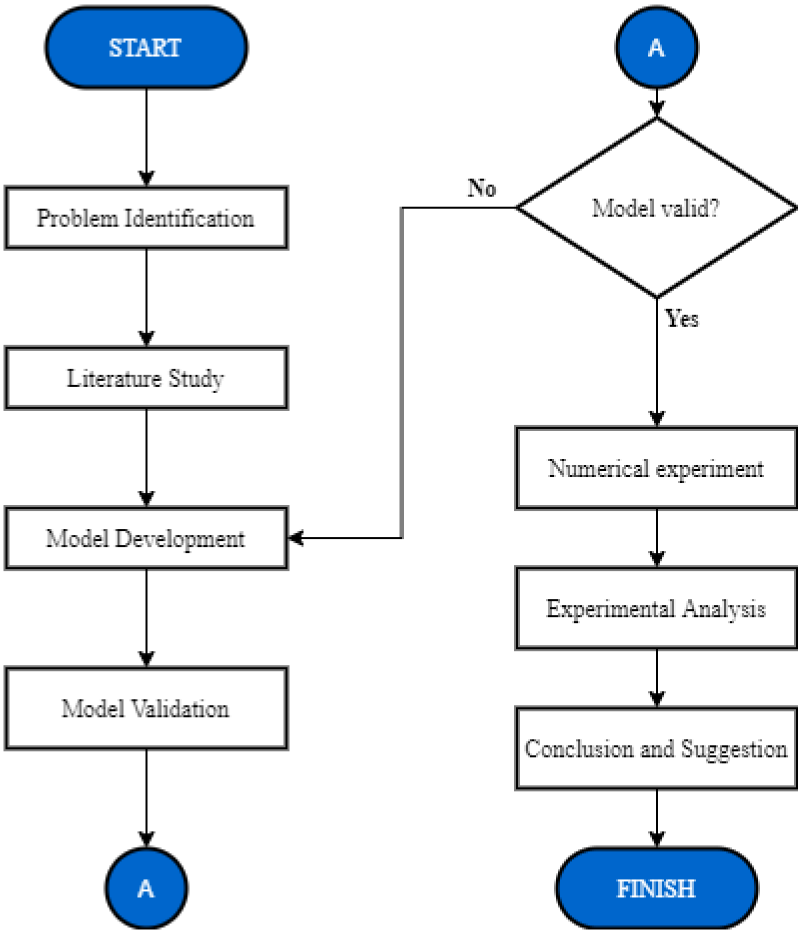


Figure 3.1 Research methodology of this report

3.2. Research Methodology Description

In this sub chapter, each process on the research methodology will be explained more in detail. The explanations are as follow.

3.2.1 Problem Identification

The research starts with problem identification. The writer conducts an extensive study of current situation regarding airline operation and performance from reliable media report, news, and press release from various international organization. The findings are present on the background of the problem located on the first chapter. The problem then stated, and solution will be proposed.

3.2.2 Literature Review

In this process, the writer conducts preliminary study from existing literature. The aim for this process is to find the basis and structure of the proposed solution. The reference is selected with relevant topic to the proposed solution which are aircraft dispatching in irregular operation. Due to the recency of the pandemic situation, there are still few publications related to the airline operation during pandemic. Thus, the literature review in this report consist of existing literature and updated information from reliable media. The literature review consists of general airline operation, airline irregular operation, airline cost structure, airline operation during pandemic situation, and time band approximation network and model.

3.2.3 Model development

Model development process consist of several steps. The model will be based on the basic algorithm of feasible aircraft routing. The model then incorporates the basic mathematical notation from Argüello et al. (1998) with the basis on time-band approximation model. Though the model will incorporate additional parameter namely operational cost and maintenance or handling cost. The next step is to develop the computer model which will be aided by Excel Visual Basic for Application (VBA). The mathematical model will be embedded on the VBA coding which act as platform for computer model.

3.2.4 Model Validation

The validation of the model applied to computer model. The validation conducted with internal validation in which basic experimental calculation will be performed. The model will run series of test and are expected to perform mathematical calculation correctly and generate consistent result. Through basic experiment, the model logic and ability to calculate the inputs can be examined. The result should be in accordance with mathematical calculation.

3.2.5 Numerical Experiment

This process aimed to understand the nature of the problem taken into account in the model. The model consists of several variables and parameters. The scenario will be built to find the best decision regarding aircraft dispatching decision. The experiment will be aided by the model previously made. The model experiment will be conducted heuristically by comparing result of simulation from different point of input parameter. The changing variables in the experiment are the number of aircraft dispatched. By this, the best solution can be chosen among the generated solution provided by the model.

3.2.6 Experimental Analysis

The result obtained from the scenarios are analyzed. This allow the writer to summarize and giving the best recommendation of aircraft dispatching decision based on constructed scenario. Additionally, the experimental analysis of scenario calculation result allows the writer to observe other aspects surrounding the model that may affect the simulation result.

3.2.7 Suggestion and Conclusion

In this process, the writer summarizes the most appropriate decision to take regarding the rescheduling aircraft routes in irregular condition. The recommendation will be based on the findings on previous process. The writer will also give conclusion to the nature of problem incorporated in the model and the significant of each parameter considered.

(This page is intentionally left blank)

CHAPTER 4
MODEL DEVELOPMENT

In this chapter, the model that will be used to simulate the dispatching scenario will be developed. The chapter start with model description and continued with model formulation and algorithm.

4.1. Model Description

The model is called for irregular operation decision support tool for aircraft dispatching. This model is specifically designed for pandemic situation. Overall, this model used time-band approximation model as the reference. There are several adjustments and modifications on the referenced model to match the proposed model and differ the model with the regular normal aircraft dispatching model. The main different between this model and time-band approximation model is the cost associated with the operation. As mention previously, there are unprecedented situation that impose aircraft to perform several operations that incur additional cost. The additional costs beside the basic cost take form on operational and grounded cost that will be further explained in following sub chapter. This model also performed a new leveraged definition of irregular operation in which unplanned aircraft shortage at operational phase will be shifted into planned aircraft shortage at planning phase. Thus, this model able to translate a tactical decision into strategical decision. This also affecting the scheduled flight input required by the model. The time-band approximation model required a scheduled flight with each flight already assigned to an aircraft, By mean that the time-band approximation model required a set of scheduled flight with aircraft assignment already been done. On the other hand, due to its occurrence in planning phase, aircraft assignment are not required as input in the proposed model. The model will construct the rescheduling in regard to the number of aircraft dispatched and later assign each dispatched aircraft to the flown flights.

On comparison with the time-band approximation model as this model reference, the objective functions are slightly different. Although both models performed cost minimization, the time-band approximation model apply the optimization to find the best tactic in form of series of flight delay and cancellation with available aircraft. While this model mainly concern on how different aircraft dispatched decision will incurred cost and which decision will generate the most desired result by heuristic approach. The constraint for this model is also slightly different with the time-band approximation model. The model is constrained by the valid routing algorithm in which mainly consist of time-band approximation model constrains. The constraints are constructed in different way, but it shares same ideas and function. The comparison of this model with the time-band approximation model as the reference can be summarize in the following table.

Table 4.1 The difference of established model and basic referenced model

	Time-band Approximation Model	**This Model**
Position on airline operation hierarchy	Operational horizon (tactical decision)	Planning horizon (strategic decision)
Cost involved	Delay cost and cancellation cost	Delay cost, cancellation cost, operational cost, and grounded cost
Routing inputs	Scheduled flight already assigned to certain aircraft	Scheduled flight without aircraft assignment
Aircraft dispatching problem	Unplanned aircraft shortage	Planned aircraft shortage
Objective function	Cost minimization of total delay and cancellation cost through optimization of available aircraft to cover all the routes	Cost minimization of total delay, cancellation, operational, and grounded costs heuristically by comparing result from different aircraft dispatching decision
Constraints	Flight cover, station-time node flow, station-sink node flow, binary aircraft flow, binary cancellation flow, and integration termination arc flow	Valid routing algorithm which incorporate flight cover, station flow, binary aircraft flow, and binary cancellation flow

The model use Microsoft Excel Visual Basic for Application (VBA) as a platform and takes form of flow of algorithm with parameter attach to it. The model should be able to give rescheduling alternative to initial scheduled flight for different parameter input. The model run two main tasks and execute calculation of the inputted data. First, the model will generate the feasible routing of all inputted scheduled flight in correspond to the assigned or dispatched aircraft. The second step is to generate network representation as well as calculate the incurred cost based on input configuration.

As mention previously, this model finds the desired solution with heuristic approach. This model does not equip with decision optimization. Thus, the model only used to simulate the numerical experiment and giving appropriate incurred total cost based on parameter inputted. The model incorporates the feasible routing algorithm to ensure the route generated is valid in regard with the inputted parameter. The conceptual model for this research model is presented by the graphical representation below.

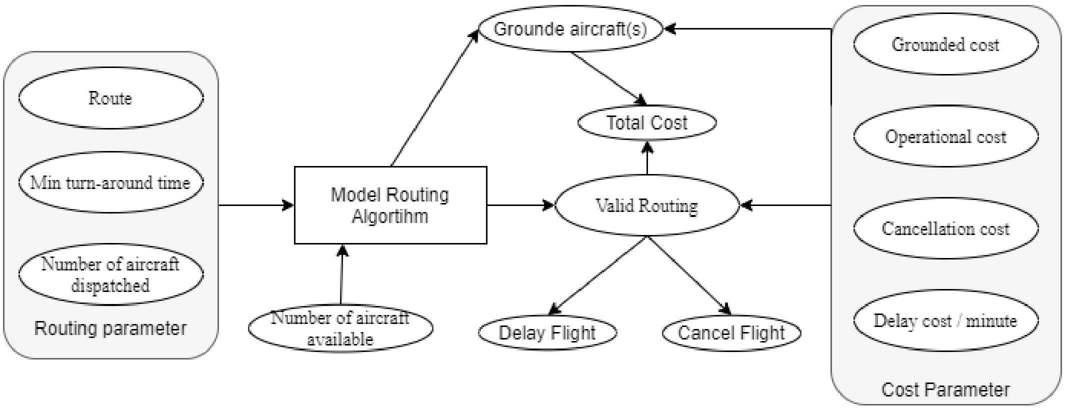


Figure 4.1 Research conceptual model

The model used routing parameters input to find valid routing for given set of schedule route. With the routing algorithm embedded in the coding, the model will generate a set of feasible scheduled flight that form valid routing. The valid routing. The output of the model will be used in accordance with cost parameter to compute the incurred cost in regard with given input. Based on the valid routing generated, the model can identify the disruption in initial scheduled flight in form of earliness, delay, or cancellation. The total cost is simply the sum of all cost components correspond to the inputs.

Beside the cost objective, the model also presents the valid routing in time-band network representation. This flight network representation is adapted from time-band approximation model. Figure 7 shows the presentation of network representation constructed by the model. The routing for each aircraft is drawn in two-dimensional graph with station in one axis and time band in another axis. The two-dimensional time-space network is developed based on the valid routing generated by the model. The construction of this network is automated with the aid of Microsoft Excel Visual Basic for Application. The graph is important as the placement of node in the network can represent the location of certain aircraft in respect with discretized time.

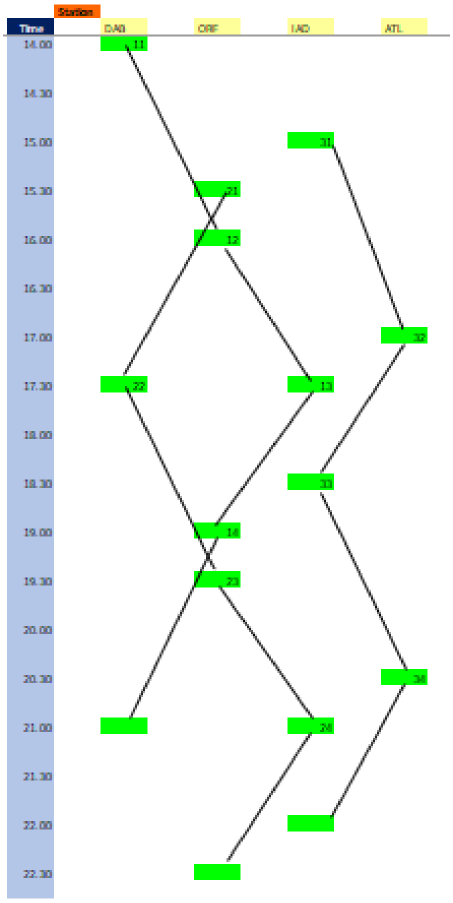


Figure 4.2 Network Representation of valid routing generated by the model

4.2.Model Inputs

The input for the model consists of two main parameters, the cost parameter and routing parameter. The routing parameters are used to construct the feasible routing. The parameter includes the initial schedule flight, minimum turn-around time, and number of dispatched aircraft. Additional input is number of available aircraft. This input will be used to determine the number of aircraft that are grounded in the network in correspond to the number of dispatched aircraft. The routes used as input must follow specific format to be processed by the model. The route defined as the scheduled flight that airline already established on the route scheduling operation. The route components used in the model are the flight number, origin station, destination station, departure time, and expected arrival time. Those inputs, together with minimum turn-around time and number of dispatched aircraft allow the model to generate feasible flight network that form valid routing.

Beside routing component, other input to the model is cost parameter. The cost parameter includes all cost considered in the model, which are operational cost, grounded cost, cancellation cost, and delay cost. These costs are essentially representation of tradeoff between operating high or low capacity flight. Operational costs are the cost incurred by operating an aircraft for a day routing cycle. This cost represents the expenditure of necessity to conduct flight as well as additional cost regarding pandemic situation such as proper cleaning and sanitation in each turn around. In contrary, the planes that are grounded or out of service will generate grounded cost. This cost represents the necessity to maintain aircraft that are stored or parked for substantial amount of time. This involve the cost of additional labor hour of maintenance to preserve the aircraft to maintain its airworthiness. Other cost considered for grounded cost is the cost for remain overnight at a station. As plane take space and require extensive protection while on ground, this cost cannot be disregarded.

Other cost involve are cancellation cost and delay cost. This cost strongly related to the valid routing output and are subject to changes based on each flight attribute. Cancellation cost defined as the profit loss by not operating the scheduled flight. Thus, it already incorporates the attribute of passenger demand for each flight. While delay cost incurred as scheduled flight shifted back from its initial scheduled departure. The delay cost is increment cost of base cost per minute. According to Bazargan (2010), the basis for delay cost per minute can obtained using conservative value of $20/minute.

In this model, any of the input in cost parameter is predefined by the user. This allow the model to be flexible and applied to different setting in accordance with the real case scenario. In addition, there are a lot of reference in cost determination approach, operational cost for instance. According to the data compiled by Civil Aviation Organization (ICAO) in 2017, the operational cost of airline varies according to the service provided, type of aircraft on the fleet, average block hour flown, and revenue stream of the airline. But there is a rigid lining on what to consider in operational cost throughout the variation of airline's charteristics. It mainly consists of variable cost and fixed cost of operating an aircraft. The variable cost made up of fuel and oil, maintenance, and crew. While the fixed cost consists of depreciation, insurance, rental cost, and other cost related to operating an aircraft. As for this model, the unit of operational cost are generalized and focused on operational fixed cost. The operational cost translated into a fixed cost over dispatching an aircraft to the given network. Though it is a fixed cost, the scope of operational cost in this model encompassed several variable cost aspects in the determination. Overall, the definition of cost consider in cost parameter might be different throughout airlines. Thus, a set of cost should be considered on each cost parameter to help guide the basic approach of cost determination to be used in the model properly. As the basis of parameter determination, below is the table that shows the detailed explanation of each cost parameter as well as the cost-scope of each cost parameter should involve. The basic scopes of costs are based on publication by Bard, et al., 2001.

Table 4.2 Cost parameters of used reference

Cost Parameter	Unit	Scope
Operational Cost	$ per aircraft dispatched for one day routing cycle	Fuel and oil, crew, maintenance, ground handling, traffic and slot expense
Delay Cost	$ per minute delay	Direct cost due to flight delay, passenger compensation
Cancellation Cost	$ per flight cancelled	Profit loss

Because of the unique condition, airline operation during pandemic situation performed slightly different form normal operation. There is unprecedented situation that impose airline to take account several additional cost. Additional cost regarding the pandemic situation added to incorporate the additional cost incurred in operation amidst pandemic situations. The cost reference for this additional cost are derived from the recent publication and report form official authorities related to aviation and air transport agency. Although there is no exact quantitative reference to these costs, the scopes of the cost can be identified and used as guiding line to cost determination. The scope of additional cost inherent in the operational and grounded cost as these cost parameters is the additional cost parameter unique to this model that aims to better represent current pandemic condition. The following table present the scope of additional scope of cost for operational and grounded cost.

Table 4.3 Cost parameter added into the model

Cost Parameter	Unit	Scope
Operational Cost	$ per aircraft dispatched for one day routing cycle	Cabin sanitation on each turn around, aircraft sterilization at the end of working day, additional maintenance labor hour.
Grounded Cost	$ per aircraft grounded for one day routing cycle	Parking cost, maintenance cost, preservation cost.

4.3. Model Algorithm

The model use aircraft routing algorithm to create valid routing based on given inputs. The general flow of algorithm can be presented in following graphical representation.

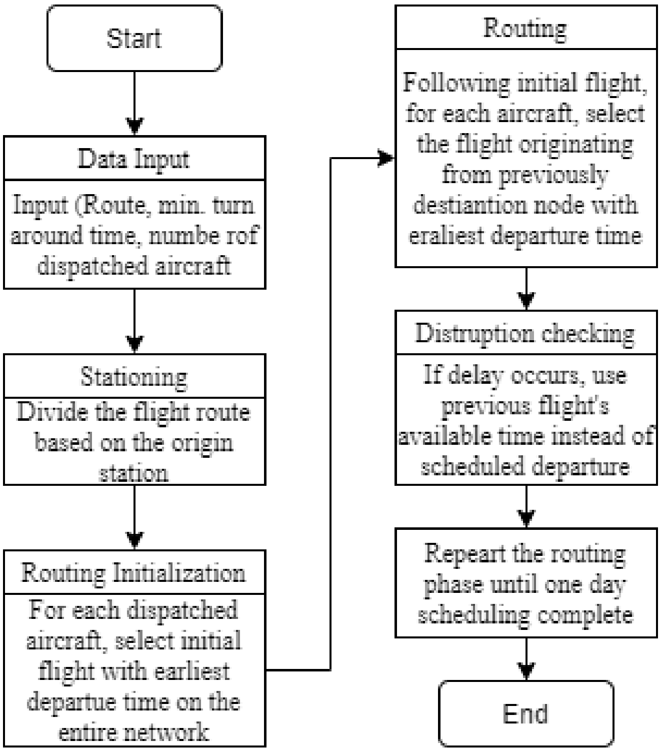


Figure 4.3 Flowchart of the algorithm

The model has several steps to complete and give appropriate routing result. In each step, a line of code is embedded to process the inputted data. The model algorithm here act as decision making program. First, the algorithm required set of data input as mention in previous sub chapter. The routing algorithm start with stationing process in which the inputted flight schedule is divided according to its originating node. This later allow the model to position the aircraft in specific station throughout the routing process. This ensure the continuity of feasible flight connection and prevent ferry flight. The next step is routing initialization. In this process, each dispatched aircraft will be assigned to the earliest departure time throughout the network. The aim of this process is to maximize the opportunity of flight connection as the first flight of each aircraft is the earliest on the whole network. The next step is the routing loop. The routing will determine the flow of flight assign on each aircraft for the whole day. During this process, disruption checking is conducted to identify the shift of the initial schedule. The flight defines as delayed if the initial scheduled departure time is sooner than the generated departure time. On the other hand, if a flight generated departure time is sooner than the initial scheduled departure, then the flight is shifted forward with earlier departure. On the end of routing loop, any absent flight in the routing will be identified as cancelled flight.

Each step in the general flow chart are constructed in Microsoft Excel VBA with set of code constructed in visual basic for application (VBE). The set of code can automatically perform a set of tasks such as stationing and routing. However, for certain part, additional logical thinking is required such as in routing initialization and looping. In those part of the process, specific algorithm is used and inherent in the code. The detailed look at the algorithm are presented in the following paragraphs.

After the user input the data, the first thing the model will perform is stationing process once the user clicks the trigger button. The code in VBA will categorize the flight based on the departure station. The name stationing refers to the table construction of each individual station consisting of every flight originating on corresponding station. The model will also create one big table consisting of all scheduled flight to compare departure time of every flight from every station. This table will be referred to as all-flights table and will be used in the routing initialization. The logical thinking embedded in the code for stationing process mainly consist of going through each flight in all-flights table and put the flight in corresponding originating station table. The originating station table is constructed one at a time as the model found a new station in the all-flight table.

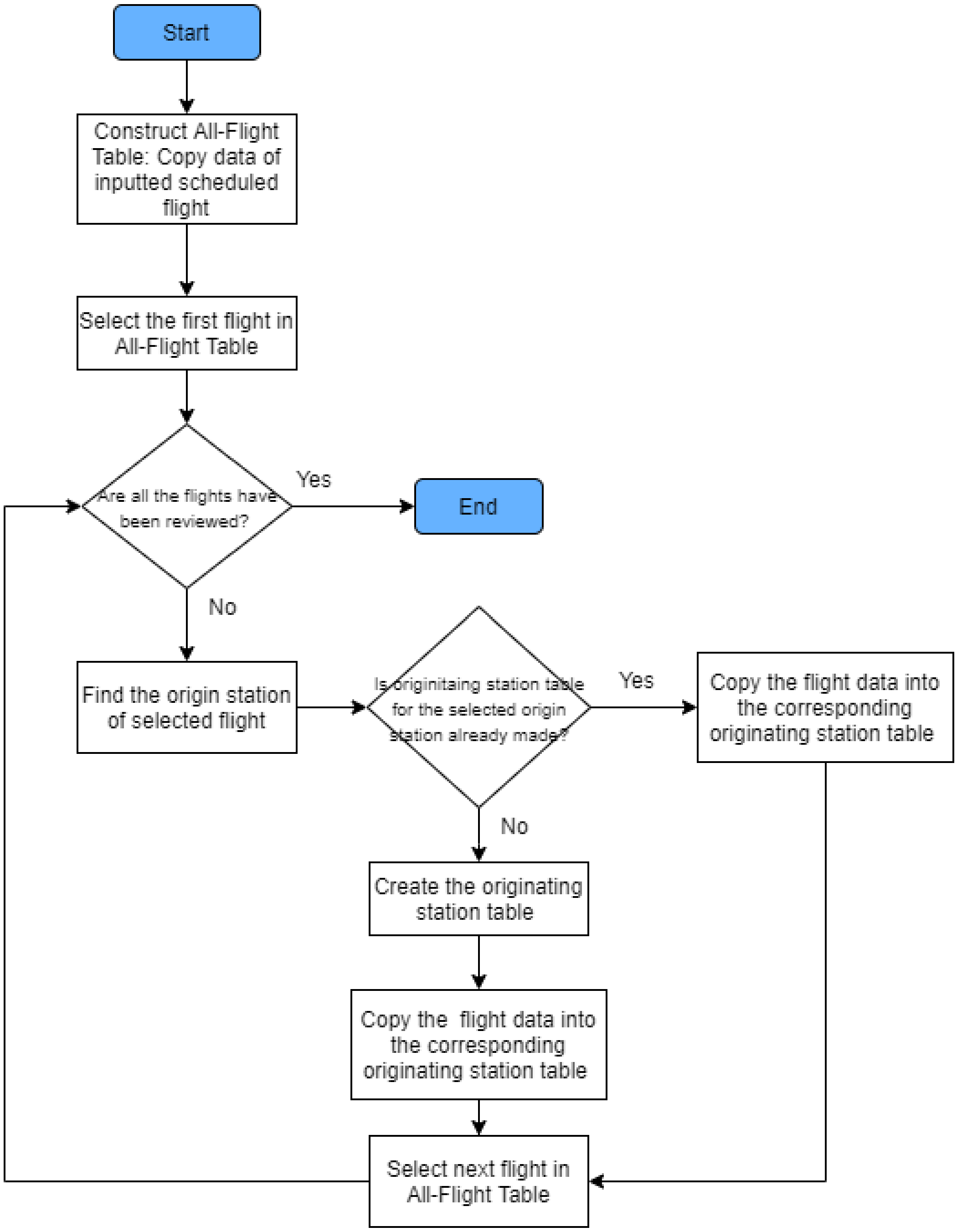


Figure 4.4 Flowchart of stationing algorithm

The next step in the algorithm after the stationing is the routing initialization. This process will assign the earliest departure time from the schedule flight to be the first flight flown by each of dispatched aircraft. For each of dispatched aircraft, a flight is assigned by finding the earliest departure time. Once a flight is assigned to an aircraft, the departure time of the selected flight will be altered into big number of big M to prevent the same flight assigned to another aircraft.

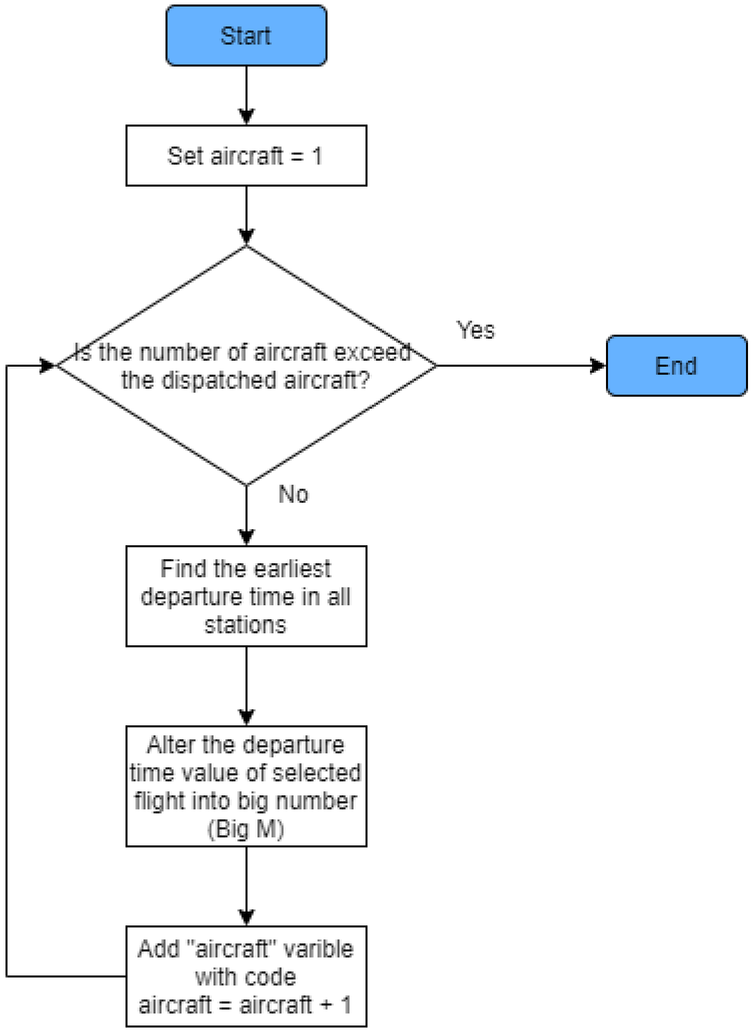


Figure 4.5 Flowchart of routing initialization algorithm

After the initialization, the routing loop will be performed. This process is the most complex part on the overall code. Beside looping the route selection, this process also involve disruption checking simultaneously. The routing loop continue as long as the earliest departure time on the network take lace before midnight which set to be curfew. The preliminary step in the routing loop is to set the variable "aircraft" which will be used to monitor the simulation run by incrementation of its value. Previous process also provide input for this process which is the earliest departure time. The routing loop consist of two big looping algorithms. The first loop cycle through the simulation code until the earliest departure time on the network exceed the predetermined curfew which is midnight. This loop act as the master loop that one the model run out of this loop, it become the termination condition. Other terminating condition incorporate in this loop is once all the flight are listed as flown flights. Once the terminating condition fulfilled, the model will identify the cancelled flight by finding the flight that are not listed in the valid airline routing.

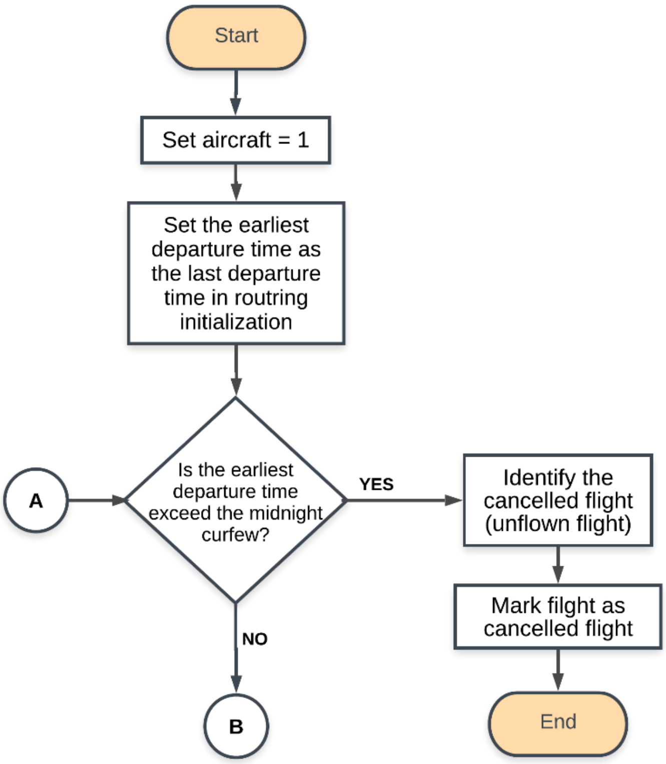


Figure 4.6 Flowchart of first loop routing loop algorithm

The second loop position inside the first loop that cycle through the code for each number of aircraft dispatched. By this, the model able to assign the route for each aircraft one at a time regarding its predecessor route. This is important as next flight should be originating from the station its previously arrived to.

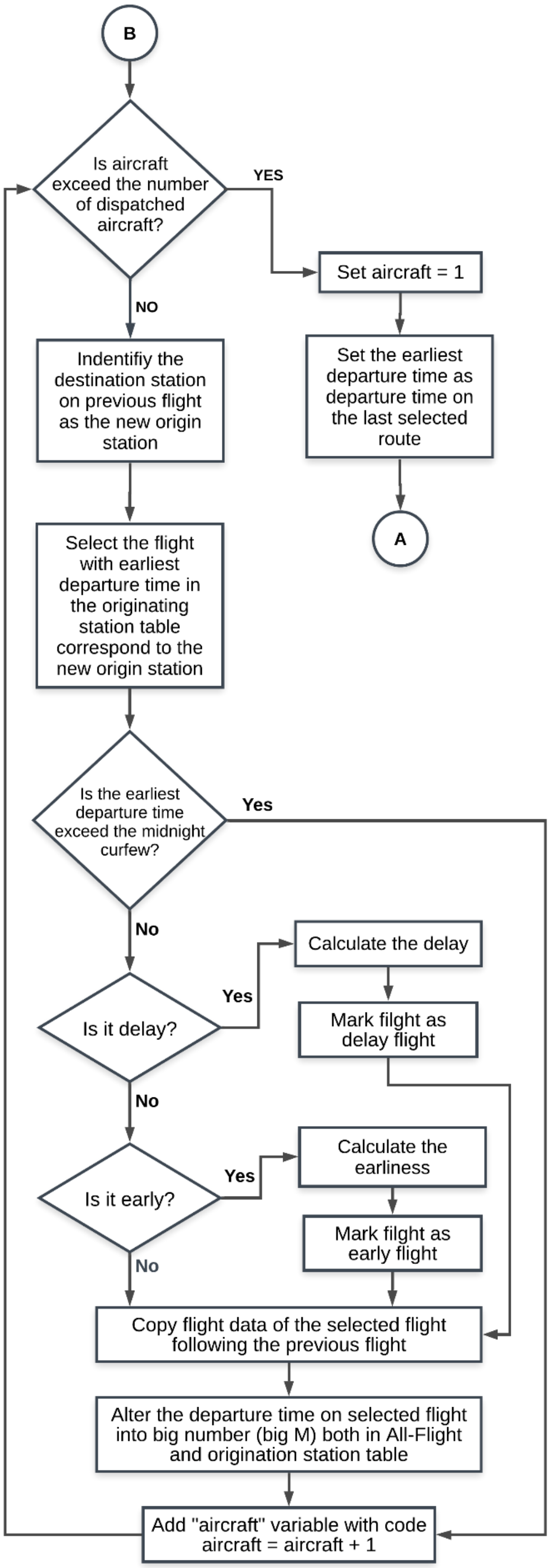


Figure 4.7 Flowchart of second loop routing loop algorithm

Inside the second loop, once a flight is selected as the next flight for an aircraft, disruption check is performed. The disruption mainly referrer to deviation of departure time compared to the initial schedule. The disruption takes form of either delay or early. The delay occurs when the initial scheduled departure time is sooner than actual departure time on the valid routing. While the early departure occurs when the actual departure time on the valid routing is sooner than initial scheduled departure time. Once the disruption identified, the value of delay and earliness are calculated for later process.

The second loop does not involve terminating condition. Once the simulation run exits the loop, the “aircraft” variable will be reset and the route selection for next batch of flight continues. This loop will continue until at some point the earliest departure time of the whole network have become big value (big M) which means all the flight are flown or all the feasible flight have been flown. There may be a case where a flight does not fly due to curfew restriction or flight connectivity issues. This termination condition refers to the first loop.

After valid routing generated, the next step is to compute the incurred result based on the constructed routing. The information regarding the identification of delay, early, and cancelled flight from the routing loop will be used in this process. Any disruption value occurred on the network will be multiplied by the corresponding cost parameter. Total of delay on the network in minutes will be multiplied by the cost of delay per minute. The cancellation flight will be summed based on the identification of cancelled flight and its corresponding cancellation cost. While the early flight does not incur any cost. These disruptions are identified to notice the user about the opportunity to better utilize the aircraft by minimizing idle time between aircraft flight. The computation also includes the cost of operational and grounded. These costs are related to the decision of the user in the number of aircraft dispatched. The available aircraft refer to the existing number of aircraft on the user’s fleet. While the dispatched aircraft refer to the number of aircraft decided to be flown by the user. The difference of available and dispatched aircraft presents the number of grounded aircrafts, as for the calculation of this function can be shown by the following equation.

Index:

k	=	Flight index

Sets:

F	=	set of flown flight
F'	=	set of cancelled flight
A	=	set of available aircrafts

Parameters:

op	=	Cost of operating an aircraft
can_k	=	Cost of canceling flight *k*
del	=	Cost of delay per minute
gr	=	Cost of grounding and aircraft

Variables:

x	=	Number of aircraft dispatched
c_k	=	Cost of canceling flight *k*
d^k	=	Delay value of flight *k*
g	=	Number of aircraft grounded

Total Cost

Total cost = $\sum_{k \in F} d^k \times del + \sum_{k \in F'} c_k + x \times op + g \times gr$

CHAPTER 5
NUMERICAL EXPERIMENT AND ANALYSIS

This chapter will present the numerical experiment conducted and the corresponding analysis of the experiment.

5.1. Model Validation

The model has been established, yet it's still needs to be tested to ensure its validity. The validation process takes form of internal validation in which the model will perform simple numerical experiment. The result of this validation run should be accordance to the mathematical model dan manual calculation. To run the experiment, a set of inputs are needed. The input used will be based on data provided by Bazargan (2010) to run a demo on its study case. The inputs for the validation process are as follow.

Table 5.1 Input for validation run

Inputs	Value
No of available aircraft	10
No of dispatched aircraft	3
Minimum turnaround time (minute)	40
Operating cost	$ 50.000
Grounded Cost	$ 17.000
Delay cost / minute	$ 200

Table 5.2 Route input for validation run

Flight No.	Origin	Destination	Departure Time		Arrival Time		Cancellation cost
11	DAB	ORF	14	10	15	20	$7.350
12	ORF	IAD	16	05	17	00	$10.231
13	IAD	ORF	17	40	18	40	$7.434
14	ORF	DAB	19	20	20	35	$14.191
21	ORF	DAB	15	45	17	00	$11.189
22	DAB	ORF	17	40	18	50	$12.985
23	ORF	IAD	19	30	20	30	$11.491
24	IAD	ORF	21	15	22	15	$9.581
31	IAD	ATL	15	15	16	20	$9.996
32	ATL	IAD	17	30	18	30	$15.180
33	IAD	ATL	19	10	20	20	$17.375
34	ATL	IAD	21	00	22	05	$15.624

The model run the program with the given input and the result is compared with the study case. This data is obtained from irregular operation study case in which 3 aircrafts are scheduled to 12 set of flights. The flight number represent the flight associated with particular aircraft. Flight 11 up to flight 14 are assigned for aircraft 1, flight 21 up to flight 24 to aircraft 2, and flight 31 up to flight 34 to flight 3. In the study case, one of aircraft suffer a mechanical breakdown which left the airline run short of available aircraft. The solution of this problem is to determine the set of tactics to cover the flights initially flown by the troubled aircraft. This concept is similar to what this research intended. The main different is that in this research, the aircraft shortage is planned, and the whole schedule can be reset as the model run the simulation in planning phase rather than operational phase.

The cost parameter not provided by the study case is added to the model. While the routing parameters are set to be exact as the study case except the number of available aircraft which are not listed in the study case. The model run the simulation and generate valid routing. The comparison of the result is shown in the following table. The result of the simulation takes form of aircraft routing, network representation, and total cost calculation. The validation will take part on the routing generation as the total cost calculation is a following procedure with valid routing as input and act as response variable to routing algorithm decision making.

Table 5.3 Valid flight schedule generated by the model

Flight No.	Origin	Destination	Departure Time		Arrival Time		Status
11	DAB	ORF	14	10	15	20	Normal
12	ORF	IAD	16	5	17	0	Normal
13	IAD	ORF	17	40	18	40	Normal
14	ORF	DAB	19	20	20	35	Normal
21	ORF	DAB	15	45	17	0	Normal
22	DAB	ORF	17	40	18	50	Normal
23	ORF	IAD	19	30	20	30	Normal
24	IAD	ORF	21	15	22	15	Normal
31	IAD	ATL	15	15	16	20	Normal
32	ATL	IAD	17	0	18	0	Early
33	IAD	ATL	18	40	19	50	Early
34	ATL	IAD	20	30	21	35	Early

Table 5.4 Detail aircraft information of simulation result

Aircraft	Utilization	Route
1	6 Hour(s), 25 Minute(s)	11 // DAB-ORF//14:10-15:20
		12 // ORF-IAD//16:05-17:00
		13 // IAD-ORF//17:40-18:40
		14 // ORF-DAB//19:20-20:35
2	6 Hour(s), 20 Minute(s)	31 // IAD-ATL//15:15-16:20
		32 // ATL-IAD//17:00-18:00
		33 // IAD-ATL//18:40-19:50
		34 // ATL-IAD//20:30-21:35
3	6 Hour(s), 30 Minute(s)	21 // ORF-DAB//15:45-17:00
		22 // DAB-ORF//17:40-18:50
		23 // ORF-IAD//19:30-20:30
		24 // IAD-ORF//21:15-22:15

Table 5.5 Detailed variable and cost calculated from the simulation

Variable		**Cost**	
Aircraft Operational	3	Total Delay cost	$ -
Aircraft Grounded	7	Total Cancellation cost	$ -
Delayed Flight	0	Total Grounded cost	$119.000
Cancelled Flight	0	Total Operational cost	$150.000
Earlier Flight	3		
Flight Flown	12	Total Cost	$269.000

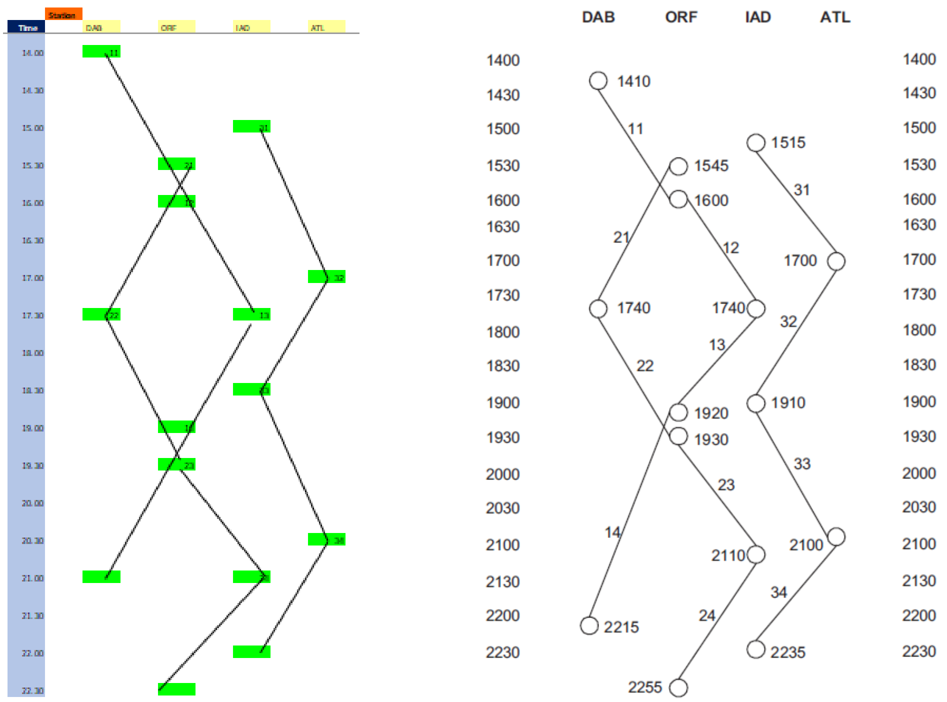


Figure 5.1 The comparison of network representation

The result from the validation run shows an accordance with the basic logic provided in the study case. The result is for running 3 aircrafts out of 6 return almost identical routing result. The main difference is the assignment of aircraft 2 for flight 31 up to flight 43 due to earlier departure difference of flight 21 and 31 in routing initialization stage. The model also discards the idle time between flight as identified in the routing of flight 32, 33, and 34. The early departure delete unnecessary idle time between flight out of 40 minutes required turn-around time. Based on the result, the model can provide a result with accordance to basic logic. The ability of the model to provide answer also show the model logics and calculation can be performed correctly.

5.2. Scenario: The effect of dispatched aircraft to the total cost

The main scenario to be observe in this research is the changing of number of dispatched aircraft. To have better understanding of the effect of different dispatching number, this scenario will use the exact same data as used in validation run with number of dispatched aircraft subjected to change. With the exact same value of parameter except the number of dispatched aircraft, the response variable comparison can be observed. The control variable in this scenario consist of cost parameter, number of aircraft available, and minimum turnaround time in the network. The cost parameter in control variable include delay cost per minute, fixed cost of operating an aircraft, and the fixed cost of grounding an aircraft for a day. The summary of model simulation for different aircraft dispatching input and the graph representing the comparison of result are presented in the following table.

Table 5.6 The result of different aircraft dispatched decision

Number of Dispatched Aircraft	1	2	3	4	5
COST ($)					
Total Delay cost	43,000	55,000	0	0	0
Total Cancellation cost	90,436	22,680	0	0	0
Total Grounded cost	153,000	136,000	119,000	102,000	85,000
Total Operational cost	50,000	100,000	150,000	200,000	250,000
Total Cost	336,436	313,680	269,000	302,000	335,000
VARIABLE					
Delayed Flight	1	2	0	0	0
Cancelled Flight	7	2	0	0	0
Earlier Flight	0	3	3	4	3
Flight Flown	5	10	12	12	12
Average Utilization	8 Hour(s), 15 Minute(s)	8 Hour(s), 8 Minute(s)	6 Hour(s), 25 Minute(s)	4 Hour(s), 38 Minute(s)	3 Hour(s), 33 Minute(s)

Tabel 5.6 The result of different aircraft dispatched decision (cont.)

Number of Dispatched Aircraft	6	7	8	9	All
COST ($)					
Total Delay cost	0	0	0	0	0
Total Cancellation cost	0	0	0	0	0
Total Grounded cost	68,000	51,000	34,000	17,000	0
Total Operational cost	300,000	350,000	400,000	450,000	500,000
Total Cost	368,000	401,000	434,000	467,000	500,000
VARIABLE					
Delayed Flight	0	0	0	0	0
Cancelled Flight	0	0	0	0	0
Earlier Flight	3	4	3	3	2
Flight Flown	12	12	12	12	12
Average Utilization	2 Hour(s), 51 Minute(s)	2 Hour(s), 21 Minute(s)	1 Hour(s), 58 Minute(s)	1 Hour(s), 41 Minute(s)	1 Hour(s), 26 Minute(s)

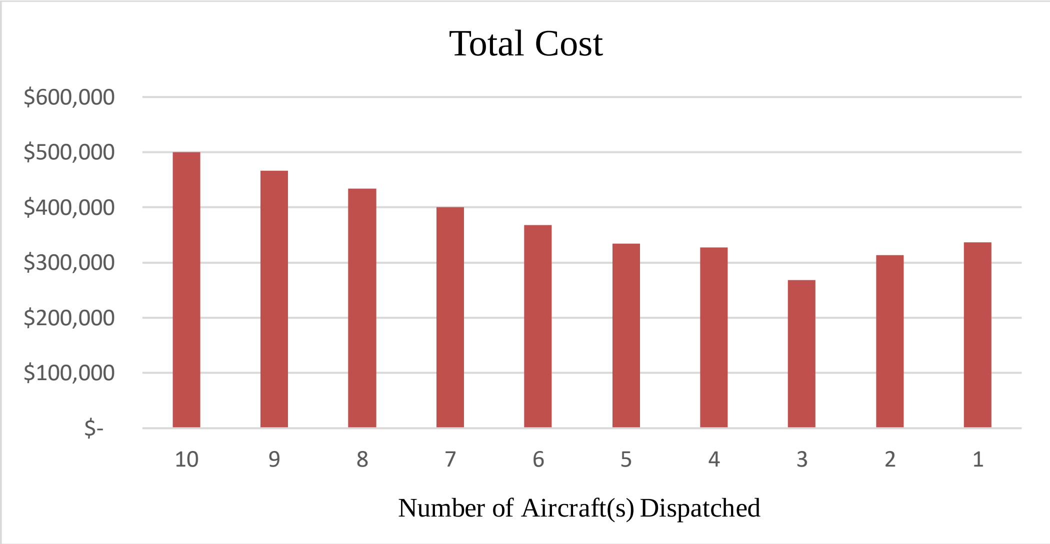


Figure 5.2 Total cost comparison

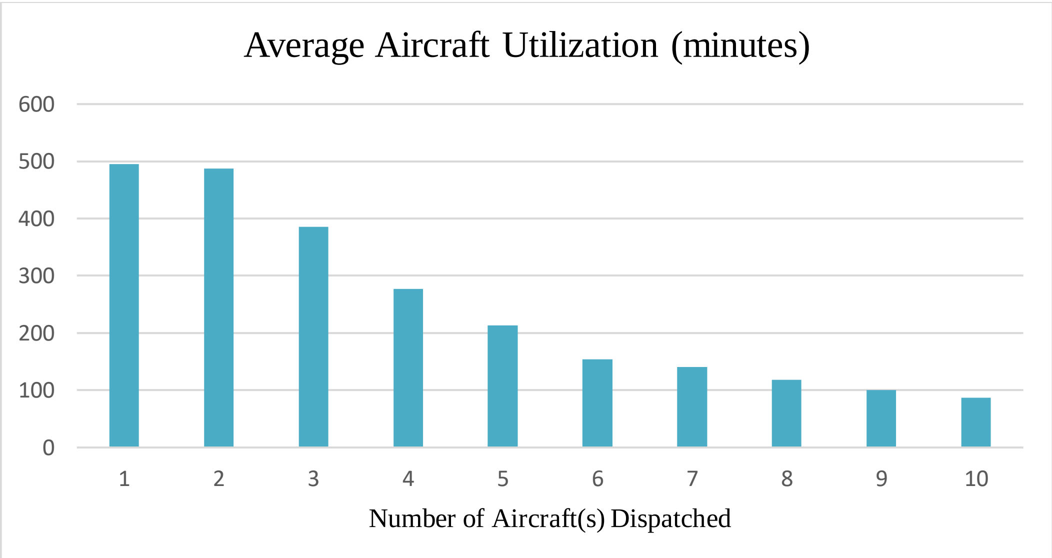


Figure 5.3 Average aircraft utilization comparison

5.3. Analysis of the Scenario

Based on the scenario run, the good solution produced is the decision to dispatch 3 aircrafts as indicated with the minimum total cost incurred. As the cost become the response variable to the decision making embedded in the model for routing, this result must have reflected the routing result. The routing used the data from study case provided by Bazargan (2010) in his study case in irregular operation chapter. The scheduled flight calls for 3 aircrafts to run the whole scheduled flight.

With 3 aircraft, the set of flights are well covered with no delays and cancellation. Thus, cancelled out the delay cost and cancellation cost parameter. All left in the cost calculation is the grounded cost and operational cost. As airline dispatch larger amount of aircraft, the opportunity of cancel and delay are greatly reduced. But it is obvious that 3 aircrafts fond to be sufficient to run the routing and cover all the flight with no delay and cancelled flight. Any number of aircraft dispatched above 3 will impact on larger total cost due to increasing operational cost. On the other hand, dispatching lower number of aircraft, in this case 2 or only 1 aircraft will generate cancellation and delayed flight. Thus, increasing the total cost even though the operational cost is decreasing. This is due to the total cancel and delay cost offset the decrease in operational cost. In addition, additional grounded cost creates increase the total cost in the equation.

Other interesting findings is that the cost parameter related to the number of dispatched aircraft, the operational and grounded aircraft does not offset the delay and cancellation cost. Using pre-determined parameter of operational and grounded cost in the simulation, it is found that the cost does not significantly affect the decision. The main driver for cost function is the delay and cancellation cost. This is proven by the best value which are the minimum required number of aircraft just enough to cover all scheduled flight. The cost of grounded and operational do affect the decision in term of creating increment curve to diverge the solution. The operational cost creates incline graph of cost increase as decision to dispatch aircraft increase. This impose the lease number of required aircraft to be preferred. On the other hand, the grounded cost become a tradeoff with the delay and cancellation cost. In this case, delay and cancellation cost have a greater significant as the increment reduce in aircraft dispatch does not offset the cost saving incurred by delay and cancellation.

Other area to be explore is the utilization of aircrafts. More aircraft dispatched to the network will significantly reduce the average utilization time of each aircraft. This part can be quite useful for user if the decision-making process consider the maximum utilization time in each day for each aircraft. By comparing the result from the simulation, the least aircraft dispatched to the network will result in higher utilization time for each aircraft. This is due to the flights covered by smaller amount of aircraft. The utilization time might also become objective function as if the decision maker wants to make sure each aircraft does not exceed predefined utilization time.

Lastly, the network of the scheduled flight also affecting the result of the model. In this case, the network consists of 12 flights with only 4 stations. Station here include all destination and destination node covered in the network. With small amount of station to connects, it is easier to find recurring flight and connectivity between station. This allow greater flexibility of the rescheduling of flights. On other circumstances, where airline implement heavily on hub and spokes network, the result might be different. Hub and spoke network mean that airline will have a major hub in one of a station and run flights to spokes station with no outbound flight from spokes station other than back to hub station. This will restrict the flight scheduling flexibility. For example, an airline has a hub in Los Angles (LAX) and run a flight to one of its spoke station New York (JFK). If the routing algorithm decide to cancel flight from LAX to JFK, there will be no flight departing from JFK as the only flight arc inbound JFK is originating from LAX and the only flight outbound JFK is to LAX.

In an attempt to compare the proposed model with the reference model, it found that both models might not be compatible to be fairly compared. As mention previously, the proposed model leverages the definition of irregular operations. This affect the objective function, solution approach, even the input of the model. Indeed, the proposed model aims to represent the complexity and condition on pandemic situation, and the reference model does not represent any modification in regard to pandemic situations. The irregular operation during normal situation is performed in operational horizon in which the flights are already assigned to dispatched aircraft. The irregular condition creates a sudden-unplanned aircraft shortage that leave the assigned routes to the troubled aircraft in danger of cancellation. The trivial solution is to cancel all the flights associated with the troubled aircraft. Yet the most optimal solution might be in form of set of aircraft delay and cancellation involving all aircraft and routes on that day. On the other hand, the proposed model run the irregular operation in planning horizon in which the users are planning on reducing the flight capacity as enforced by the reduction in flight traffic. The planned aircraft shortage takes form of reduction of dispatched aircraft with consideration of initial scheduled flight and its corresponding cost parameters. The initial scheduled flight for the proposed model input excludes the aircraft assignment decision. This mean that the aircrafts have not been assigned to the scheduled flight. The main difference between the basic referenced model and the proposed model is that to incorporate additional cost incurred by the pandemic situation. the cost parameter in the solution is modified by the additional operational and grounded cost. These costs are used as additional barrier of tradeoff on aircraft dispatching decision. By considering the additional cost, the model can cover broader cost consideration. As operational and grounded costs are subject to changes along with user's preference, the decision on aircraft dispatched might be varies. This is related to the significance of each cost parameter and how it drives factors of the total cost. In addition, the proposed model also equipped with valid routing algorithm that act as constraint to the model. The routing algorithm provide a good solution by emphasis on the earliest departure time selection that maximize aircraft utilization. Thus, the proposed model might give a more sensible cost approximation to the aircraft dispatching scenario in the pandemic situation.

(This page is intentionally left blank)

CHAPTER 6
CONCLUSION AND SUGGESTION

The conclusion of this research followed by suggestions will be present in this chapter

6.1.Conclusion

1 The model created able to generate valid routing with given routing input and cost parameter
2 The routing input play important role of the best number of dispatch as it defines the optimal minimum required aircraft to run the network
3 The decision support tool developed able to give recommendation of number of dispatched aircraft amidst pandemic situation by simulation the cost incurred by each number of dispatched aircraft.
4 With the study case input used in the simulation, the best scenario for aircraft dispatch is with three aircraft over twelve flights with no delay and cancellation cost. It is found to be the minimum number of aircraft required to cover all flight with no disruption

6.2. Suggestion

1 The further study should incorporate airport balance on the routing algorithm
2 A more comprehensive cost parameter input can be applied to further analyze each cost parameter in detail
3 The proposed model can be used as decision support system as a basis of decision making in determining number of aircraft to be dispatched on given scheduled route

REFERENCES

Allung Blegur, F.M., Bakhtiar, T. and Aman, A. (2014). Scenarios for Fleet Assignment: A Case Study at Lion Air. *IOSR Journal of Mathematics*, 10(5), pp.64–68.

Arguello, M.F., Bard J.F., and Yu G. (1998). Models and methods for managing airline irregular operations, *Operations Research in the Airline Industry*, edited by G. Yu. Boston: Kluwer Academic Publishers, 1–45.

Bard, J.F., Yu, G. and Argüello, M.F. (2001). Optimizing Aircraft Routings in response to Groundings and Delays. *IIE Transactions*, 33(10), pp.931–947.

Bazargan, M. (2010). Airline Operations And Scheduling. 2nd ed. Florence: Taylor and Francis, pp.155-170.

García, S. and Cadarso, L. (2017). Airline Re-Fleeting Managing Revenues and Maintenance Operations. *Transportation Research Procedia*, 27(2017), pp.1121–1128.

Gugus Tugas Percepatan Penanganan COVID-19 (2020). *Kriteria Pembatasan Perjalanan Orang Dalam Rangka Percepatan Penanganan Corona Virus Disease 2019 (COVID-19)*. Available at: https://covid19.go.id/storage/app/media/Regulasi/SE%20Kriteria%20Pembatasan%20Perjalanan%20Orang%20dalam%20Rangka%20Percepatan%20Penanganan%20COVID-19.pdf [Accessed 10 May 2020].

Hancerliogullari Koksalmis, G. (2019). Operations Management Perspectives in the Air Transport Management. *Journal of Business Administration Research*, 2(1), pp. 1-10.

Horton, W. (2020). *How Air Canada Quickly Turned 777 Passenger Planes Into Quasi Freighters To Haul Medical Supplies*. [online] Forbes. Available at: https://www.forbes.com/sites/willhorton1/2020/04/13/air-canadas-777-freighters-what-they-can-and-cant-do-for-air-cargo/#69cba4b7ed7f [Accessed 5 May 2020].

IATA (2020). *Airlines Facing Rapid Cash Burn*. [online] Press Release www.iata.org. Available at: https://www.iata.org/en/pressroom/pr/2020-03-31-01/ [Accessed 5 May 2020].

IATA (2020). *COVID -19 Updated Impact Assessment*. [online] IATA. Available at: https://www.iata.org/en/iata-repository/publications/economic-reports/covid-fourth-impact-assessment/ [Accessed 15 April 2020].

ICAO (2017). *Airline Operating Costs and Productivity*. [online] *ICAO*. Available at:https://www.icao.int/MID/Documents/2017/Aviation%20Data%20and%20Analysis%20Seminar/PPT3%20%20Airlines%20Operating%20costs%20and%20productivity.pdf [Accessed 2 May. 2020].

Jamili, A. (2017). A robust mathematical model and heuristic algorithms for integrated aircraft routing and scheduling, with consideration of fleet assignment problem. *Journal of Air Transport Management*, 58(2017), pp.21–30.

Kilmer, J. (2020). *Delta Air Lines Storage*. *AirTeamImages.com*. Available at: https://www.airteamimages.com/airbus-a321__delta-air-lines_356374.html [Accessed 12 April 2020].

Kotoky, A., Stringer, D. and Saxena, R. (2020). *Two-Thirds of the World's Passengers Jets Are Grounded Amid COVID-19. Here's What That Means*. [online] TIME. Available at: https://time.com/5823395/grounded-planes-coronavirus-storage/ [Accessed 8 May 2020].

Lazare, L. (2020). *United Airlines Alters Aircraft-Cleaning, Inflight-Service Procedures Because Of Coronavirus*. [online] Bizjournals.com; Chicago Business Journal. Available at: https://www.bizjournals.com/chicago/news/2020/03/09/united-airlines-alters-aircraft-cleaning-inflight.html [Accessed 26 April 2020].

Mangili, A., Vindenes, T. and Gendreau, M. (2015b). Infectious Risks of Air Travel. *Microbiology spectrum*, 3(5), pp.1–9.

Martín, J.C. and Román, C. (2010). Airlines and their Focus on Cost Control and Productivity. *European Journal of Transport and Infrastructure Research*, 8(2), pp.117–136.

Mathaisel, D.F.X. (1996). Decision support for airline system operations control and irregular operations. *Computers & Operations Research*, 23(11), pp.1083–1098.

Menteri Perhubungan Republik Indonesia (2020). *Peraturan Menteri Perhubungan*

Republik Indonesia Nomor PM 18 Tahun 2020 Tentang Pengendalian Transportasi Dalam Rangka Pencegahan Penyebaran Corona Virus Disease 2019 (COVID-19). Available at: http://jdih.dephub.go.id/assets/uudocs/permen/2020/PM_18_TAHUN_2020.pdf [Accessed 10 May 2020].

Menteri Perhubungan Republik Indonesia (2020). *Peraturan Menteri Perhubungan Republik Indonesia Nomor PM 25 Tahun 2020 Tentang Pengendalian Transportasi Selama Masa Mudik Idul Fitri Tahun 1441 Hijriah Dalam Rangka Pencegahan Penyebaran Corona Virus Disease 2019 (COVID-19)*. Available at: http://jdih.dephub.go.id/assets/uudocs/permen/2020/PM_25_TAHUN_2020.pdf [Accessed 10 May 2020].

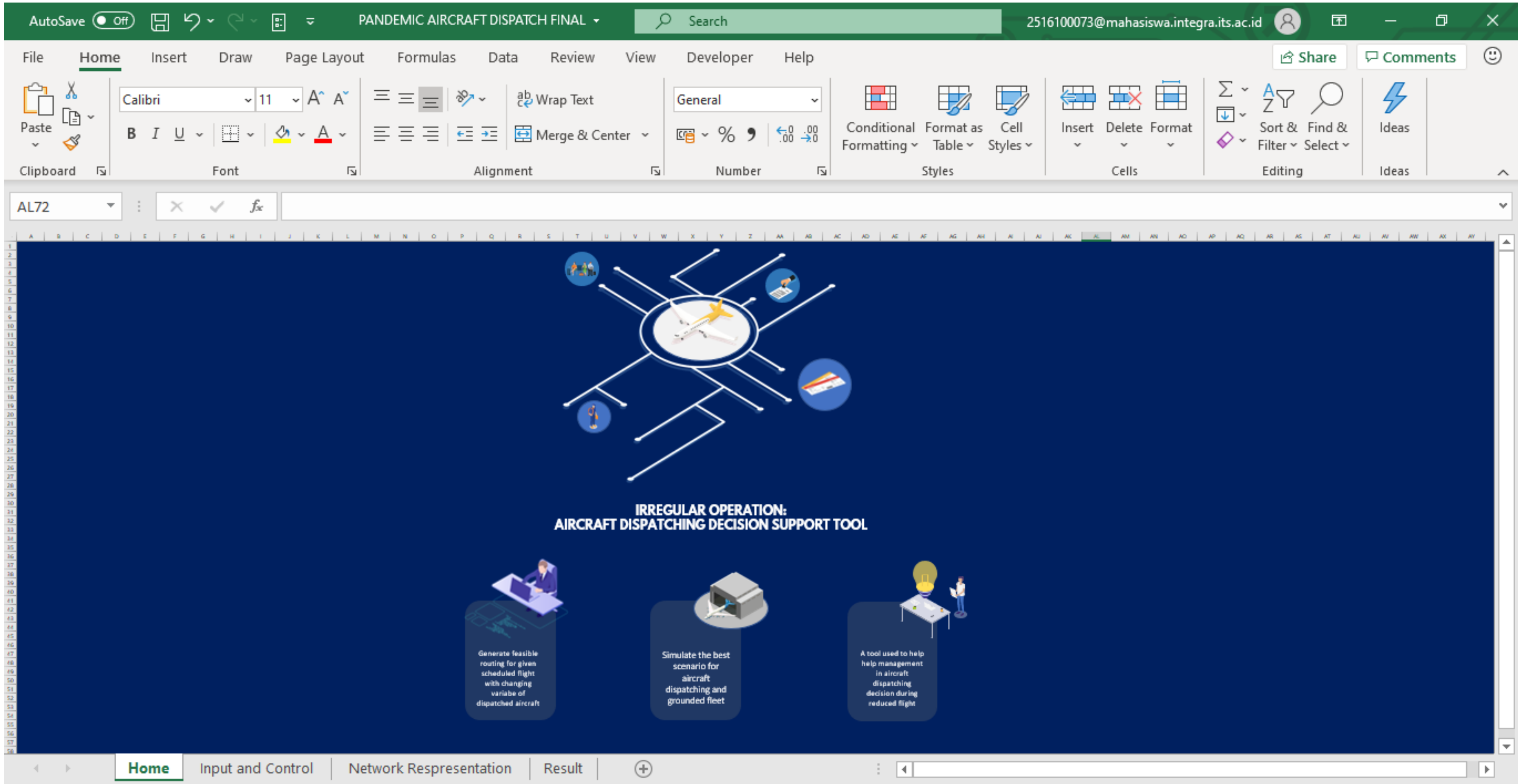
Ozili, P. and Arun, T. (2020). Spillover of COVID-19: Impact on the Global Economy. *SSRN Electronic Journal*, [online] Available at: https://www.researchgate.net/publication/340236487_Spillover_of_COVID-19_impact_on_the_Global_Economy [Accessed 12 April 2020].

Puckett, J. (2020). *Airlines Are Getting Bailout Money—But There Are a Lot of Strings Attached*. [online] Condé Nast Traveler. Available at: https://www.cntraveler.com/story/airlines-are-getting-bailout-money-but-there-are-a-lot-of-strings-attached [Accessed 2 May 2020].

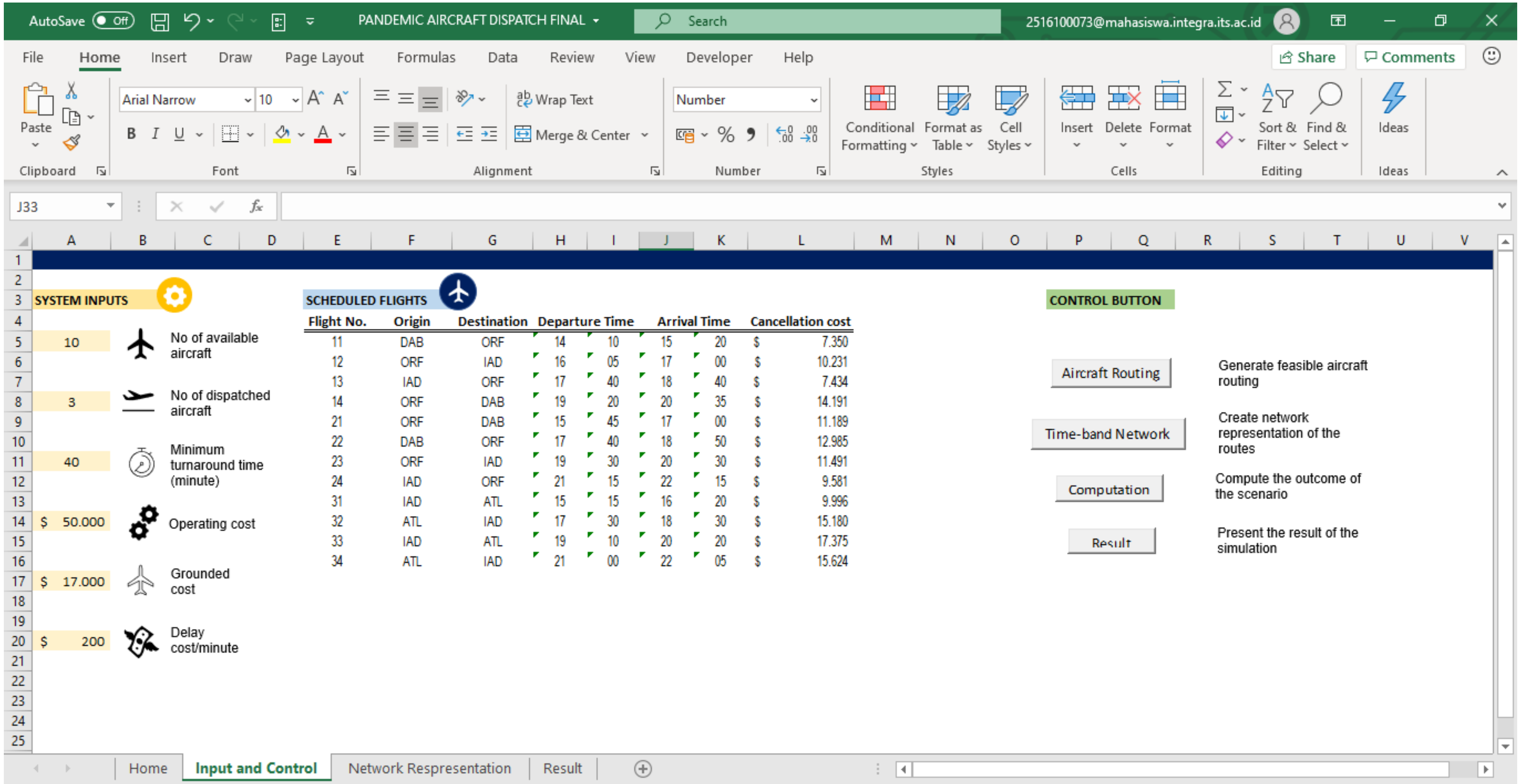
APPENDIX

APPENDIX 1: User Interface

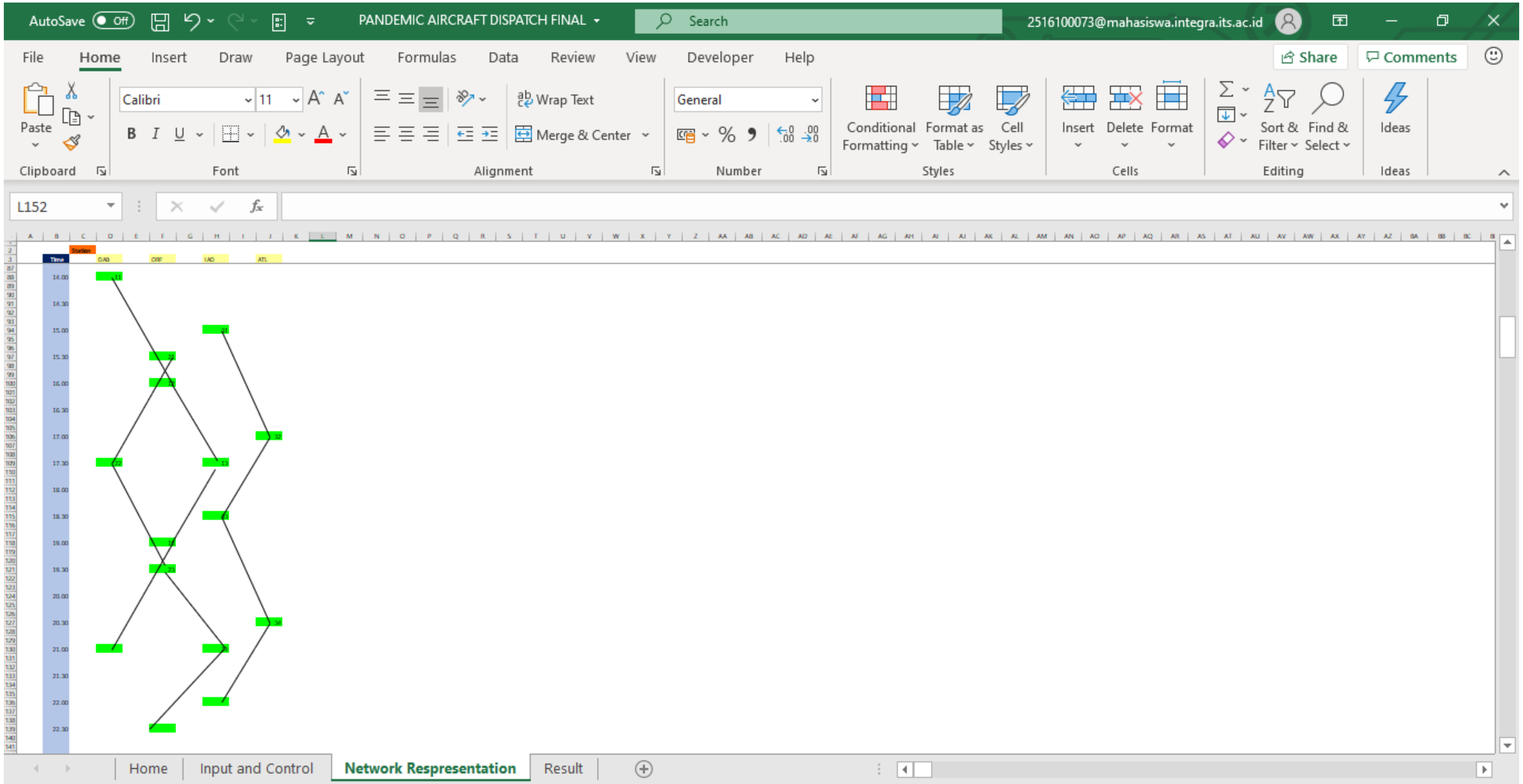
Home page of the model in Microsoft Excel 365



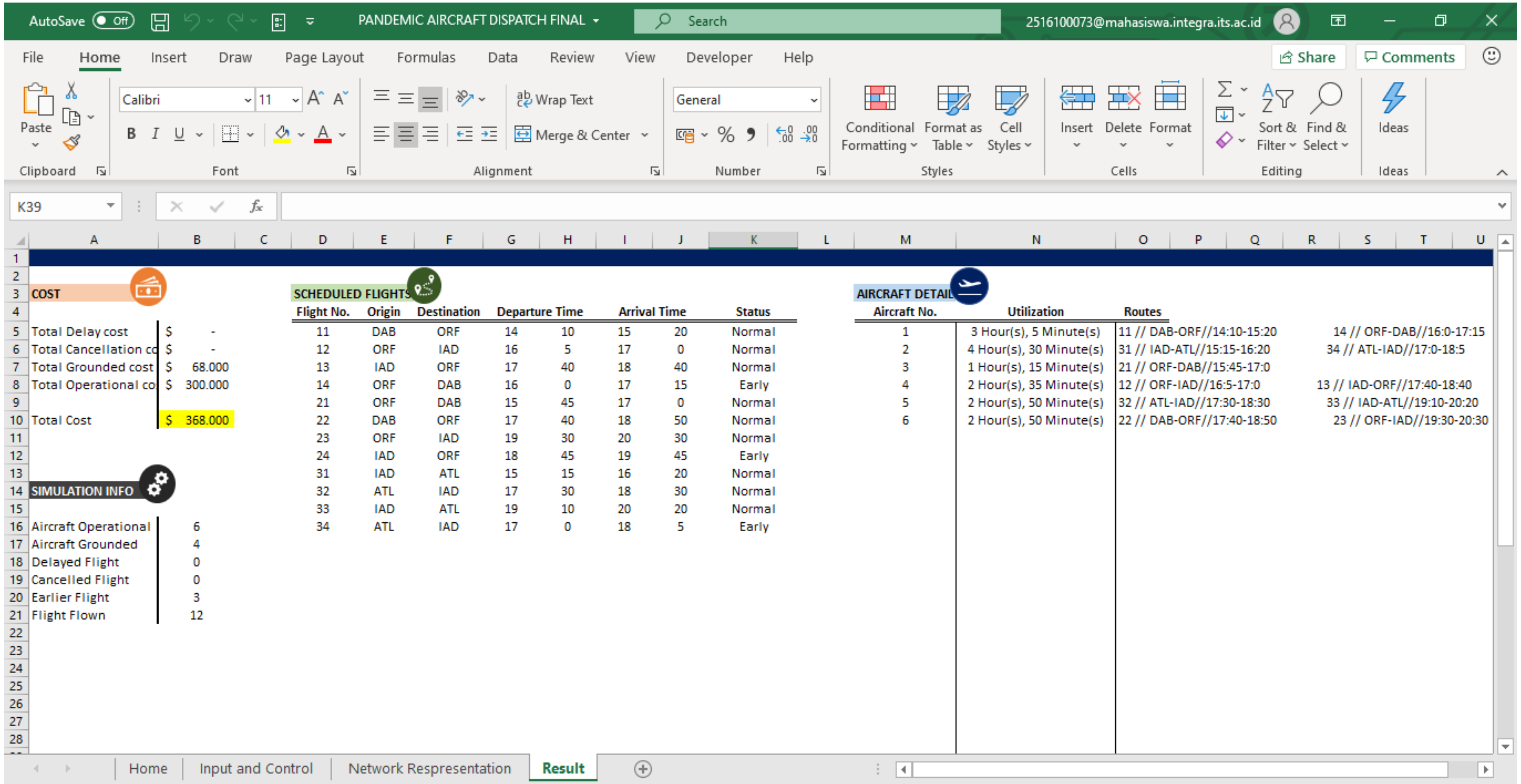
Input and control page



Network representation page



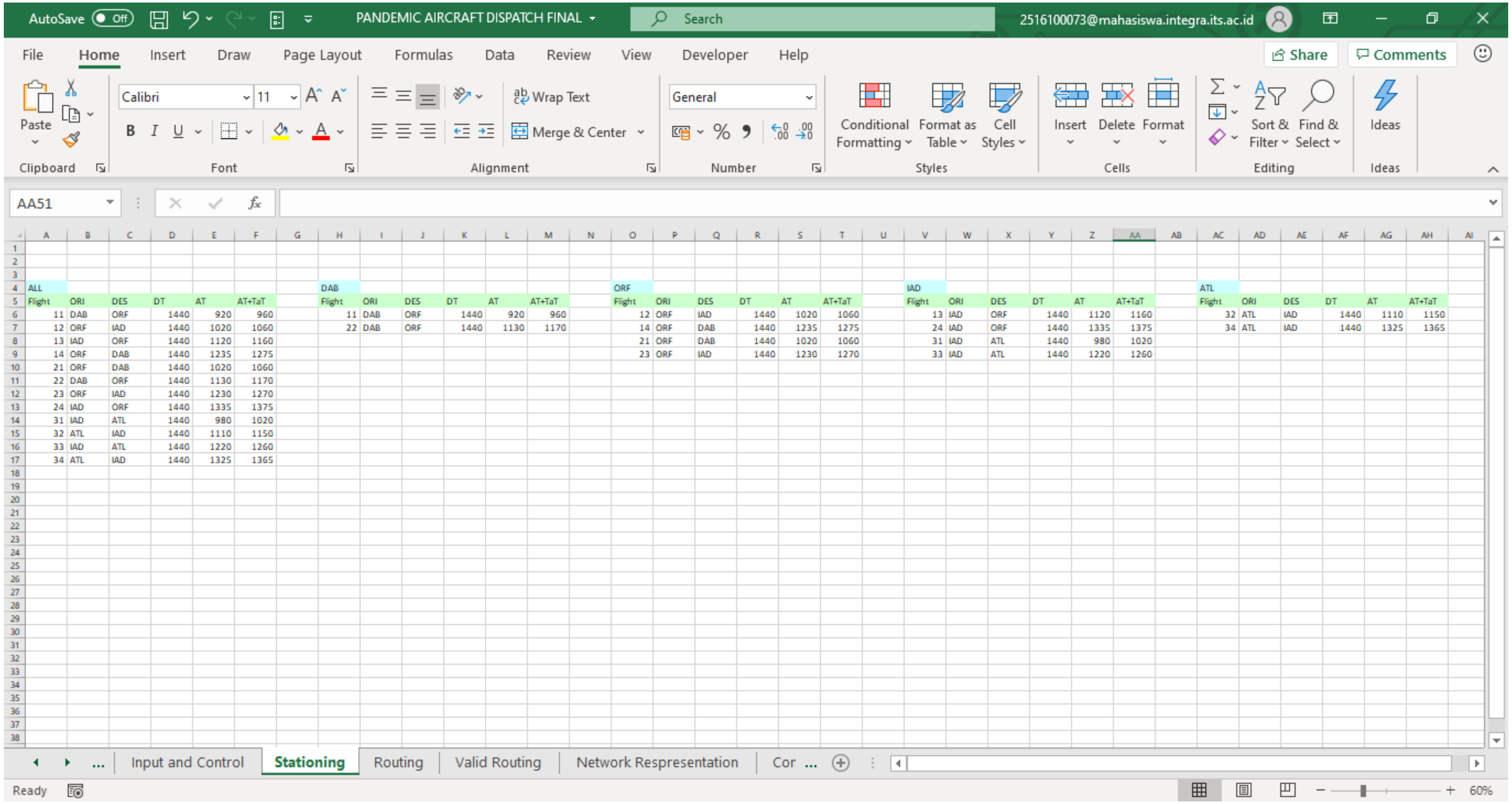
Result Page



PANDEMIC AIRCRAFT DISPATCH FINAL
COST
Total Delay cost $ -
Total Cancellation co $ -
Total Grounded cost $ 68.000
Total Operational co $ 300.000
Total Cost $ 368.000
SIMULATION INFO
Aircraft Operational 6
Aircraft Grounded 4
Delayed Flight 0
Cancelled Flight 0
Earlier Flight 3
Flight Flown 12
SCHEDULED FLIGHTS
Flight No. Origin Destination Departure Time Arrival Time Status
11 DAB ORF 14 10 15 20 Normal
12 ORF IAD 16 5 17 0 Normal
13 IAD ORF 17 40 18 40 Normal
14 ORF DAB 16 0 17 15 Early
21 ORF DAB 15 45 17 0 Normal
22 DAB ORF 17 40 18 50 Normal
23 ORF IAD 19 30 20 30 Normal
24 IAD ORF 18 45 19 45 Early
31 IAD ATL 15 15 16 20 Normal
32 ATL IAD 17 30 18 30 Normal
33 IAD ATL 19 10 20 20 Normal
34 ATL IAD 17 0 18 5 Early
AIRCRAFT DETAIL
Aircraft No. Utilization Routes
1 3 Hour(s), 5 Minute(s) 11 // DAB-ORF//14:10-15:20 14 // ORF-DAB//16:0-17:15
2 4 Hour(s), 30 Minute(s) 31 // IAD-ATL//15:15-16:20 34 // ATL-IAD//17:0-18:5
3 1 Hour(s), 15 Minute(s) 21 // ORF-DAB//15:45-17:0
4 2 Hour(s), 35 Minute(s) 12 // ORF-IAD//16:5-17:0 13 // IAD-ORF//17:40-18:40
5 2 Hour(s), 50 Minute(s) 32 // ATL-IAD//17:30-18:30 33 // IAD-ATL//19:10-20:20
6 2 Hour(s), 50 Minute(s) 22 // DAB-ORF//17:40-18:50 23 // ORF-IAD//19:30-20:30
Home Input and Control Network Respresentation Result

APPENDIX 2: Background Interface

Stationing page



ALL

Flight	ORI	DES	DT	AT	AT+TaT
11	DAB	ORF	1440	920	960
12	ORF	IAD	1440	1020	1060
13	IAD	ORF	1440	1120	1160
14	ORF	DAB	1440	1235	1275
21	ORF	DAB	1440	1020	1060
22	DAB	ORF	1440	1130	1170
23	ORF	IAD	1440	1230	1270
24	IAD	ORF	1440	1335	1375
31	IAD	ATL	1440	980	1020
32	ATL	IAD	1440	1110	1150
33	IAD	ATL	1440	1220	1260
34	ATL	IAD	1440	1325	1365

DAB

Flight	ORI	DES	DT	AT	AT+TaT
11	DAB	ORF	1440	920	960
22	DAB	ORF	1440	1130	1170

ORF

Flight	ORI	DES	DT	AT	AT+TaT
12	ORF	IAD	1440	1020	1060
14	ORF	DAB	1440	1235	1275
21	ORF	DAB	1440	1020	1060
23	ORF	IAD	1440	1230	1270

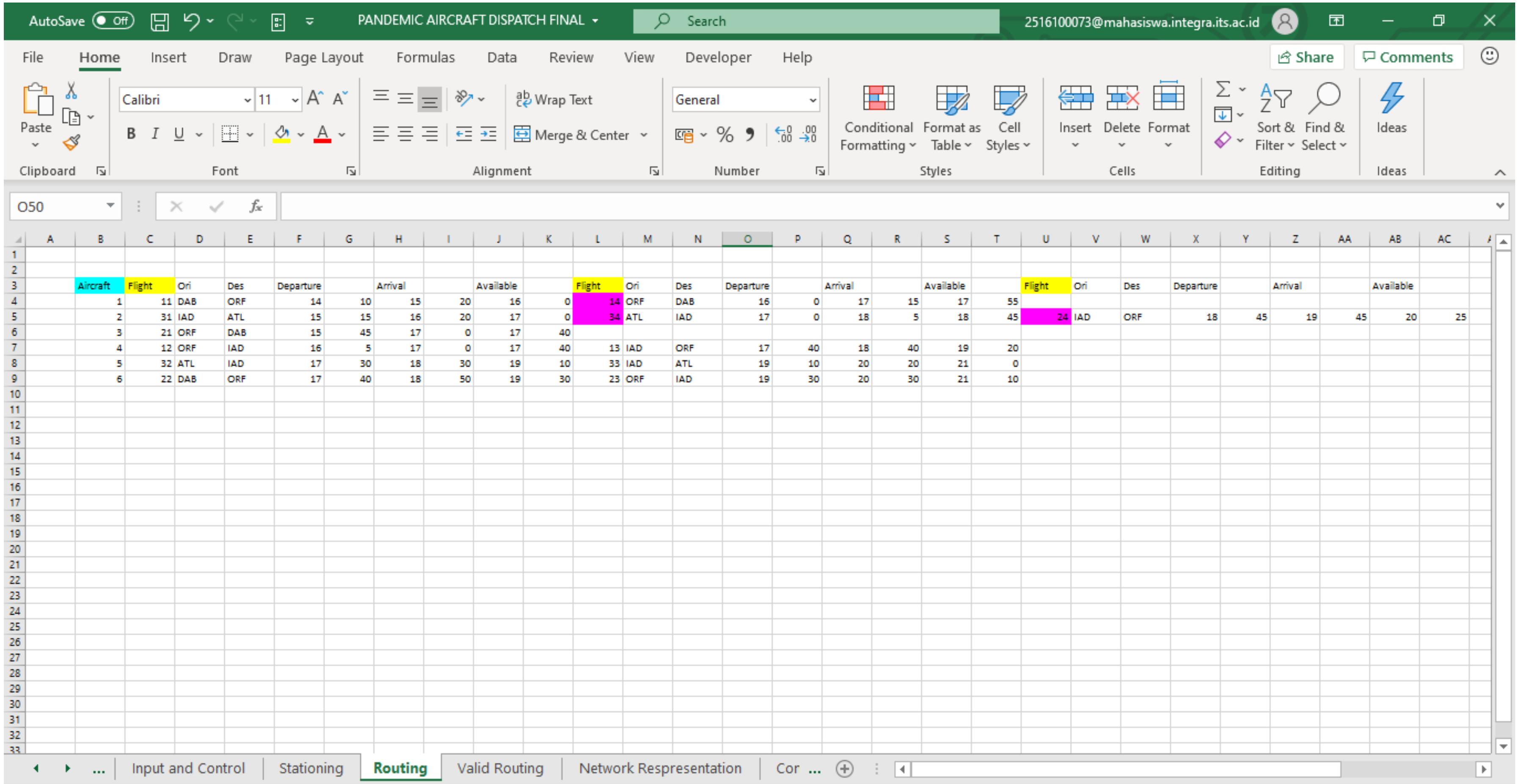
IAD

Flight	ORI	DES	DT	AT	AT+TaT
13	IAD	ORF	1440	1120	1160
24	IAD	ORF	1440	1335	1375
31	IAD	ATL	1440	980	1020
33	IAD	ATL	1440	1220	1260

ATL

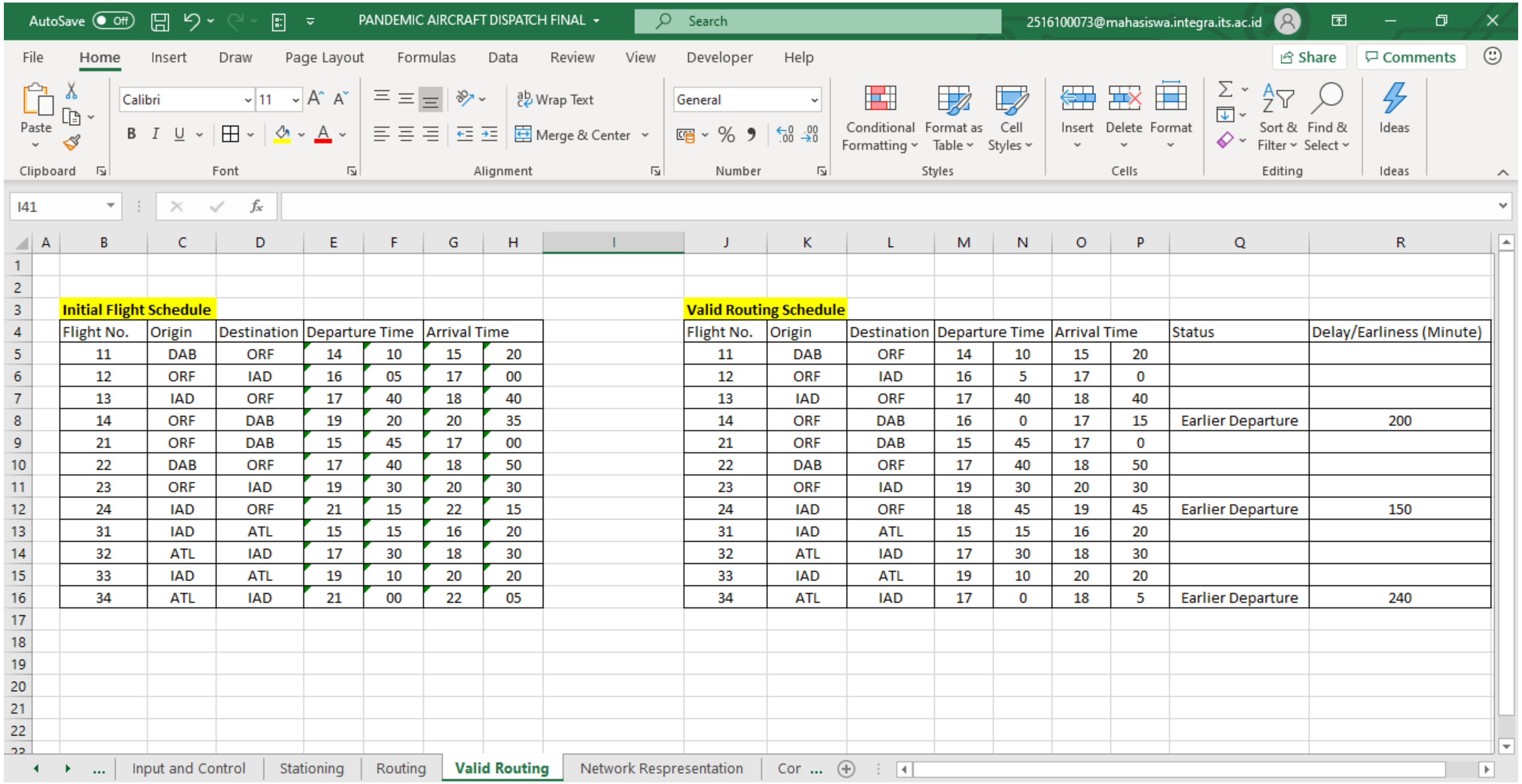
Flight	ORI	DES	DT	AT	AT+TaT
32	ATL	IAD	1440	1110	1150
34	ATL	IAD	1440	1325	1365

Routing loop page



Aircraft	Flight	Ori	Des	Departure		Arrival		Available		Flight	Ori	Des	Departure		Arrival		Available		Flight	Ori	Des	Departure		Arrival		Available	
1	11	DAB	ORF	14	10	15	20	16	0	14	ORF	DAB	16	0	17	15	17	55									
2	31	IAD	ATL	15	15	16	20	17	0	34	ATL	IAD	17	0	18	5	18	45	24	IAD	ORF	18	45	19	45	20	25
3	21	ORF	DAB	15	45	17	0	17	40																		
4	12	ORF	IAD	16	5	17	0	17	40	13	IAD	ORF	17	40	18	40	19	20									
5	32	ATL	IAD	17	30	18	30	19	10	33	IAD	ATL	19	10	20	20	21	0									
6	22	DAB	ORF	17	40	18	50	19	30	23	ORF	IAD	19	30	20	30	21	10									

Valid routing page



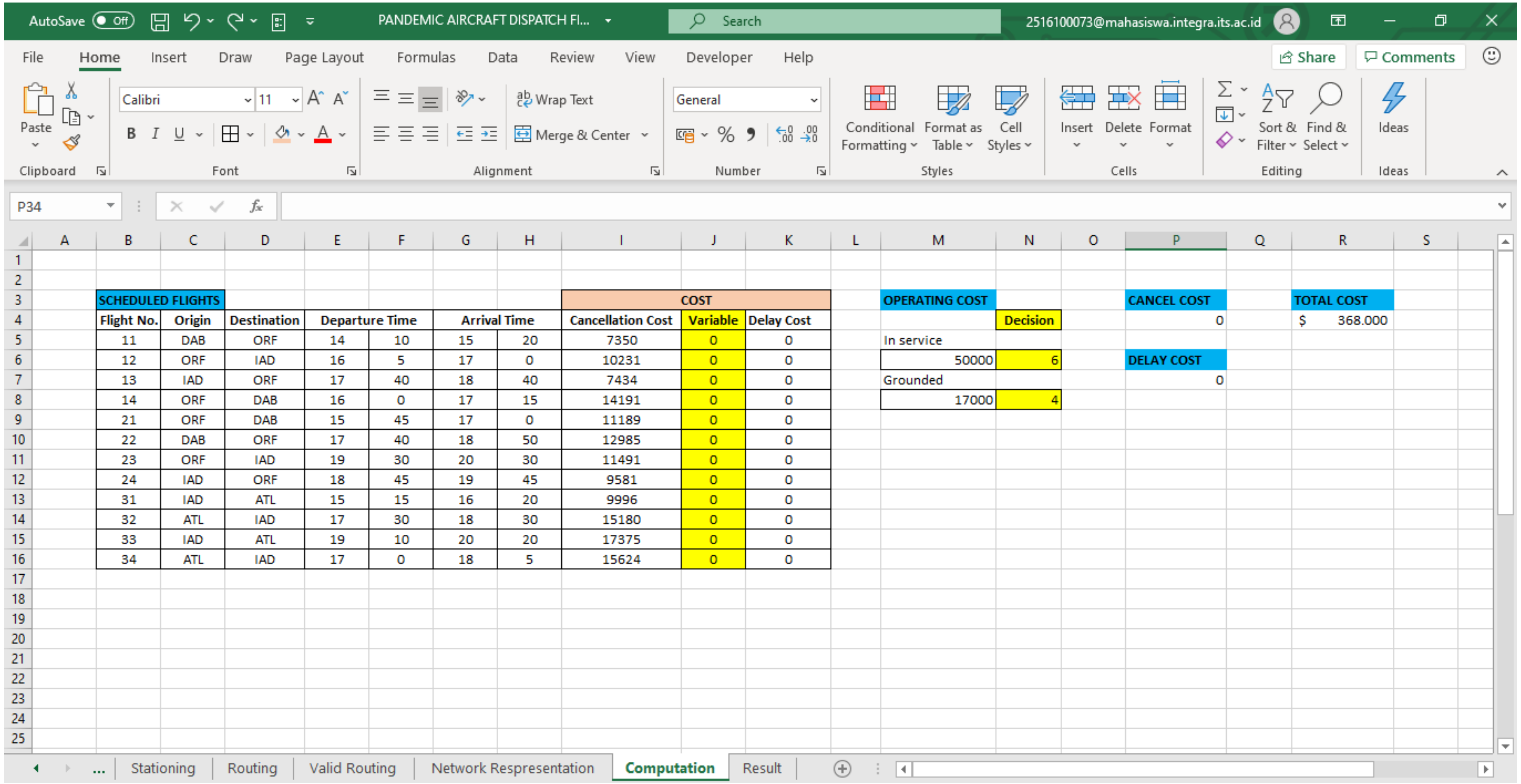
Initial Flight Schedule

Flight No.	Origin	Destination	Departure Time		Arrival Time	
11	DAB	ORF	14	10	15	20
12	ORF	IAD	16	05	17	00
13	IAD	ORF	17	40	18	40
14	ORF	DAB	19	20	20	35
21	ORF	DAB	15	45	17	00
22	DAB	ORF	17	40	18	50
23	ORF	IAD	19	30	20	30
24	IAD	ORF	21	15	22	15
31	IAD	ATL	15	15	16	20
32	ATL	IAD	17	30	18	30
33	IAD	ATL	19	10	20	20
34	ATL	IAD	21	00	22	05

Valid Routing Schedule

Flight No.	Origin	Destination	Departure Time		Arrival Time		Status	Delay/Earliness (Minute)
11	DAB	ORF	14	10	15	20		
12	ORF	IAD	16	5	17	0		
13	IAD	ORF	17	40	18	40		
14	ORF	DAB	16	0	17	15	Earlier Departure	200
21	ORF	DAB	15	45	17	0		
22	DAB	ORF	17	40	18	50		
23	ORF	IAD	19	30	20	30		
24	IAD	ORF	18	45	19	45	Earlier Departure	150
31	IAD	ATL	15	15	16	20		
32	ATL	IAD	17	30	18	30		
33	IAD	ATL	19	10	20	20		
34	ATL	IAD	17	0	18	5	Earlier Departure	240

Computation page



SCHEDULED FLIGHTS							COST		
Flight No.	Origin	Destination	Departure Time		Arrival Time		Cancellation Cost	Variable	Delay Cost
11	DAB	ORF	14	10	15	20	7350	0	0
12	ORF	IAD	16	5	17	0	10231	0	0
13	IAD	ORF	17	40	18	40	7434	0	0
14	ORF	DAB	16	0	17	15	14191	0	0
21	ORF	DAB	15	45	17	0	11189	0	0
22	DAB	ORF	17	40	18	50	12985	0	0
23	ORF	IAD	19	30	20	30	11491	0	0
24	IAD	ORF	18	45	19	45	9581	0	0
31	IAD	ATL	15	15	16	20	9996	0	0
32	ATL	IAD	17	30	18	30	15180	0	0
33	IAD	ATL	19	10	20	20	17375	0	0
34	ATL	IAD	17	0	18	5	15624	0	0

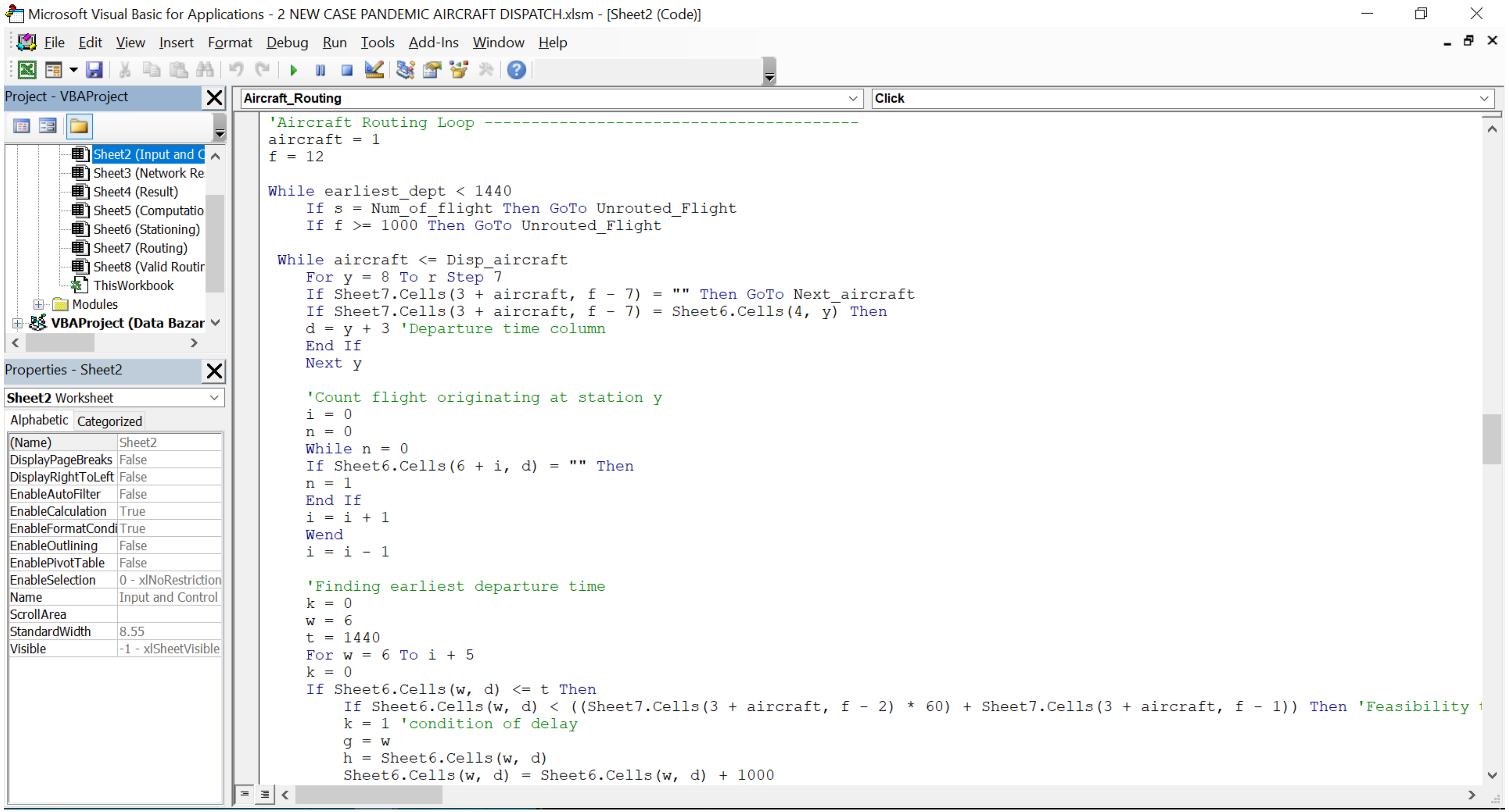
OPERATING COST	Decision
In service	
50000	6
Grounded	
17000	4

CANCEL COST: 0

DELAY COST: 0

TOTAL COST: $ 368.000

Visual Basic Editor (VBE) interface



AUTHOR'S BIOGRAPHY

Risang Arkaan Jauza was born in Jakarta, 5th August 1998. He started his formal education in SD Kartika VIII-I. He later continues his education at 49 Junior High School Jakarta in bilingual class where he practiced a lot of his English proficiency. After graduated Junior High School in 2013, he went to 28 Senior High School Jakarta.

After graduated from high school, he continues his study at Industrial and System Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya. He was accepted in international class of 2016. During his undergraduate study, he was involved in Himpunan Mahasiswa Teknik Industri under entrepreneurship department. His interest in logistics and supply chain, and particularly air transport and aviation as general brought him to be part of Logistics and Supply Chain Management Laboratory. He became the assistance at LSCM laboratory and involved in various event held by LSCM.

During his study, he also participating at several competition such as business case competition, industrial engineering competition, paper competition, and Program Kreatifitas Mahasiswa (PKM) held by ministry of research and technology. He also expanding his network and international exposure by participating in international program. He became one of participant in Kumamoto University Spring Program Japan in 2018.