Analysing the influence of the COVID-19 pandemic on air travel behaviour

An approach of stated choice experiment

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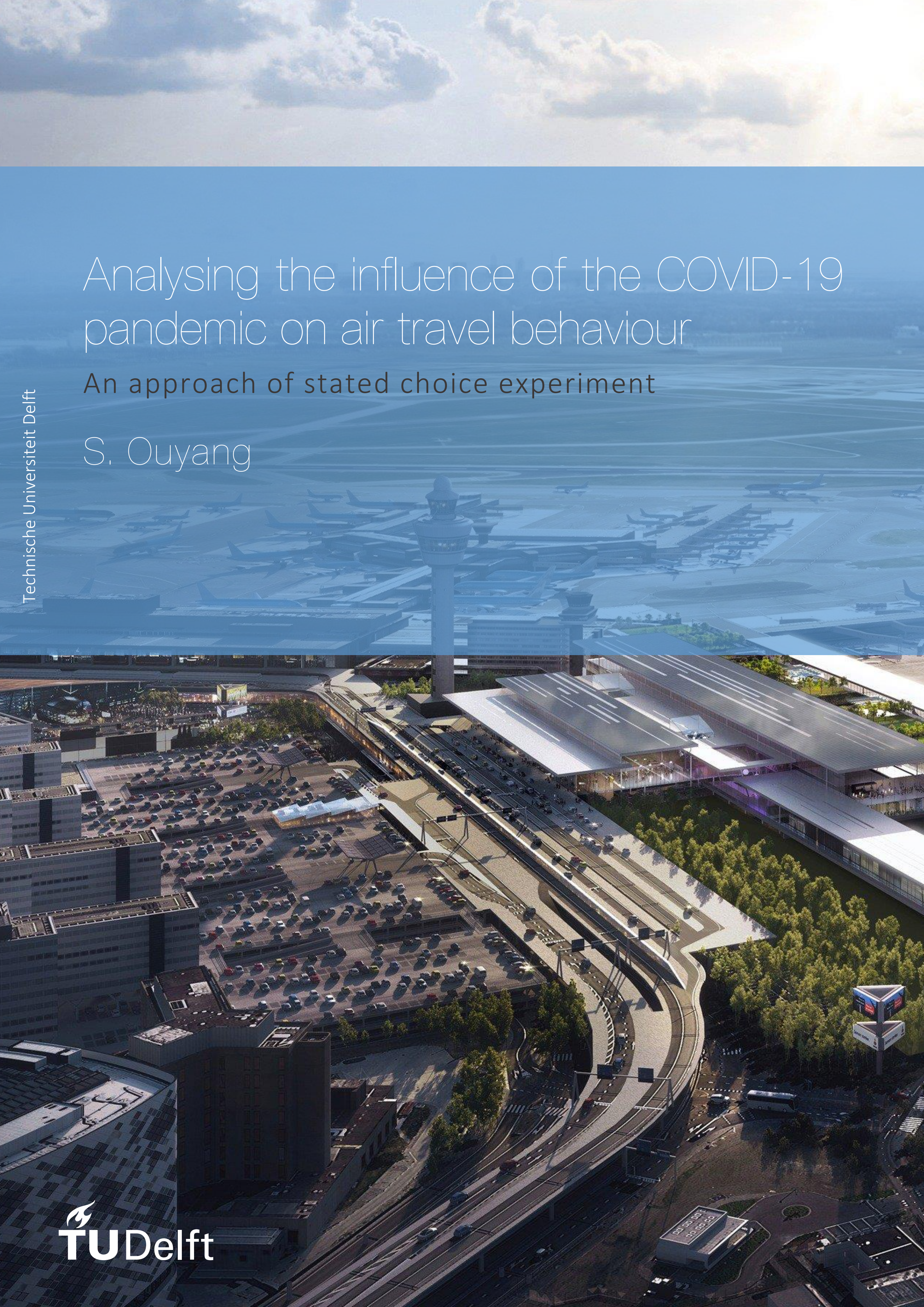

TU Delft

Analysing the influence of the COVID-19 pandemic on air travel behaviour:

An approach of stated choice experiments

By

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in partial fulfilment of the requirements for the degree of

Master of Science
in Transport, Infrastructure and Logistics

at the Delft University of Technology,
to be defended publicly on 13th of April 2021.

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Preface

In the first year of my study at TU Delft, Caspar and Eric's course of Statistical Analysis of Choice Behaviour was the major source for me to feel the sense of achievement. At first, it was hard. But the more I learn and the harder I follow, the more interested I get in what they teach. They magically turned a word I used to be afraid to hear, statistics, into an intriguing tool to solve many interesting problems in my head during daily life. Through their lecturing, I built up my interests in choice behaviour.

I have always been hoping to apply the knowledge I learned to something that society can benefit from. So, when Kees proposed the option to study the impact of the COVID-19 on air travel behaviour as the topic of my graduation thesis, there hardly was a hesitation before I said yes.

It feels good to do what you like. During the past several months, I keep reading, learning and practising in order to make this thesis into being. With my knowledgeable and supportive committee members, I was never afraid of whatever problems challenging me. I quote here from Julius Caesar: Veni, vidi, vici. With respect, I proudly present this thesis to you.

I express my greatest gratitude to my committee members for their limitless patience and tutoring.

In grateful remembrance of my friends, because they made my study at TU Delft colourful and full of fun.

For my girlfriend: Bamboo. Because she offered unconditional support.

Especially for my parents. Because they truly are the wind beneath my wings.

Sicong Ouyang

Delft, March 2021

Summary

The outbreak of the COVID-19 pandemic in 2020 seriously impacted the world. Some previous researches suggest that global incidents could strongly influence the demand for passenger air transport services (Sobieralski, 2020). And the impacts on the demand can be ascribed to the change in the air travel behaviour of travellers (Ito & Lee, 2005). However, the influence of a pandemic on passengers' air travel behaviour has been rarely studied. This thesis studies the differences in air travel behaviour between the COVID-19 period and the non-pandemic period, in order to benefit the decision-making of policy-makers.

In this thesis, it is assumed that the COVID-19 pandemic influences air travel behaviour through changing the air transport context. Three context aspects are found to influence how air travellers behave during the pandemic. Firstly, the policies including travel restrictions and travel recommendations imposed by the government discourage travel motivation. Secondly, the rise in public risk perception triggers their health-protective behaviour which leads to low willingness to fly or changes in travel choice decision-making. The operation adjustments of the airlines in response to the COVID-19 pandemic also influence the offered flight options in the market which could change flight choice behaviour.

Two important air travel choice behaviours during the COVID-19 pandemic are further studied, which are the choice between flying and not flying (willingness to fly) and the choice between flight alternatives. Stated choice data is used since it avoids the bias of revealed choice data in studying willingness to fly. Discrete choice modelling is used because of its advantage in studying individual choice.

Air travel convenience and airborne health safety are considered important to air travel choice-making during the pandemic. Therefore, they are added as two attributes in the stated choice experiment. The perception of them is scaled by the perception rating experiment using the Hierarchical Information Integration theory. The results show that the perception of air travel convenience is influenced by the requirement of health-related paperwork, such as health statement and virus test result, for travelling and the travel flexibility, such as change and return policy given, by the airlines. The perceived health safety is influenced by the intensity of the virus precautionary measures implemented in the cabin.

The results of the stated choice experiment show a considerable change in the attribute trade-off between flight alternatives made by air travellers during the pandemic. Perceived health safety is the foremost factor that air travellers consider. If an intermediate serious pandemic is assumed, air travellers are willing to pay at least 100% more money to improve the virus precautionary measures by 1 level compared to the non-pandemic situation. This percentage difference becomes larger when the safety level Increases to a higher level, which means that air travellers are more willing to take the safest flight during the pandemic. Transfer and flying time are considered as other two important attribute during the pandemic because they indicate the chance of the exposure to the risky environment. Therefore, travellers are willing to pay 87.9 euro during a serious pandemic to reduce 1 transfer, while

they would only pay 42.6 euro during the non-pandemic period. Correspondingly, the ticket price of the flight becomes less important in the exchange for a better performance of other attributes.

The willingness to fly is significantly deteriorated by the COVID-19 pandemic. In the case of a serious pandemic, the willingness to fly reduces from 83.5% to 37.6% if the flights in the market have a medium attribute performance. Although improving several flight attributes including price, transfer, travel convenience and health safety can pull up the willingness to fly, however, the negative impact of the pandemic is so strong that even the most extreme attribute improvement, ignoring the profitability and sustainability, still cannot totally offset the willingness to fly reduction because of the COVID-19.

The following recommendations are given to policy-makers. Firstly, meeting the customers' expectation of health safety is the best way for airlines to compete during the COVID-19 pandemic. Two methods to do so include providing non-stop flights as much as possible and improving the intensity of virus precautionary measures in the cabin. Reducing the price is still effective in attracting customers, but less than during the non-pandemic period. Secondly, airlines can increase their load factor by improving flight attributes. But the negative impact of the virus cannot be fully compensated. Thirdly, because the willingness to fly is strongly related to the seriousness of the pandemic, the government should never underestimate the rebound of travel motivation in order to avoid the uncontrollability of the pandemic when the situation gets better. Fourthly, as the COVID-19 is unlikely to disappear soon, the low willingness to fly will remain and threaten the survival of airlines. The governments should work out a sustainable financial aid plan with airlines that can also balance the other goals for the society including economic growth and environmental protection.

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List of Abbreviations

HII	Hierarchical Information Integration
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ML	Mixed Logit
MNL	Multinomial Logit
RC	Revealed choice
RQ	Research question
RUM	Random Utility Maximization
SC	Stated choice
SQ	Sub-question
WHO	World Health Organization
WtF	Willingness to fly
WTP	Willingness to pay

1 Introduction

1.1. Research background

The COVID-19 pandemic which first broke out in 2019 shows its impact on the air transport industry. A dramatic scale-down of air transport capacity was observed in 2020 when the number of seats offered by airlines reduced by 51% worldwide (ICAO, 2021). This result can be ascribed to two reasons. First, after the outbreak, many governments imposed stricter travel regulations to restrain population movement and to slow down international air transport (Sun et al., 2020). Second, the travel demand was reduced by the pandemic. The public generally expressed their concerns about the threat of the virus. Gerhold (2020) found in his research that people are particularly worried about possible infection in places with a high density of crowd such as public transportation.

As a result, the number of people who took flights in 2020 considerably decreased compared to the previous years. According to the statistics (ICAO, 2021), a 2,887 to 2,892 million air passenger reduction worldwide was caused because of the COVID-19 pandemic in 2020. Due to the weak air travel demand, the passenger aviation industry undertook a massive financial loss. Many entities, including airlines, airports and even airplane manufacturers, struggled to survive.

1.2. Problem statement & research contributions

A global incident, such as armed conflict, terrorist attack, political unrest, economic recession, global pandemic and etcetera, could affect many socio-economic aspects including the way that people travel (discussed in Sub-Chapter 3.1). Because the COVID-19 pandemic has heavily interfered with the development of the air transport industry, this thesis assumes that one of the contributors to such a heavy impact is the changes in the air travel behaviour of people during the pandemic.

However, the air travel behaviour under the context of a pandemic has not been sufficiently studied by the literature. Some previous researches associated public risk perception with risk avoidance actions in order to explain the changes in how people behave in emergency situations (Bayham et al., 2015) & (Eiser et al., 2012). These theories lay the foundation to explain air travel behaviour changes during a pandemic. There were also researches that observed some specific travel behaviour changes during a pandemic. Such changes include starting to wear masks and consulting doctors for recommendations (Lau et al., 2004), and postponing or cancelling trip plans (Fenichel et al., 2013). However, the full image of the pandemic's impact on air travel behaviour is not completed. Travel behavioural study outcomes are especially rare for a pandemic as severe as the COVID-19. To be more specific, what is still missing in the literature includes how a pandemic influences air travel behaviour and the extent to which the COVID-19 influences the way that people make decisions for air travelling. Therefore, this thesis dedicates itself to solve these two problems.

Solving these two problems will bring three major benefits. First, it fills the knowledge gaps and improves the understanding of the impact of a pandemic on air travel behaviour. Although this thesis is carried out based on the case of the COVID-19, the outcome of this research could also be used for other pandemic situations or other types of global incidents in the future. Second, it provides new insights into the passenger aviation industry and benefits to relevant stakeholders. Air travel behaviour has always been paid attention to by relevant stakeholders, especially airlines. This is because understanding passengers' preferences and tastes could help airlines to improve their services and business by adjusting their operational and marketing strategies accordingly. The COVID-19 pandemic brought a huge impact on the industry, therefore, understanding their travel behaviour could possibly provide more useful information for crisis management countermeasures. Thirdly, international air transport plays an important role to spread the virus. Therefore, many governments monitor and regulate it to have better control of the pandemic situation. Understanding passengers' air travel behaviour during the pandemic could help the government to better anticipate the travel intentions and choices of people for better policy decision-making and preparedness.

1.3. Research questions

The main objective of this thesis is to show how and what air travel behaviour is influenced by the COVID-19 pandemic. This leads to the main research question for the thesis to be formulated:

> ***What is the difference in air travel behaviour between the COVID-19 period and the non-pandemic period?***

The process for answering the main research question is divided into several stages. These stages break down the main question into several practically solvable questions. By answering them, the answer to the main research question can be finally given. These sub-questions are listed below:

SQ1: What is the context of the COVID-19 pandemic influencing air travel behaviour?

- **SQ1a: What are the context aspects that are affected by the pandemic and may influence air travel behaviour?**
- **SQ1b: What air travel behaviour could be changed by these context aspects?**

SQ2: How does COVID-19 pandemic influence willingness to fly?

- **SQ2a: To what extent is the willingness to fly influenced by the COVID-19 pandemic?**
- **SQ2b: To what extent can the willingness to fly be increased by improving the flight attributes?**

SQ3: How does COVID-19 pandemic influence flight choice behaviour?

SQ3a: How are flight attributes in terms of travel convenience and health safety perceived by air travellers during the pandemic?

SQ3b: To what extent does the pandemic influence the trade-off across flight attributes when choosing the flight for travelling?

In order to study the air travel behaviour during the COVID-19 pandemic, the context for air travel during the pandemic should be known well, which is why SQ1 is formulated. This thesis makes an assumption that it is neither the virus nor the pandemic but the changed air travel context that influences the air travel behaviour. Therefore, SQ1 consists of two questions to study the changes in context and its association with possible influences on travel behaviour.

In Chapter 5, the scope of air travel behaviour study is narrowed down to two specific travel choices, which are the choice between flying and not flying and the choice between flight alternatives. The first choice is viewed as willingness to fly and the second choice is described as flight choice behaviour. Therefore, SQ2 and SQ3 are formulated for two travel choices respectively.

The situation of the COVID-19 pandemic is considered an important factor influencing people's willingness to fly. Therefore, SQ2a is formulated. On the other hand, the performance of a flight alternative is assumed to have impact on people's willingness to fly also, which is why SQ2b is formulated.

In Chapter 6, flight attributes in terms of travel convenience and health safety are identified important to air travelling during the pandemic. Therefore, they are added as the factors to study both flight choice behaviour and willingness to fly. Because it is difficult to objectively quantify them, SQ3a is formulated to study the scientific way to properly scale them for the choice behaviour study. At last, in SQ3b, the trade-off across flight attributes including the above two attributes will be studied to reveal flight choice behaviour change during the pandemic.

1.4. Research approach

In order to give the answer to sub-question 1, literature review and conceptual modelling will be adopted as the research methods. Relevant key-words in aspects including the background of the COVID-19 pandemic, air transport context during the COVID-19, theories of behaviour in response to emergencies and risky environment and air travel choice behaviour will be retrieved.

Answering sub-question 2 and 3 involves the application of the Stated Choice experiment. Two travel choice behaviours will be analysed respectively with the help of the Multinomial Logit (MNL) model and Mixed Logit (ML) model using Stated Choice data. This method has never been used to study travel choice behaviour during an emergency situation in terms of a pandemic. This thesis will provide an example to use the well-known method of stated choice experiment to study a topic that is brand new.

An elaborated methodology introduction can be found in Chapter 2. The methodology step that explains how the research questions are answered by the research methods can be found in Figure 1 below:

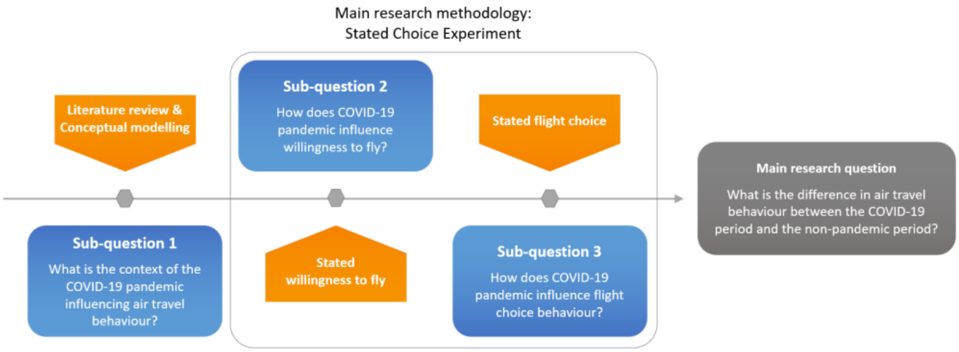


Figure 1 – Methodology steps to answer the research questions

1.5. Thesis layout

This thesis contains 11 chapters which are divided into 3 phases including Mapping & Conceptualization, Experiment Design and Estimation & Analysis. The diagrammatic illustration of the thesis layout including the main contents that are included by each chapter can be found in Figure 2 below:

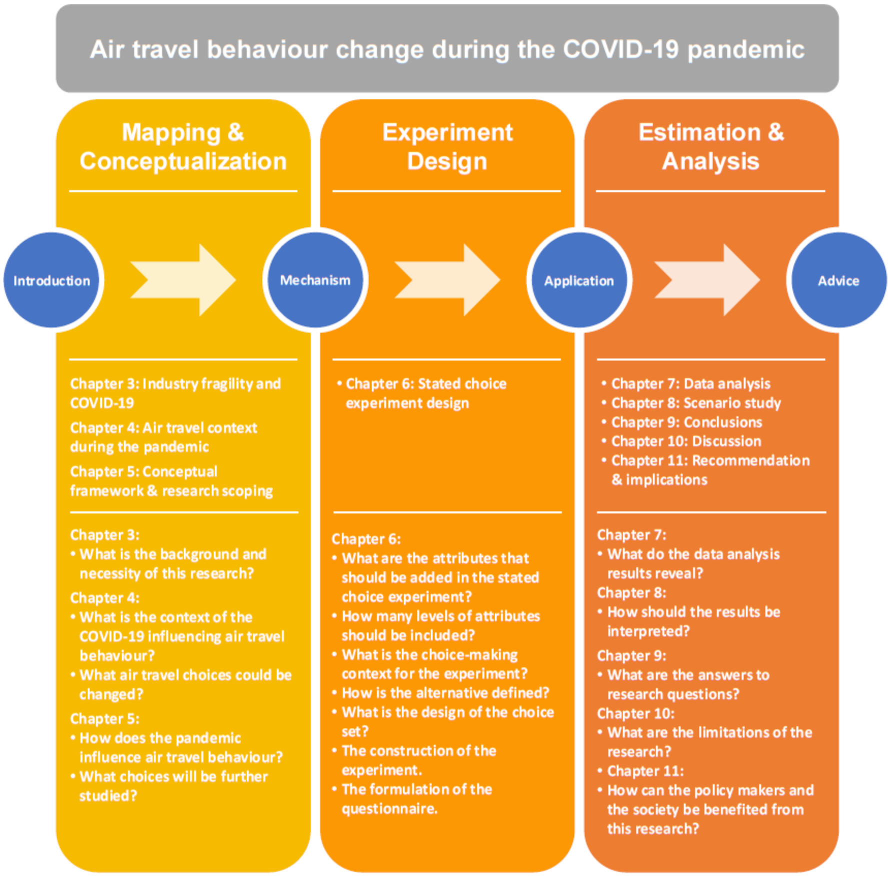


Figure 2 – Thesis layout

Phase 0: Preparation

This phase includes Chapter 1 to Chapter 2. The former gives a brief introduction of the thesis and the latter discusses the methodology that will be implemented in the research process.

Phase 1: Mapping & conceptualization

This phase includes Chapter 3 to Chapter 5 in which the background, concepts and scope for this research are elaborated. Chapter 3 introduces the background of the research at the industrial level, which also implies the necessity of the research. Chapter 4 discusses the air travel context of the COVID-19 pandemic. The changes in some context aspects and their influences on air travel choices are identified. Chapter 5 creates the conceptual model based on the findings from Chapter 4 and scopes down the studied travel choices for the stated choice experiment.

Phase 2: Experiment design

This phase includes Chapter 6 where the stated choice experiment is designed. It firstly identifies and discusses the attributes to add in the experiment. Determination of the attribute levels comes as follow. Then the other details of the experiment are discussed and defined which include choice-making context, alternative, choice sets and background characteristics of the respondents. Thereafter, the experiment construction and the formulation of the stated choice questionnaire are discussed respectively.

Phase 3: Estimation & analysis

This phase consists of Chapter 7 to Chapter 11 where the experiment data is analysed and the result of the thesis is concluded and discussed. In Chapter 7, the linear regression analysis is performed for studying the way that travel convenience and health safety are perceived. Then the discrete choice models including the Multinomial Logit (MNL) model and Mixed Logit (ML) model are used to analyse flight choice behaviour and willingness to fly. In Chapter 8, two scenario studies are performed to more directly interpret the meaning of the parameter estimation result from last chapter in the sense of air travel behaviour change. In Chapter 9 the conclusions of the result are made which is followed by Chapter 10 discussing the research details and possible improvements. In Chapter 11 the recommendations for policy-makers of both industry and the government are elaborated.

2 Methodological approach

This chapter introduces the methodology that is applied in this thesis. First, the method of literature review is discussed in Sub-Chapter 2.1. In Sub-Chapter 2.2, the stated choice experiment, which is the main research method of this thesis is introduced. The methods that are used to analyse the collected data also are included.

2.1. Literature review

Literature review is applied for achieving three objectives. The first is to highlight the necessity of the research topic. The second is to introduce the research background. The third is to depict the context of the COVID-19 for air travelling and to associate it to possible influences on air travel behaviour. Google Scholar and Google Search Engine will be used as two databases for retrieving information. The criteria to determine which databases to use depends on the types of information that are needed. The academic publications will be accessed via Google scholar. The information from other non-academic sources will be accessed by Google Search Engine as a complement.

Identifying the necessity of the research involves reviewing the literature that studies the air travel behaviour under emergency situations. The COVID-19 pandemic is an example of a global incident that influences many public sectors including international transport. Studying the behavioural impact of previous global incidents lays the basis to make reliable assumptions for the impacts of the COVID-19 pandemic. Important information for achieving this objective includes the background of the previous global incidents, impacts of them on the air travel behaviour and the impact on the industry due to the air travel behaviour change.

In order to introduce the research background, literature that provides the basic information about the COVID-19 pandemic and its general impacts on the air transport will be referred. Considering the COVID-19 is a relatively new research topic that some facts and outcomes might have not been published academically yet, non-academic information sources will be also referred to provide the background of the study. Important information for the research background includes the transmission feature of the COVID-19, the situation of the pandemic development and the general impact on the passenger aviation industry.

Given the background of the research, the literature review will depict the air transport context during the COVID-19 pandemic. Context aspects that are influenced by the COVID-19 pandemic which could also influence the air travel behaviour will be identified. The identification of changes in transport context will enable this study to link them to possible air travel behaviour changes. Again, since it is a novel research topic, information retrieve will not only be based on academic publications. News, editorials, white papers and organization reports could also be referred to provide the up to date information. The information about the societal impact of the pandemic, air travel choices and human behaviours under the risky situation will be retrieved.

2.2. Stated choice experiment

As mentioned in Chapter 1, after conducting the literature review, there will be two travel choice behaviours studied further by this thesis. Which are willingness to fly and flight choice behaviour. As a Discrete Choice Approach, Stated Choice experiment has two important advantages to study these two individual choice behaviours. First, it assumes that people make decision between mutually exclusive alternatives. In other words, if an individual chooses one option, then he automatically gives up the other option. This feature makes it widely applied for researches in the transport sector (Koppelman, 2007) and therefore, suitable for studying the above two air travel choice behaviours. Another advantage of it is that it has ability to create multiple different but specific environment for each choice-making situation. The environment is influenced by a number of factors such as individuals' socioeconomic characteristics, attributes of the alternative and the circumstances that characterise the context under which the choice is made. This feature enables to better disaggregate different choice behaviour and to observe their preferences according to their motives and characteristics (Aloulou, 2018). Therefore, Stated Choice experiment is applied to study the two air travel choices that are focused by this thesis.

The experiment will be loaded on website via Qualtrics, an online questionnaire design and distribution platform developed by SAP. This platform can easily accommodate different formats of stated choice experiment question. The distribution of the questionnaire will rely on social media and social networking softwares including WhatsApp, Facebook and LinkedIn. The selection of participants should comply with the design of the choice context, which is defined in Sub-Chapter 6.3. According to the design, respondents should be to a certain extent familiar with the European air travel environment including currency, customs and etcetera. Therefore, respondents who live or used to live in Europe are ideal for the participation. On the other hand, because the questionnaire will be presented in English, respondents should have sufficient language capability to be able to read, comprehend and respond to the questions. According to the design of the experiment details introduced in Chapter 6, the target number of participants is set at around 100. The experiment construction will rely on NGene, a software which can create orthogonal design for the stated choice experiment. The data analysing tool will be Excel conducting linear regression analysis because of its easiness to use, and Biogeme, which is a powerful and opensource package for analysing stated choice data.

2.2.1 Experiment setup

In the stated choice experiment, respondents will face different choice questions and indicate their preferred choices including whether they want to fly and which flight alternatives they prefer to take if they fly. The performance of flight alternatives will be described by a number of attributes that define how good an alternative is from different aspects. There choices between different alternatives show what kinds of preference they have and how they make trade-off across the attributes. Their choices will be made under different pandemic situations which allows the choice behaviours under different pandemic context to be compared. The difference can be concluded as the influence of the pandemic on air travel behaviour.

2.2.2 Experiment structure

As briefly introduced in Chapter 1, air travel convenience and health safety are two important attributes playing roles in air transport during the COVID-19 pandemic. Unlike other attributes that can be easily quantified and included in the stated choice experiment, these two attributes can be only perceived subjectively by respondents. Therefore, a method should be found to scale them and to acquire their value which allows them to be compared and traded-off with other flight attributes.

One existing method that has been successfully implemented by a previous research (Molin et al., 2017) can be used to achieve this goal. Such method was inspired by the concept of Hierarchical Information Integration (HII) invented by Louviere (1984). In their theory, it was argued that multiple attributes that cannot be overseen by the decision-makers could be grouped and presented in the stated choice experiments in order to avoid presenting too many attributes in the choice question to prevent overwhelming the respondents. In their research that studies the importance of flight safety to flight choice behaviour, it has been argued that people's flight safety perception is influenced by many sub-factors in terms of airline safety index, type of carrier, whether the flight fly over water and etcetera. Therefore, in order to test how people trade-off flight attributes including flight safety, they conducted a perception experiment. This experiment presents objective safety performance of a flight that is described by the combination of above sub-factors. Based on this, participants were asked to rate flight safety performance. This step is finished with the help of stated choice approach and enables them to get the scale of passengers' risk perception.

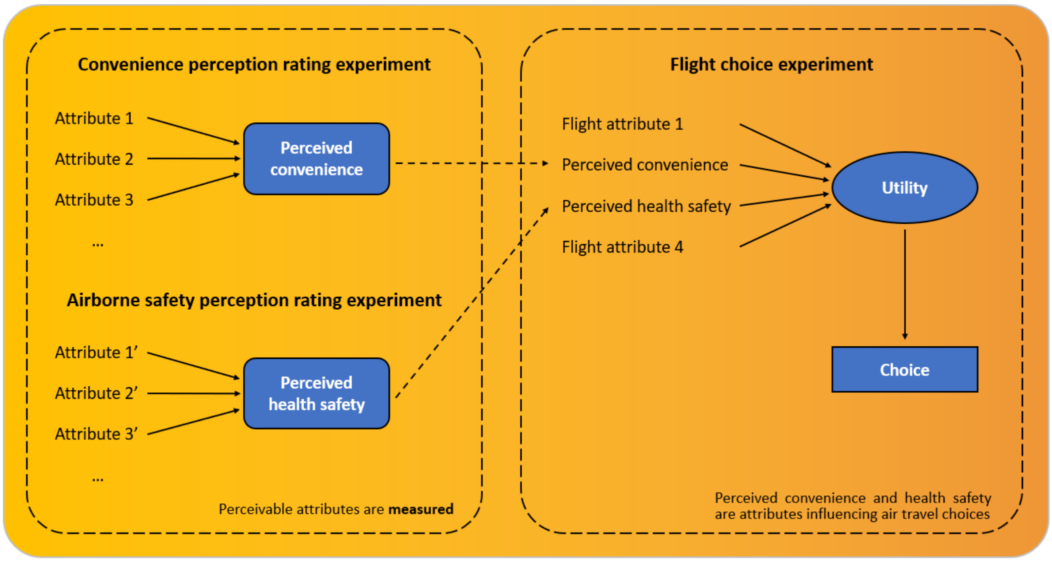


Figure 3 – Graphical display of two levels of experiment

In this thesis, the above method is adopted to overcome the issue of incorporating perceived attributes into stated choice experiment. This means, two perception experiments are conducted in order to obtain the scale and attribute value of perceived travel convenience and perceived airborne health safety. According to the main idea of HII, factors that could influence these two attributes should be grouped and presented as the sub-attributes in the perception rating sub-experiment. This rating sub-experiment is one-level-lower than the stated choice experiment. Two experiments will be bridged by the presenting of perceived attributes in the main stated choice experiment. The setup of the two experiments is presented in the Figure 3.

In the perception rating sub-experiment, taking the travel convenience for an example, respondents will be asked to evaluate different flights based on how convenient they feel. They give the answers by scoring them on a rating scale. The convenience level of a flight is described by sub-attributes that are influential on people's perception of travel convenience. These sub-attributes are inspired by the literature review in Chapter 4 and stated specifically in Chapter 6. This sub-experiment enables the further study about the attribute trade-off in the stated choice experiment.

In the stated flight choice experiment, respondents will be asked to give their choice between flight alternatives and to indicate their willingness to fly. The alternatives are described by attributes including air travel convenience perception and the airborne health safety perception. The attributes other than the mentioned two will be also discussed in Chapter 4 and given specifically in Chapter 6. This stated choice experiment reveals the influence of the COVID-19 pandemic on flight choice behaviour and willingness to fly.

2.2.3 Data analysis

After collecting the data via the stated choice experiment, the data analysis will be carried out. Because of the different characteristics of the data provided by two different experiments, two data analysis methods will be respectively applied. For the perception rating sub-experiment, Linear Regression analysis is chosen, which will be discussed in Sub-Section 2.2.3.1. For the stated flight choice experiment, the Discrete Choice Approach is used, which will be discussed in Sub-Section 2.2.3.2.

2.2.3.1 Perception rating sub-experiment data analysis

For the perception rating sub-experiment, the decision is made to apply linear regression models to analyse respondent's perception of travel convenience and airborne health safety based on the rates they give.

It could be argued that respondents' rate should be seen as an ordinal scale. Therefore, interpolation is not possible between rate values. Thus, linear regression becomes unapplicable. However, in order to be consistent with this setup, perceived attributes in flight choice experiment should also be regarded as a set of dummy variables. In this case, it would not allow interpolation for unselected intermediate values. Since this thesis wants to achieve interpolation so that perceived attribute levels can be compared, it is assumed that the scaling of perceived attributes is of interval measurement. This allows estimating linear parameters for perception attributes.

Since it is assumed that there is a linear relationship between the dependent variables, which are the perceived air travel convenience and the airborne health safety, and the independent variables, which are sub-attributes that determine the perception of the attribute performance, the relationships can be described by the formula below:

$$Y_i = C + \sum (B_i * X_i)$$

Where Y_i stands for the rate given by the respondents for the perceived attribute performance, C stands for the regression constant and B_i stands for the coefficient for each dependent variable X_i which represent the status of the sub-attributes.

2.2.3.2 Stated flight choice experiment data analysis

For analysing the stated choice data, the Discrete Choice Approach is applied, which consists of different elements including decision rule, choice model, statistical estimation method.

Decision rule

Decision Rule is the criteria that respondents rely on to determine the best choice out from the given alternatives. In this research, the Random Utility Maximization (RUM) theory introduced by Manski (1977) will be applied. It assumes that people face a set of alternatives and choose the one that has the highest utility. The utility of the alternatives is determined by the performance of several attributes. An advantage of this theory is that it contains probabilistic dimensions to reflect the respondent heterogeneity and the uncertainties which result in choice behaviour that the observed decision rule could not explain. For example, in reality, the alternatives that appear to be the best is not always chosen. Such uncertainties in choice process can be expressed by the random element in the utility function. The utility of alternative i can be expressed by the function listed below:

$$U_i = V_i + \varepsilon_i = \Sigma_m \beta_m \cdot x_{im} + \varepsilon_i$$

Where U_i represent the total perceived utility as the sum of V_i representing the systematic utility including everything that can be related to observed factors and ε_i representing everything unknown to analyst which includes unobserved attributes and randomness in choices. Systematic utility V_i is described by a function $f(\beta_m, x_{im})$, where β_m is a vector of parameters describing decision-makers' taste of attributes and x_{im} stand for a vector of performance of attribute m for alternative i.

Because decision-makers are assumed to make their choice based on the performance of utility of alternatives in a choice set and the alternative with the highest utility is chosen, the probability that alternative i in a choice set C_n is chosen can be described by the function below:

$$P(i|C_n) = P[U_{in} \geq U_{jn}, \forall\, j \in C_n]$$

Choice model

In the discrete choice modelling, a choice model is needed to associate the random utility of an alternative to the actual probability of it to be chosen. In this research, Multinomial Logit (MNL) model and Mixed Logit (ML) model are applied to do so.

The choice probabilities of alternative i in a choice set C_n can be given by the MNL model (Hausman & McFadden, 1984):

$$P(i|C_n) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}}$$

MNL model is one of the most widely used model to explain and to estimate individuals' discrete travel choices (Wardman, 1991). However, MNL model has some limitations. For example, it ignores the unobserved heterogeneity in terms of mode preference and attribute taste and the stability of preference held by the same individual giving multiple choices.

The Mixed Logit (ML) model is a more advanced alternative of MNL model that takes the individual heterogeneity and choice consistency into account (McFadden & Train, 2000). Instead of seeing β_i as a fixed value by MNL model, ML model adds the random part to it which allows the taste of attribute or preference of alternative to vary among individaul. This is consistent with the reality where preference and taste depend on different people. Mixed Logit model could also deal with panel data which means it does not view each choice independent. Alternatively, it take the correlation between choices made by the same individual into account to improve the model fit, which is closer to the choice behaviour in the real-world.

The way that ML model deals with the penal effect can be described by the likelihood function presented below while applying Likelihood maximization theory.

$$Likelihood = \int_{v_n,\beta_n} \left(\prod_{t=1}^{T} (P_{ni}^t | v_n, \beta_n) \cdot f(v_n, \beta_n) \right) dv_n d\beta_n$$

In this research, both MNL model and ML model are applied for flight choice modelling. Because MNL model is efficient and easy to estimate, it will be firstly used to acquire the significant parameters in a time-saving manner. Then the ML model will be implemented, because its advancement in incorporating individual heterogeneity and dealing with panel effects. The use of the ML model is for the potential model fit improvement.

Statistical estimation method

Choice modelling involves the process of statistical estimation of parameter. One of the most widely used method for doing it is maximum likelihood which invented by Ronald Fisher.

The computation of likelihood for choice modelling is done in the following way. Based on the proposed parameter, the probability of choosing the option that is actually chosen by the respondent will be calculated. The likelihood equals to the product of probabilities of all observed choices. The mathematical representation of this computation is shown below, where $y(i) = 1$ when alternative i is chosen, 0 otherwise.

$$L(B) = \prod n \prod i \, P_n(i|\beta)^{y_n(i)}$$

Since the probability is lower than one, therefore, a number of choices result in a low likelihood value which is close to 0. The solution is to use log of likelihood which achieves maximum at same value of beta. The mathematic formulation is given below:

$$LL(B) = \ln(\prod n \prod i \, P_n(i|\beta)^{y_n(i)}) = \sum n \sum i \, y_n(i) \cdot \ln(P_n(i|\beta))$$

By the conversion of the above formula, the estimation of β becomes the question of finding a set of β that could maximize the Log-Likelihood function presented above.

In this research, the parameter estimation for the flight choice model will be finished with the help of Biogeme freeware that implements likelihood maximization principle using iterative finding method (Bierlaire, 2003).

3 Industry fragility and COVID-19

In this chapter, the research background including the fragility of the airline industry and the impact of COVID-19 are elaborated. One can grasp a better understanding of the possible influences that a global incident could have on industry development and air travel behaviour. The background information about the COVID-19 is introduced with its general impacts on the industry. Through this chapter, the necessity of studying passengers' air travel behaviour changes during the COVID-19 pandemic is implied.

3.1. Impacts of global incidents on air transport

The airline industry is vulnerable to global incidents and has always been threatened by emergency context throughout history. Such emergencies and incidents are various in terms of armed conflict, terrorist attack, political unrest, economic recession, global pandemic and etcetera. These incidents generate uncertainties and bring a lot of impact on the industry and society. In this case, airlines are forced to take countermeasures including downsizing schedule, unloading asset, furloughing crews and retrenching budget which often results in industry downturns (Sobieralski, 2020). For example, as the consequence of economic recession combined with the Gulf War in the early 1990s, the industry was heavily impacted and a 10 billion US dollar loss in the air transport industry worldwide was caused (Cappelli, 1995).

Such industry downturns often lay as the result of a decrease in air travel demand. In the situation with uncertainties, concerns and worries raised among air travellers. This often leads to a significant deterioration in their willingness to fly. Therefore, less travel demand is generated. A decreased demand results in overcapacity in the market. In such a case, price declines as airlines are struggling to fill seats and to retain the load rate. Therefore, the yield, the difference between the cost per available seat mile and revenue per available seat mile, of airlines becomes marginal (Rhoades, 2009). This makes airlines more difficult to maintain and operate.

The 9/11 incident, the terrorist attack that occurred in The United States in 2001, provides an example to understand the negative impacts of global incidents on air travel demand. Although temporarily, the terrorist attack in New York and Washington caused a complete shut-down of the national commercial aviation system. This created a short-term but massively strong setback on airline operation (Guzhva & Pagiavlas, 2004). The attack not only forced many travellers to reduce or avoid air travel because of a newly perceived risk associated with it but also caused many companies to put a temporary freeze on business trip plans (Goodrich, 2002). Despite the fact that the immediate shock of September 11 is largely dissipated after 5 months, the attack created aftershocks imposing a more lasting impact on the demand for airline services.

It was suggested that this incident resulted in both a negative transitory shock of over 30% and a long-term negative demand influence amounting to roughly 7.4% of pre-September 11 demand in the US (Ito & Lee, 2005). The impacts of 9/11 overshadowed the travel demand in the U.S. for nearly 3 years. Until July 2004, the American air transport industry finally surpasses the pre 9/11 level of the number of passengers carried (United States Department of Transportation, 2017).

In order to understand the long-term shock of the 9/11 event on the air transport industry, scientists took different perspectives to research travel behavioural factors laying behind the lasting low demand. One study ascribes this shock to the accumulation of travel anxiety due to terrorism's impact on the safety perception of air travellers (Baker, 2014). This phenomenon was particularly observed in the tourism industry. In consequence, trip makers' choice behaviour changed in choosing transportation modes and determining travel destinations. The public fear of being hijacked and attacked is attributed as the main reasons for such change. In order to improve the safety perception of air passengers, deploying more security facilities and implementing more security measures were adopted as a solution. However, redundant security measures made travelling by air more time-consuming and far less convenient than before. A further study notes that the implementation of such security equipment in the US's busiest airport could lead to 9% of air travel demand decrease (Blalock et al., 2007). Such an effect is especially noticeable on the demand for short-haul trips. For example, the number of passengers for the trip distance shorter than 250 miles was 26.2% fewer in June 2003 than in June 2001 (Ito & Lee, 2005).

A more detailed travel intention study (Floyd et.al, 2004) in the aftermath of the 9/11 event also adds up to understand the lasting low travel demand. The research presented more evidence to prove the negative impact of the attack on people's risk perception and linked it up to passengers' travel behaviour. It was found out that people's intention of making a flight trip for leisure purpose in 12 months after the 9/11 event was related to safety concerns, perceived social risk, travel experience and income level. The research team suggested that there is a strong correlation between high safety concerns and low trave intention. In other words, individuals who prioritize safety show less interest in travelling by plane after the attack. Secondly, social risk, represented by the disapproval of vacation plans by family and friends was also associated with a lower likelihood of taking a leisure trip after the attack. Other factors like air travel experience and income of passengers lay as positive contributors to the high intention of flying. Through their study, it has been highlighted the connection between global incidents and passengers' change in travel behaviour (in terms of the intention of travel by planes in this case).

Through the example of the 9/11 event, a conclusion could be drawn that global incident could bring changes to many different aspects in regards to the transport sector and profoundly influence people's air travel behaviour. The changes can be reflected by people's travel choice and their willingness to make a flight trip. These effects could last for several seasons that seriously interfere the development of the airline industry.

3.2. COVID-19 pandemic and airline industry

In December 2019 in Wuhan, China, an infectious disease (lately named as COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first identified, which caused an acute wave of transmission over China. The virus was later discovered in many other countries and kept active and spread globally resulting in the ongoing COVID-19 pandemic worldwide. As of 27 November 2020, more than 61.1 million cases have been reported across 191 countries or regions, resulting in more than 1,435,000 death (Johns Hopkins University, 2020).

The spread of COVID-19 forced governments to implement containment measures and took mitigation actions. The most common responses to COVID-19 include case-tracking, self-isolation and compulsory quarantine. In the meantime, public health prevention measures in terms of hands-washing, social distancing and wearing mouth caps were encouraged in many countries (Bedford et.al, 2020).

On the other hand, regarded as one of the major ways that catalyses the spread of the disease (Lau et al., 2020), international traveling has been discouraged by many governments in terms of The United States, The United Kingdoms and European Union (US CDC, 2020), (GOV.UK, 2020), (European Commission, 2020). Such discouragement through travel recommendation is sometimes followed by stricter measures if the result is not effective enough (Bamberg et.al, 2011). For example, many countries and regions have imposed compulsory quarantine, COVID test or other forms of prevention on travellers entering their border to reduce the possibility of importing COVID-19 cases. Moreover, despite World Health Organization's concern of that suspension of international trade and travel could severely restrict the movement of medical experts and supplies (Devi, 2020), travel restriction, border closure and airways shut-down were put into effect in some countries, especially in which are most affected by COVID-19. (Schwartz, 2020).

Not only regarded as a major way to spread COVID-19 internationally, travelling by planes during the pandemic is also seen as a risk of passenger infection. COVID-19 spreads between people via a number of means when an infected person is in close contact with other healthy people (WHO, 2020). WHO suggested that COVID-19 not only transmits through small liquid particles (which vary in size from larger respiratory droplets to smaller aerosols) when virus carriers cough, sneeze, speak, sing or breathe heavily, but also infect other people through objects when they touch the surfaces which are contaminated by COVID-19 then contact their eyes, noses or mouths without having cleaned their hands first.

Air travel requires spending time in queues at airport terminals. It also exposes one to the crowd in a close distance while boarding and deboarding the plane, which increases the chance of being in close contact with other people. Therefore, air travel increases the risk of transmission between people. In the case of cabin transmission, according to US CDC (2020), most viruses and other germs do not spread easily on flights because of the special design of air circulation, ventilation and filtering system in airplanes. However, the challenges come from the difficulty of keeping social distancing rules onboard, as passengers may have to sit near others closely sometimes for hours, which may increase the risk of exposing to the virus that causes COVID-19.

Flight volume in multiple regions was observed to drop after the deterioration of pandemic situation (Ovask et al., 2021). For example, despite that air traffic in China was increased by around 5% in January compared to year 2019, after the lockdown of Wuhan with follow-up travel restriction taken by other regions within the country, it dropped sharply by 80% by the mid of February. In the Middle East, the traffic volume began falling rapidly two days before the US governmental restricted travel from Iran. The similar trend was also observed in European countries when Italian government executed the lockdown in cities most hit by the virus on 2nd of March, air traffic volume began falling to only 10% of the number of 2019. From the global perspective, the falling of flight movement is also consistent with the transmission trend of the pandemic, with the international flights being most impacted. To be more specific, the number of flight reduction was firstly observed in Asia, which is followed by Europe, North America and Latin America after. As of May 4, 2020, there was an 80% decrease in international flight across the board. According to the relatively up to date data from Flightradar24 (2021), The world commercial (Figure 4) air traffic which is reflected by the number of flights (including passenger flights, cargo flights, charter flights and business jet flights) was hugely decreased after March 2020 and maintained lower than 60% of the level of the same period last year.

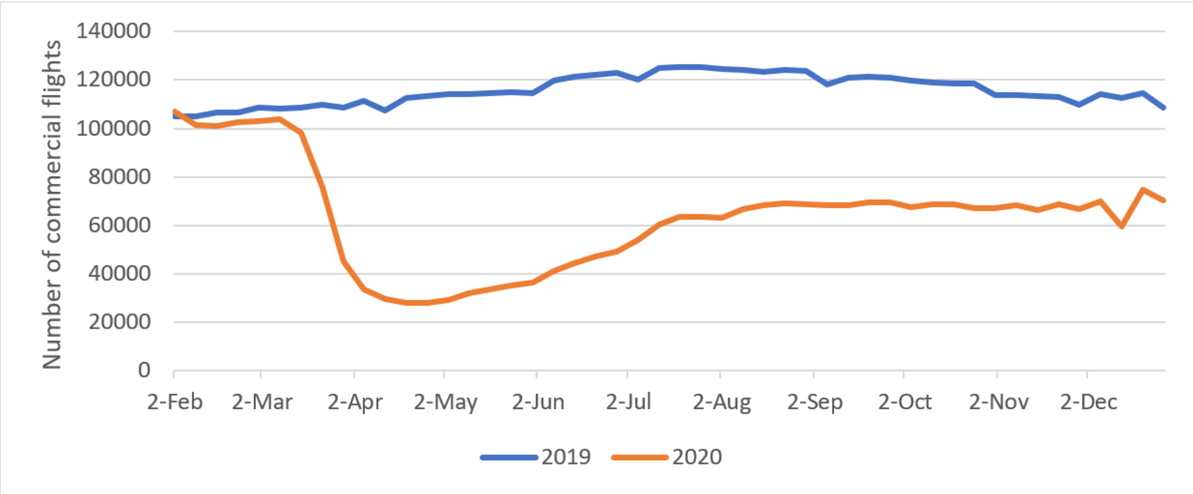


Figure 4 – Commercial air traffic worldwide in 2020 (Flightradar24, 2021)

3.3. Summary

The case of 9/11 attack and its impact on aviation industry shows that global incidents have ability to greatly influence the airline operation and to cause huge financial loss by causing low air travel demand. One of the reasons for the weak market demand can be ascribed to change in passenger's air travel behaviour. During the period of COVID-19 pandemic, much evidence indicates that due to the fear of the potential infection and the effect of governmental actions, the air travel demand decreased dramatically. In the light of travel behavioural changes as the consequence of previous global incidents in terms of 9/11 attack, the assumption is made that the industry downtrend that happens during the COVID-19 pandemic can be partly ascribed to changes in air travel behaviour.

4 Air travel context during the pandemic

The COVID-19 pandemic reshaped the context of air transport. The changes in some context aspects could affect people's air travel behaviour. In this chapter, this new context will be depicted by the elaboration of changes in three aspects including transport policy, public risk perception and airline operation. Their changes will be associated with the potential influence on air travel choices that travellers make.

4.1 Transport policy

Air travelling during the COVID-19 pandemic is regarded as a major way to spread the virus globally (Nakamura & Managi, 2020). Therefore, a variety of transport policies were imposed to control the traveller movement in order to slow down the pace of pandemic propagation. The purpose of those travel policies implies its possible influence on air travel behaviour, which makes it the first aspect to discuss.

4.1.1 Hard transport policy and soft transport policy

Before the study of the policy context during the COVID-19 pandemic, the classification of transport policy is discussed. Two types of transport policy are briefly introduced in this section, which are hard transport policy and soft transport policy. Because they influence public travel behaviour in different ways, understanding their differences could help to better discuss their potential effects.

The main difference between the two types of policy is the way they convey their influence. Hard transport policy focuses on the physical change of the transport capacity or feasibility. Therefore, public travel behaviour is rather directly shaped by hard policies because the transport supply is changed. However, soft transport policy focuses on using techniques of information dissemination and persuasion to influence travellers' actual behaviour (Bamberg et al., 2011). In this case, travel behaviour changes only if the people are nudged by soft transport policies. Because it is up to the people to decide whether to comply with the policy, it influences travellers in a more indirect way.

The application of hard and soft transport policy has been elaborately studied in the field of urban transport and especially on reducing the use of private cars (Friman et al. 2013). Both types of transport policy are proven to be effective to a certain extent but also have their own limitations that they cannot always be useful without the support of each other. In general, though the effectiveness of different transport policy may vary from case to case, hard transport policy is stricter and more compulsory without compromises, therefore, has a better guarantee of the policy outcome.

4.1.2 Restrictive travel policy

As of 6th April 2020, 96% of all worldwide destinations had imposed travel restrictions in response to the pandemic (UNWTO, 2020).

4.1.2.1 Types of restrictive transport policy

The forms of travel restriction are various that include many different kinds of policy and regulation. Based on the intensity of the measures, these travel restrictions can be classified into two groups (IOM, 2020):

1. **Entry Restrictions (ER)**: These are total restrictions that do not allow the entry of passengers of a given country, territory, or area (C/T/A). These include a complete border closure, nationality ban, suspension of visa issuances and suspension of flights, etcetera.
2. **Conditional Authorized Entry (CAE)**: These are partial restrictions in the form of specific requirements upon which entry is incumbent. These conditions include medical measures, new requirements on visa/travel documents or other specific requirements for entry.

Both types of restriction can be viewed as hard transport policies. According to the definition, they change the travel feasibility or capacity on a specific route or to a specific destination. This result could hamper the mobility of travellers thus directly affect their travel choices.

Entry Restriction is by far the most drastic policy measure that affects international air transport. Because, under no legitimate condition, a passenger could enter a country that has closed its border. Therefore, it results in trip cancellation without other options. On the other hand, conditional Authorized Entry (CAE), is still strict though but does allow essential travellers to keep travelling if there is a real need. However, passengers have to meet the specific requirement to be qualified for the entry. One example of the requirement is that people have to test negative to the virus. This rises the threshold of the travel by making it more complicated. This new requirement can be viewed as a form of travel cost. Because acquiring a virus test certificate could not only cost financial expenditure but also non-monetary spend in terms of time and effort.

4.1.2.2 Application of restrictive transport policy

With the development of the pandemic, the portion of adopted restrictive measures keeps evolving. By looking at Figure 5, a shifting popularity trend of restrictive measures from Entry Restriction to Conditional Authorised Entry can be observed over time (IOM, 2020). The percentage of Entry Restriction reached to its highest point in April 2020 where it accounted for more than 80% of adopted restrictive measures in response to COVID-19. However, this proportion had gradually decreased to 26% as of 21st December 2020.

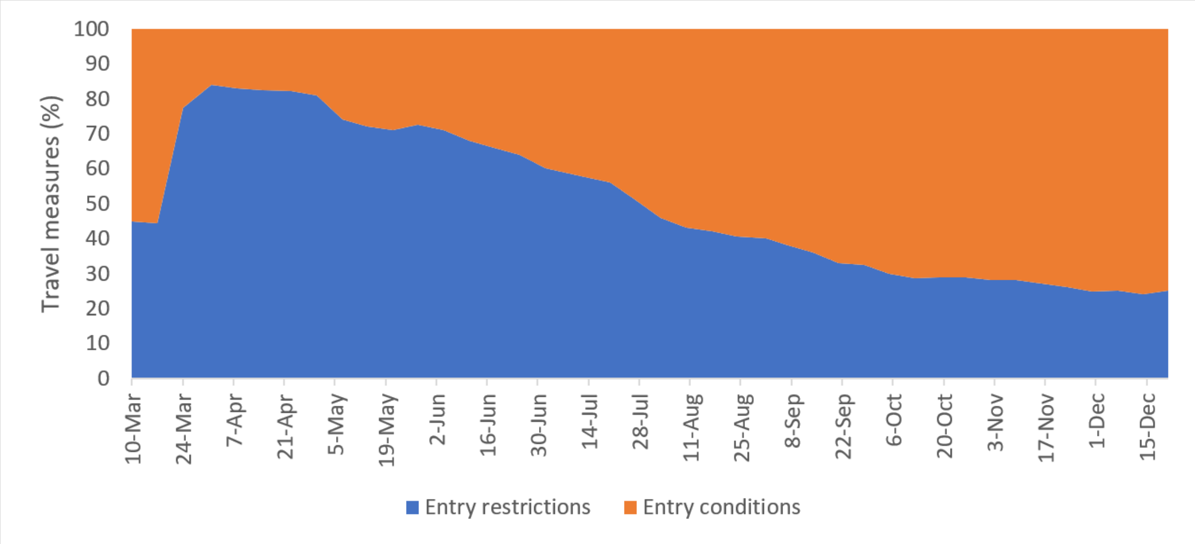


Figure 5 – Entry restrictions vs. conditions for authorized entry (IOM, 2020)

By taking a further look at the specific measures that the above proportions consist of, the most commonly imposed measures of travel restrictive policy can be found in Figure 6 which represents the situation in December 2020. Medical requirement which consists of compulsory quarantine, health statement, virus test certificate and etcetera, is the most popular policy measure followed by the destination specific entry restriction. The measure preference over time can be illustrated by Figure 7 which shows the trend of measure implementation from March 2020 to December 2020.

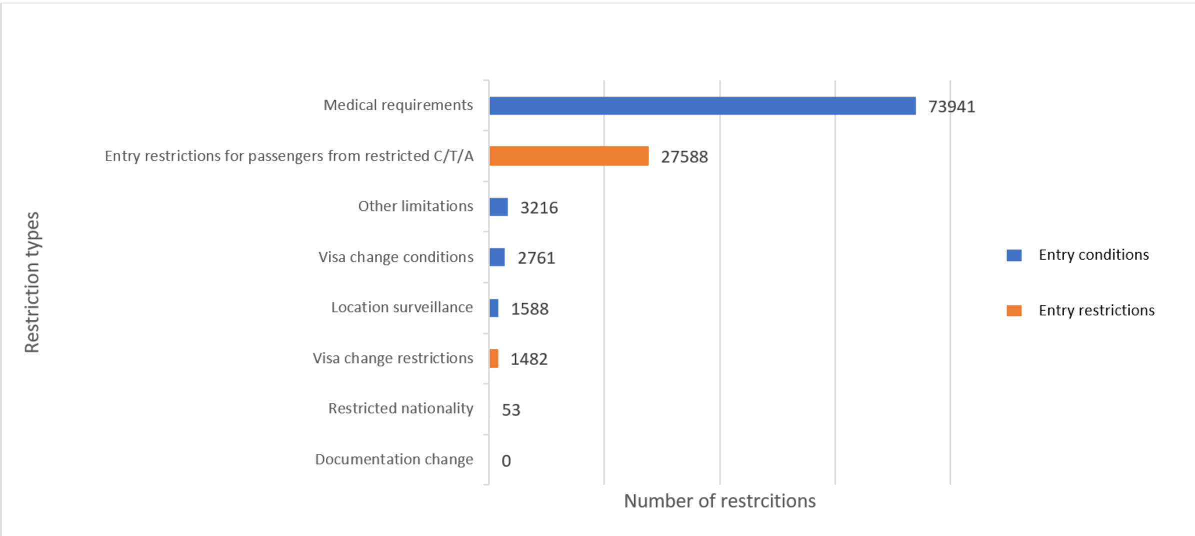


Figure 6 – Restrictions and conditions for authorized entry by popularity (IOM, 2020)

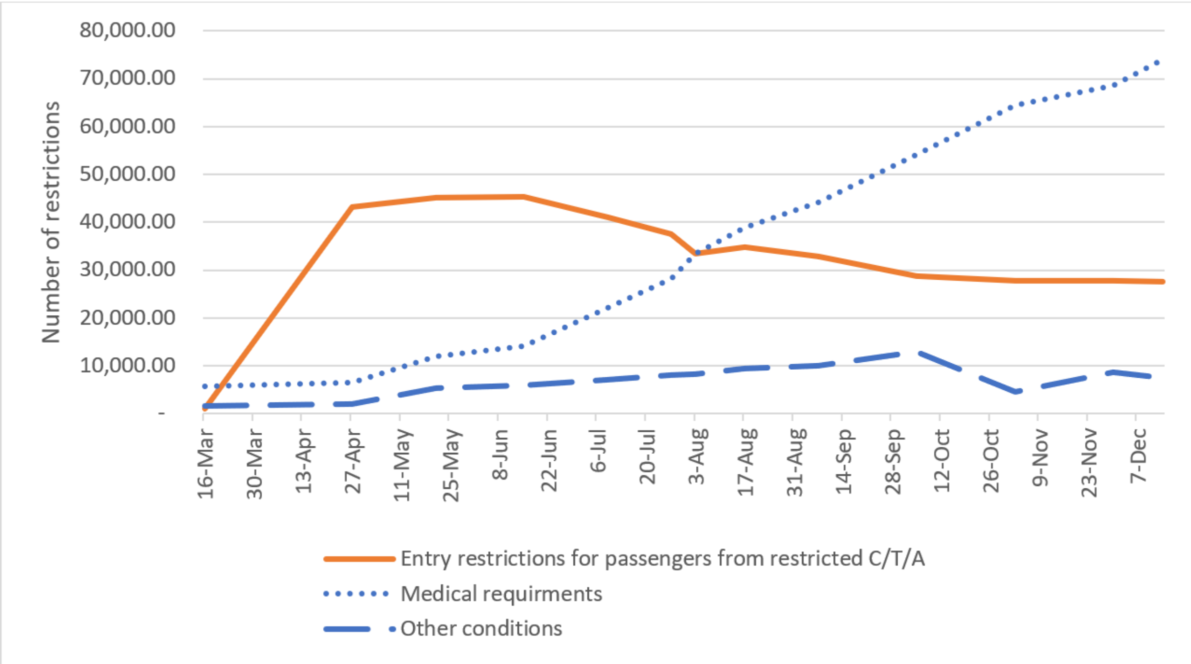


Figure 7 – Trend of restrictions and conditions for authorized entry by type (IOM, 2020)

4.1.3 Travel recommendations

Apart from the travel restrictive policy, many governments have also announced travel recommendations. According to the policy definition, travel recommendation, because it is often not compulsory, is a type of soft transport policy that deliver its effect by persuasion.

Two types of travel recommendation are often used. The first is to encourage the public to stay at home as much as possible and avoid travelling. The second is to give a specific travel recommendation for the target country based on its pandemic situation.

So far, there is no research that has been found to specifically study the effectiveness of travel recommendation specifically for the case of the COVID-19 pandemic. However, its effectiveness is debatable since some contradicting outcomes can be found in the literature studying the public attitudes towards governmental advice during the previous pandemics. During H1N1 influenza, there were two groups of people thinking differently. The first group of people expect credible virus information and reliable precaution recommendation from the government (Gray et al., 2012). However, there is also another group of people who show their scepticism towards the advice from the government and question its feasibility and appropriateness (Teasdale & Yardley, 2011). Therefore, to what extent the travel recommendation is effective might vary from case to case and depending on the real situation.

4.1.4 Impacts of transport policy on air travel behaviour

Both hard transport policy in terms of travel restriction and soft transport policy such as travel recommendation could influence actual air travel behaviour to a certain extent. As the consequence of the policy implementation during the COVID-19, trip cancellation, trip postponement and travel destination switch have a higher probability to occur.

Although soft and hard transport policies may lead to similar changes in air travel behaviour, the ways that they exert their influence are different. Restrictive travel policies take effect in a stricter way because they are compulsory and supported by rule of law. Therefore, they are uncompromisable and more effect-guaranteed. On the other hand, soft transport policies like travel recommendations are not obligatory to be complied with. Therefore, they are more unpredictable in terms of their effects on influencing travel behaviour.

Heterogeneity may exist among air travellers in regard to receiving policy impact. Travel purpose is the most important factor to influence the travel choice because it determines the necessity and urgency of the trip. Essential travellers who have unbendable travel need are unlikely to be affected by the policies. However, holiday travellers might cancel or postpone their original trip plan. What choice is also likely to be made is changing the travel destination to a low-risk country or region. The effectiveness of transport policy, especially for the travel recommendation, may also be affected by the other factors in terms of government credibility, social norm, political beliefs, public consensus, etcetera. Which influence the level of obedience and compliance that the people show to those policies.

4.2 Public risk perception & protective behaviour

Transport policies reflect the official's influence on air travel behaviour. Under its influence, people's behaviours are either forced or persuaded to change. However, the implementation of transport policy only reflects the perspective of authorities and how governments see the risk of the pandemic. What also matters is individuals' experience and perception of the risk. The risk perception of the public can be generated because of the COVID-19 which leads to spontaneous behaviour changes. This theory will be introduced in this sub-chapter.

4.2.1 Public risk perception

Human beings' risk perception can be interpreted as the ability to sense harmful environmental conditions. The process of perceiving risk involves a set of activities including information collecting, processing, analysing and interpreting (Wachinger et al., 2013). Individual's risk perception sometimes can be very subjective which often deviate from the objective situation. Because the internalization of the risk can be influenced (reinforced, modified, amplified or attenuated) by media reports, peer influences and other communication processes (Morgan et al., 2002). Apart from the societal context, the perception might also be influenced by the features of the risk itself which include the type of risk, the context of risk. Wachinger et al. (2010) also found that risk perception is also dependent on the intrinsic characteristics of the individual.

A global pandemic, because of its threat to people's health, is a clear example of risk. Factors that influence this risk perception of a pandemic are various that include the seriousness of the situation, severity of illness, potential personal impact, likelihood of infection and preparedness of the society (Prati et al., 2011). Risk perception is a basis to explain human behaviours during emergency situations. The logic behind these behaviours is the motivation to maximize the benefits while minimizing the losses (Powell, 2007). Therefore, the behaviour of the public during emergencies is often the consequence of risk perception and trade-off. Therefore, the risk perception towards the pandemic is believed to lead to a variety of spontaneous behavioural changes (Poletti et al., 2011).

4.2.2 Health-protective behaviour theory

Health-protective behaviour is a theory to explain public behaviour in response to dangerous crises, incidents or emergencies. The core mindset behind these behaviours is the intention to reduce the risk of health (Bermúdez, 1999).

Protective behaviour widely exists during a pandemic and can be classified into three types: preventive, avoidant and management of disease behaviours (Bish & Michie, 2010). Preventive behaviours consist of actions that reduce the health risk. These includes hygiene actions (in terms of hand washing, coughing or sneezing into an elbow and surface cleaning), wearing masks and uptake of vaccinations. Avoidant behaviours focus on risk avoidance. These behaviours include avoiding crowds and public space, working from home and compliance with quarantine restrictions. Management of disease behaviour includes taking antiviral medicines, seeking help from the doctors and etcetera.

Health-protective intention is found in air travellers' behaviour in responses to influenza H1N1 in 2009 (Fenichel et al., 2013). By analysing the correlation across perceived epidemic severity, actual epidemic severity and the rate that people skipped their purchased trip, it was concluded that people tended to voluntarily engage in health-protective behaviour by forgoing non-refundable flights in order to avoid the risk of infection. A research studying the behaviour changes during SARS in 2003 also shows that actions to reduce health risk in terms of wearing masks and improving hygiene level widely exist (Lau et al., 2004).

4.2.3 Impact of risk perception on air travel behaviour

The direct consequence of the increase of risk perception is triggering health-protective behaviour. Preventive and avoidant actions are two types of health-protective behaviour that potentially have a close relation to travel choice-making changes during the pandemic. Preventive behaviour is likely to happen when travellers make choice between different flight alternatives. Owing to the motive of reducing health risk, flights with better hygiene performance are more likely to be chosen. The choice of travel destination could also be changed especially for the holiday travellers. The destinations that are perceived to have higher health risk are more likely to be deserted. The choice on flight trajectory could also be changed due to this reason. The transfer airport in the country which has less severe pandemic situation has a higher probability to be chosen. As for avoidant behaviour, cancelling or postponing the trip plan are most likely to happen. Travellers with the destination that is restrained by the purpose of the trip might take avoidant behaviour if risking to fly is not worthy. Heterogeneity is also possible to be reflected by health-protective behaviours due to the different risk perception, which is influenced by many intrinsic and extrinsic factors introduced in Section 3.2.1.

4.3 Airline operation

Compared to the previous two context aspects, airline operation is more complex since it is not only influenced by the COVID-19 itself but also receives impacts from other changed aspects. Therefore, the new pattern of airline operation during the pandemic is the integrated consequence of travel policy and public risk perception. In this sub-section, the changes in airline operation and their associations to potential air travel behaviour changes are discussed.

4.3.1 Reduced capacity in response to the demand decrease

During the COVID-19 pandemic, the air travel demand was dramatically reduced. Airlines took a set of actions to tackle with the low travel demand. Albers & Rundshagen (2020) have sorted them into four categories, namely retrenchment, persevering, innovating and exit. The popular measures under each category are listed below in Table 1.

Table 1 – Airlines' response to COVID-19 crisis

Response category	Measures
Retrenchment	Fleet grounding Job cut Work pattern reduction Big airliner retirement Fleet reduction Growth strategy adjustment Service network restructure
Persevering	Searching for grants, loans or subsidies
Innovation	Reconfiguring aircraft for cargo Switching aircraft to freight operation Providing new services Joint-venture with other airlines
Exit	Cease operations Bankruptcy Court administration Exit base at specific airport Close subsidiary Giving up bid

There are three categories of countermeasures could reduce the air transport capacity supplied in the market which are retrenchment, innovation and exit. The reduce in capacity supply inevitably results in less available flight choices, restructured service network and possibly poorer connectivity between airports. This has the potential to influence the price of the ticket, the offered flight services and the proportion of non-stop flight. Passengers' travel experience, therefore, could be influenced by these effects.

4.3.2 Health safety improvement

As introduced in Chapter 3, airplane cabin is considered as a dangerous place that the COVID-19 virus can easily spread. Therefore, in order to reduce transmission risk, not only many airlines implemented a set of precautionary measures, but international organizations also involved in the standard establishment.

International Civil Aviation Organization (ICAO) has issued Council Aviation Recovery Taskforce(CART) in order to guild the industry to restart the international air transport. CART provides practical and aligned guidance to airline operators and helps them to safely and sustainably operate during the COVID-19 pandemic. In their guidance, some safety improvement recommendations are provided (ICAO, 2020):

- Boarding and disembarking passengers should be conducted in ways that reduce the likelihood of passengers passing in close proximity to each other.
- Seats should be assigned for adequate physical distancing between passengers.

- The activities that could incur unnecessary interaction between human should be temporarily suspended or minimized.
- Non-essential in-flight supplies such as blanket and pillows should be reduced to minimize the risk of cross-infection.
- Passengers should use the designated lavatory that is assigned based on the seat assignment to limit passenger movement and reduce the risk of cross-infection.
- Crews should be well protected by safety equipment.

International Air Transport Association (IATA) also gives advice to air passengers when they travel by plane during the COVID-19 pandemic (IATA, 2020a). It emphasises that wearing a mask when travelling by air is mandatory as its ability to protect both people who wear the mask and people sitting around. It also suggests that air passengers should avoid unnecessary movement during the flight and wash or sanitize hands frequently etcetera.

These health safety measures are important to both airlines and passengers. Therefore, almost every airline adopted a set of precautionary measures to protect crews and customers. Many airlines also made their adopted measures transparent to customers in order to gain the trust of passengers. Flight ticket sales platforms in terms of Skyscanner also introduced third party health safety evaluation organization to report safety index and health measures information for every flight.

The improvement of health safety measures and their transparency on flights reflects the special need of air passengers during the pandemic. It implies the change in travellers' attitude towards health safety. The importance of health safety has likely been increased, therefore, could be reflected by air travellers' flying choice behaviour.

4.3.3 Air travel inconvenience

Travel inconvenience is largely increased during the pandemic. Due to the introduced health screening process in many airports, the actual waiting time is likely to be increased. Preventive measures that have been adopted also increase the complexity of travelling. Schiphol Airport (2020) introduced a policy that passengers have to acquire a health statement granted by general practitioners in order to check-in, which increases the inconvenience of air travel preparation. On the other hand, as introduced earlier, many airlines have grounded redundant airplanes and adjust their service network. This could cause fewer flight options and reduce the connectivity between airports via non-stop flights.

Travel inconvenience could reflect on many aspects during the COVID-19 pandemic. The examples include less flight options, extra time-consuming travel processes, complicated documentations, poorer direct flight connection, etcetera. Under the light of the case of the 9/11 incident that travel convenience can profoundly influence air travel behaviour and air travel demand. The travel inconvenience during the COVID-19 pandemic is, therefore, assumed to impact travellers' choices. The study that researches the air passenger behaviour during the COVID-19 pandemic confirmed that many factors that raised air travel complexity to influence the decision of passengers on whether fly or not during the pandemic (Song & Choi, 2020).

4.3.4 Airfare

This section will study the impact of the COVID-19 pandemic on airfare. Several factors that play roles in influencing the price of the flight tickets will be discussed.

The first to consider is the supply and demand of the air travel services. It has been introduced that air transport capacity is dramatically reduced because of the low service demand. This leads to the lower supply in the market. However, just because of the reduce in air transport supply does not necessarily mean that the air travel service is now undersupplied because the demand also dropped. Passenger Load Factor (PLF) provides a good indicator to search for the answer. PLF represents the extent to which the plane of airline is filled with passengers in the average level. The PLF trend (Statista, 2021a) in 2020 presented in Figure 8 below shows that the average PLF in Europe is reduced since January from 82.7% to 27.7% as of April. Although it bounced back to 57.1% in the August and then dropped again to 45.6% by November 2020, the overall level of it still remains low compared to the data in 2019, which was 85.7% (EuroControl, 2019). The low PLF indicates that even if airlines took actions to cut off redundant capacity to match the demand, airlines still cannot attract enough passengers to take flight during the pandemic. In this since, the airfare should not have been raised.

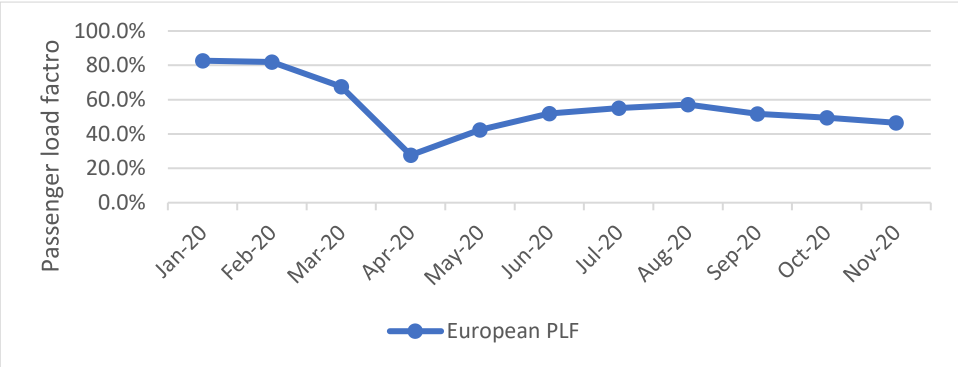


Figure 8 – Passenger load factor of Europe in 2020 (Statista, 2021)

Second, the fuel is cheaper in 2020. Average annual Brent crude oil price shows that the price of crude oil in 2020 has dropped by 36.2% from 64.3 USD to 41.01 USD (Statista, 2021b). Considering the fact that jet fuel typically accounts for 15% of an airlines' operating expenses (Morrell & Swan, 2006), the saving on fuel gives airlines more chance to reduce price. Secondly, the retrenchment has helped airlines to be more lean.

Third, the job cut and reduction in work pattern reduce the airlines' cost. But the airplanes that have been grounded need maintenance, which likely compensate the saving from other aspects.

Forth, the hygiene improvement brings airlines with more cost to spend. Because of the risk of infection onboard, airlines adopted better health protection as introduced above. The purchase and implementation of these equipment could be translated to the ticket price. Also, some authorities depending on the regions have introduced regulation that limit the maximum load rate of the plane in order to guarantee the social distancing onboard. This could also reduce airlines' profit and give them reasons to raise price.

Last but not least, in order to attract passenger, some airlines eliminate the flight change fee. This fee used to be a big part of profit source that airlines rely on. According to the data from the U.S. Department of Transportation (2019), flight change fee brought in more than 2.8 billion to U.S carriers in 2019. This part of loss could be charged in other ways from passengers.

By this time, there is no published paper studying the change in the price of flight ticket during the pandemic. Looking at the reports from news agencies, some evidence shows that the ticket price during the pandemic has gone lower (Pitrelli, 2020). Domestic flights within the U.S. are 41% lower on average. The same trend was observed on international flights from the U.S., which was 35% cheaper.

4.3.5 Impact of airline operation on air travel behaviour

The responses of airline operation to the COVID-19 pandemic affect the transport services provided in the market. In this section, reduced capacity, improved health safety measures, less convenient flying experience and cheaper travel fare are identified to appear during the COVID-19 pandemic. These changes have high probability to influence air travel behaviour. Two travel choice behaviours are assumed to receive the impact, which are willingness to fly and flight choice behaviour. The heterogeneity of travellers' travel preference affects the level of influence.

5 Conceptual framework & research scoping

5.1 Conceptual model of COVID-19's impact

In Chapter 4, the changes in three context aspects under the influence of the COVID-19 pandemic are discussed. These context aspects are highly related to air travelling and expected to influence several air travel choices during the pandemic. In this sub-chapter, a conceptual model is constructed to illustrate the mechanism of the COVID-19 pandemic influencing air travel behaviour, which is illustrated in Figure 9 below:

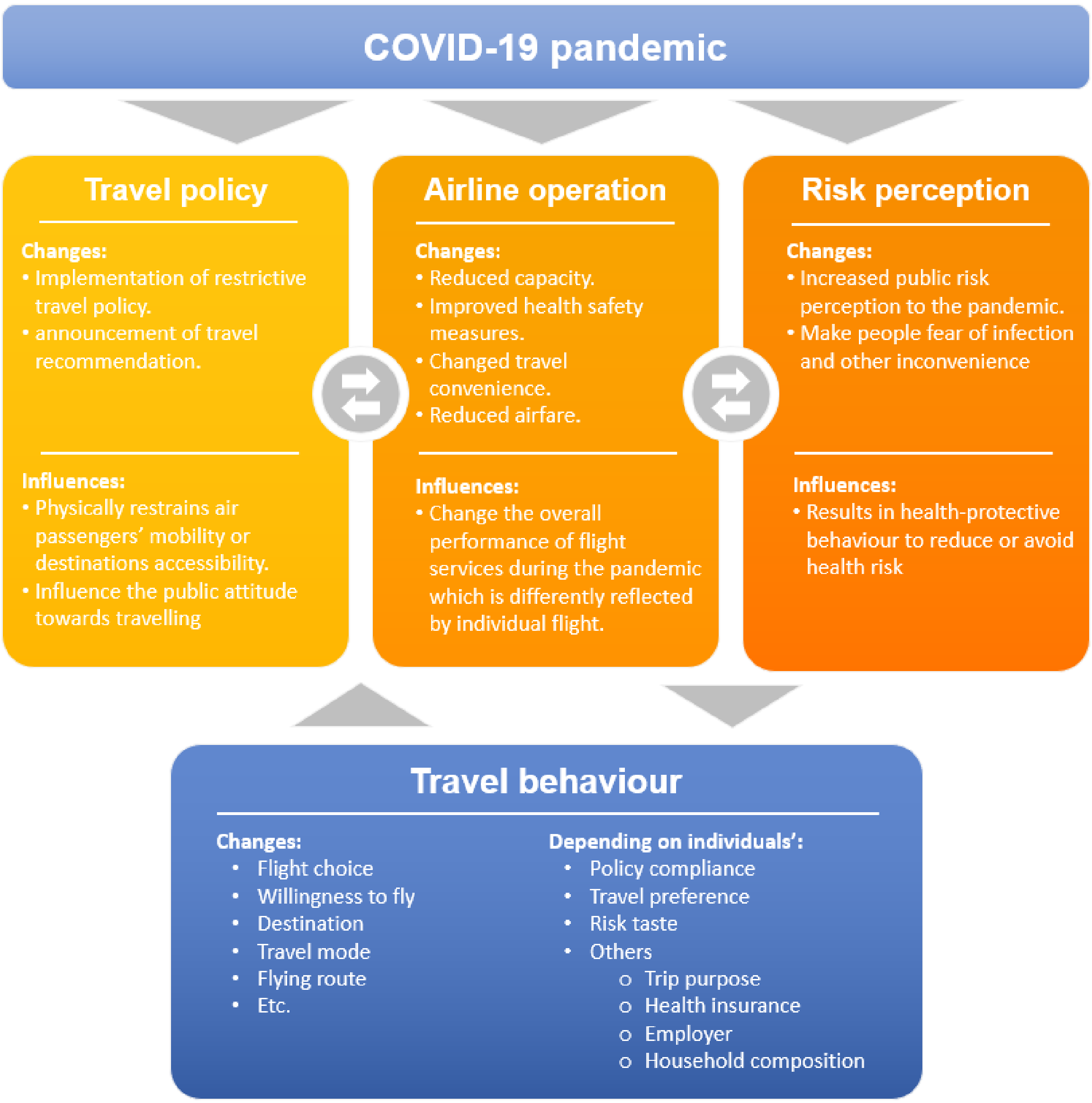


Figure 9 – Conceptual framework of COVID-19's impact on air travel behaviour

This conceptual model assumes that the changes in air travel behaviour are not directly caused by the virus or the pandemic themselves. Instead, it is the pandemic that reshapes the air travel context which consequently changes the travel choice behaviours. In this model, three context aspects are identified to impact air travel behaviour during the pandemic. They are travel policy, airline operation and public risk perception.

Firstly, the changes in travel policy are reflected by the implementation of travel restrictions and travel recommendations. Travel restrictions change the accessibility of destination by fully or conditionally banning the entrance of the travellers. This makes air travel impossible or less convenient and largely restrains air travellers' mobility. On the other hand, travel recommendations influence travellers' attitude towards flying during the pandemic. They are persuaded to voluntarily engage in travel avoidance. Because of these new policies, a higher rate of travel cancellation and postponement can be expected. On the other hand, because of the border closure, some travellers might also adjust their destination and flying route.

The second changed context aspect is the public's risk perception. The COVID-19 is a big threat to public health. By processing pandemic-related information, risk perception is created which results in health-protective behaviours. These behaviours include avoidance of air travelling. This results in a low willingness to fly. Risk-reduction behaviour could also occur, which leads to changes in the choice of flights, destinations, travel modes, flying routes and etcetera.

Thirdly, airline operation is influenced by the COVID-19 pandemic. The reflections include reduced transport capacity, improved in-flight virus preventive measures, less convenient air travel services and generally lower price of flight tickets. These changes could result in different flight services provide in the market. Therefore, some air travel choices might be affected in terms of flight choice, willingness to fly, travel mode choice and etcetera.

It is also worth mentioning that there are interactions across three identified context aspects and actual travel behaviour. For example, because of the imposition of new air travel policies the operation of airlines is impacted. Some airways are forced to shut down because of the border closure. On the other hand, travel policy reflects the seriousness of the pandemic situation. Therefore, it can be taken by the public to judge the current risk level to create the perception of it. The risk perception of the public is also taken by the airline industry to improve their service owing to the objective to ease and attract the customer. Finally, actual air travel behaviour creates the feedback loop which influences the intensity of the travel policy and the action of airlines.

The influence of context changes on air travel behaviour is unlikely to be equally received by different individuals. For example, factors that influence an individual's policy compliance could affect to what extent the travel recommendation works on him or her. Travel preferences can change the influences of different flight attributes on air travellers' choice-making. The difference in people's risk taste could result in different levels of risk perception and therefore, different responses reflected by the health-protective behaviour. There are some other factors, in terms of trip purpose, individual's health insurance, employment situation and policy and household composition and family situation, to potentially influence the air travel behaviour.

5.2 Experiment scope

The conceptual framework summarizes several travel choices that could be affected by the changes in context during the COVID-19 pandemic. This sub-chapter narrows down the research scope onto two travel choices for the stated choice experiment that is carried out by this thesis further.

Firstly studied, is people's choice behaviour regarding whether making a flight trip during the COVID-19 pandemic. In Sub-chapter 4.1, it has been discussed that air travel is not recommended by the government and sometimes prohibited by strict measures that close the border for entries. The general willingness to fly could be affected by it. In the discussion of Sub-chapter 4.2, the willingness to fly is also affected by their risk perception which resulted in protective behaviour including risk avoidance. Sub-chapter 4.3 provides evidence that airline operation is changed by the COVID-19 pandemic. The changes in provided flight services could either positively or negatively influence air passengers' willingness to fly. Considering the benefit of studying willingness to fly for both governments and airlines, the impact of the COVID-19 pandemic on the choice between flying or not is scoped in the remainder of this thesis.

Secondly studied, is the choice that air travellers make between flight alternatives. As discussed in Sub-chapter 4.3, the COVID-19 pandemic strongly influenced the way that airlines operate. Many processes and details of air travelling have been changed. On the other hand, with the increase of the public's risk perception, the preferences of flight alternatives are assumed to evolve. Some assumptions about changes in flight choice behaviour are made including increased weight for travel safety and convenience of a flight, less importance of ticket price and etcetera. Studying flight choice behaviour during the pandemic could provide insights to airlines on improving their operating strategy during the pandemic. Therefore, it is chosen for further research in this thesis.

6 Stated choice experiment design

The details in the design of the stated choice experiment will be elaborated in this chapter. The selection of the attributes is firstly introduced in Sub-Chapter 6.1 followed by Sub-Chapter 6.2 specifying the attribute levels. Then, the decision-making context is defined in Sub-Chapter 6.3. Then, the specification of choice alternatives will be given thereafter in Sub-Chapter 6.4. Sub-Chapter 6.5 defines the choice set by specifying how many alternatives should be included in each choice task. Once all the design aspects are carefully defined, the experiment is constructed with the help of NGene which is introduced in Sub-Chapter 6.6. The questionnaire formulation is presented in Sub-Chapter 6.7.

6.1. Attribute selection

6.1.1 Context attribute: COVID-19 seriousness

As discussed in Chapter 4, the COVID-19 pandemic triggers the public's risk perception which results in health-protective behaviour. This could be reflected by the changes in air travel choices made by people. The seriousness of the pandemic is considered an important factor to influence this process. Therefore, it is important to add it as a context attribute to test its influence on the degree of the impact on choice-making.

The seriousness of the pandemic can be described in different ways. Therefore, it should be determined in which way the pandemic seriousness should be presented in the stated choice experiment. The popular forms of description of pandemic seriousness can be sorted into three categories: numerical, visual and verbal:

- Numerical
    - Aggregated number of cases: The number of cases tested positive throughout history. It takes people who have already been healed into account. Therefore, it does not reflect the current situation.
    - Current positive cases: The number of cases tested positive at this moment. It reflects the current seriousness of the pandemic. But it requires that respondents are well informed. Being informed is dependent on the available information itself, and the interest of the respondent in it.
    - Newly report number of cases: The number of cases tested positive in a certain period in the past. It provides the latest trend of the pandemic. However, it has the same problem as current positive cases.
    - Total positive cases per a number of population: It gives the positive number per a number of people which helps to avoid potential recognition bias from different size of countries in terms of population. However, the number of

population unity is not unified in practice which might cause confusion or misunderstanding among different people.

- visual
    - Colour presentation: It is widely used in COVID-19 dashboards combined with numerical representation. The different seriousness levels are distinguished by different colours.
    - Bubble shape presentation: it has also been used of bubble map to represent the seriousness of the pandemic. In this form, the size of the bubbles (circles) reflects the infection number. The bigger the circle is, the more cases there are in a country or region.
- Verbal
    - Verbal description is the most widely used. It directly describes the situation of the pandemic in words often as the interpretation of numerical indicators.

The numerical description is not adopted as the method to describe the pandemic seriousness because of two reasons. Firstly, though numerical data is widely used, different governments have their own preference and selection which results in the different interpretation ability of the people across nationalities because of the difference in familiarity. Secondly, this difference could also come from the level of interest of an individual in the development of the pandemic. In order to avoid different perceptions of the same seriousness description, this familiarity difference to numerical data should be avoided.

In this research, the decision is made to implement the verbal description to describe the seriousness of the pandemic. Verbal description avoids the issue of different interpretations of numerical indicators because of different educational background. For those who have difficulties judging the seriousness of the situation based on numbers, verbal description directly gives the answer. By applying this method, respondents stand on the same page for the choice experiment.

On the other hand, the perception of colour is proven to have a strong connection to the psychological functioning of humans (Elliot & Maier, 2014). Differentiation with colours is not only used in retailing industry to influence customers' purchase behaviour (Labrecque & Milne, 2012), but also able to shape people's risk perception (Leonard, 1999) and thus to influence their decision-making (Williams & Noyes, 2007). Therefore, adding the colour difference in the font of verbal description could not only help people to identify different risk level, but could also reduce misreading due to unexpected carelessness.

6.1.2 Flight attributes

Before the selection of the attributes, it is important to determine the number of attributes that shall be selected. In Caussade et al.'s research (2005), It has been concluded that the number of attributes could affect the complexity of the experiment. With the increase of the number of attributes, the reliability of trade-off information is likely to decrease, resulting in higher error variance. Because Caussade et al.'s research shows the statistical significance of the estimations starts to decrease when the number of attributes goes more than 5. Therefore, the number of attributes is determined to be lower than 5.

In Chapter 4, the changes in airline operation during the COVID-19 pandemic has been discussed. What has been mostly impacted are flight cost, service network of airlines, travel convenience of passengers and the infection risk onboard. Therefore, the attribute selection should be able to reflect these factors in order to test the impacts of their changes on passengers' choice behaviour.

Firstly, flight cost can be easily represented by the monetary price of the flight ticket. Secondly, the changed air route network affects the connectivity between airports. Therefore, the number of transfers can describe this change. Thirdly, the effect of travel convenience and safety level onboard are more abstract and therefore hard to be describe by objective attributes. Therefore, they will be presented as perceived attributes, which are perceived travel convenience and perceived airborne health safety.

In the bullet points below, the importance of each selected attributes to air travel choice behaviour is briefly discussed:

- **Ticket price**: According to the findings in Chapter 4, the flight ticket price showed a downtrend during the pandemic. On the other hand, it is added by almost every travel choice study because of its importance. As the basic consumer psychology suggests, customers intend to buy the best product at the lowest price. Therefore, travel cost is one of the most important attributes to consider for a flight choice between alternatives. It also allows to compare the importance between the flight attributes by converting the importance of the attributes into monetary price.
- **Transfer and travel time**: They are also important for an air travel choice as non-monetary costs, effort and time. For most of the travellers, a travel choice with a lower travel time or less transfers is preferred. Note that despite of separated as two attributes and used to describe different performance aspect of a flight, the number of transfers and the travel time are in reality strongly correlated. Most of the time, the more transfers a flight has, the longer total travel time it has. Therefore, the number of transfers and total travel time will have full correlation in the experiment to comply with the real-world situation.
- **Perceived travel convenience**: as introduced in Chapter 4, COVID-19 pandemic bring more uncertainties which could make air travelling less convenient. Therefore, this attribute is assumed to have an important role to affect passenger's flight choice and willingness to fly.
- **Perceived airborne health safety**: This attribute is selected for three reasons introduced in the literature review. First, it is an fact that COVID-19 can be spread onboard. Second, a large number of people are afraid of getting infected by the virus. Third, airlines implement a variety of precautionary measures to convince people that flying is still safe.

6.1.3 Sub-attributes for the perceived attribute rating sub-experiments

Based on the HII theory introduced in Chapter 2, the perception of travel convenience and airborne safety are determined by a number of sub-attributes influencing them. Therefore, in this section, these attributes are identified.

6.1.3.1 Travel convenience and flexibility

Travel convenience is a rather broad word which can be understood in different ways. Therefore, the interpretation of such term varies within different contexts. For example, urban public transportation researches (Al Mamun & Lownes, 2011) & (Murray & Wu, 2003) often refer travel convenience to accessibility and efficiency of the public transit network. In the field of passenger air transport, convenience can be linked to responsiveness of flight attendants to passenger's demand, which influence passenger's satisfaction (Clemes et al., 2008). In another air transport research, convenience was used to refer to the performance of flight schedule which is influenced by flight schedule time (departure and arrival) and schedule delay (Proussaloglou & Koppelman, 1999). In the post 9/11 era, the decrease of travel demand was attributed to the complicated security check which reduce the travel convenience (Blalock et al., 2007). On the other hand, it is also possible that passengers consider the combination of travel time, number of transfer and the complexity of ticket booking process as a form of convenience (Athiyaman, 2002). In conclusion, there is not a universal standard to understand travel convenience in travel behaviour studies. Therefore, it should be clearly defined and explained before presenting to the respondents.

In this research, the term travel convenience refers to the amount of effort that is spent on preparing the flight trip. As introduced in Chapter 4, some governments and airlines implement new rules for air travel that sometimes request passengers to present a health statement or a negative virus test result before the check-in or entering the border. These two measures are intuitively assumed to negatively impact travel convenience since the extra effort and expenditures are needed to acquire them.

Another aspect that this research intends to incorporate is travel flexibility improvement that is done by airlines during the COVID-19 pandemic. Free flight cancellation policy and money refund policies are commonly adopted by airlines to improve travel convenience. Such measures could ease people's concerns about uncertainties during the pandemic. When people can easily cancel their trip if the pandemic situation gets worse or travel becomes impossible for some reasons, people feel less worried about the uncertainties and therefore more willing to travel.

In summary, 4 factors will be added in the perceived travel safety sub-experiment to test how travel convenience is evaluated by potential air passengers. They are: the requirement of a health statement issued by a general practitioner, the requirement of a negative virus test result, whether the flight cancellation or change is free of charge, whether the refund is in cash or vouchers in case of flight cancelled.

6.1.3.2 Airborne health safety and risk

As introduced in Chapter 3 about the transmission characteristics of COVID-19, the virus could be spread in the airplane cabin. Therefore, people's safety perception can be influenced by the possible transmission while travelling by planes. In this case, the virus-related precautionary measures are considered to be the major way to relief this concern and make people to feel safer.

During the pandemic, many different virus preventive measures are taken by airlines. But as discussed earlier, too many attributes could overwhelm the respondents and facilitate experiment-taking fatigue. In order to avoid this issue, the same way as how it was done for the flight choice experiment, the number of measures to be presented in the perceived airborne health safety sub-experiment should be limited, which is again set to a maximum of 5.

The selected measures are discussed below:

- Sequential boarding and deboarding: Passengers sequentially board in accordance with their seat location from the tail to the front. In this way, the human contact can be avoided maximally. This measure was firstly adopted by airlines in The US (Frost, 2020). This method is proven to improve onboard safety (Milne et al., 2020).
- Face masks mandatory: The mandatory mask-wearing rule is one of the most common measures that is imposed to deal with COVID-19 in many occasions. Because it is implemented globally, it has good public acceptance. Therefore, it is also put into effect by almost every airline worldwide. In some countries, not doing so is a legal offense (IATA, 2020b).
- Flight crews wearing protective equipment: Attendants serve passengers during their work. Therefore, having a great amount of human contact for them is unavoidable. Having flight crews wearing mask, gloves, visors and etcetera. helps passengers to feel safer.
- Disinfection supplies offered: Disinfecting supplies including disinfectant or cleaning wipes are often provided in the public space. Using them could disinfect passengers, especially their hands in case they touch other organs like nose or eyes which can lead to the infection.
- Empty neighbour seats: Because of the fact that COVID-19 transmission is often caused due to the close human contact. Some airlines implemented empty neighbour seats rule to retain the social distance. For single-aisle aircraft (Such as Boeing 737 series and Airbus A320 series), the middle seats are blocked so that no passengers could be allocated directly next to each other. A research concluded that blocking the middle seat could help to reduce infection rate by 40% (Barnett, 2020).

6.1.4 Structure of the experiment and attributes

After the introduction of the attribute selection, according to the experiment structure introduced in Chapter 2, all attributes presented in the stated choice experiment can be seen in Figure 10 below:

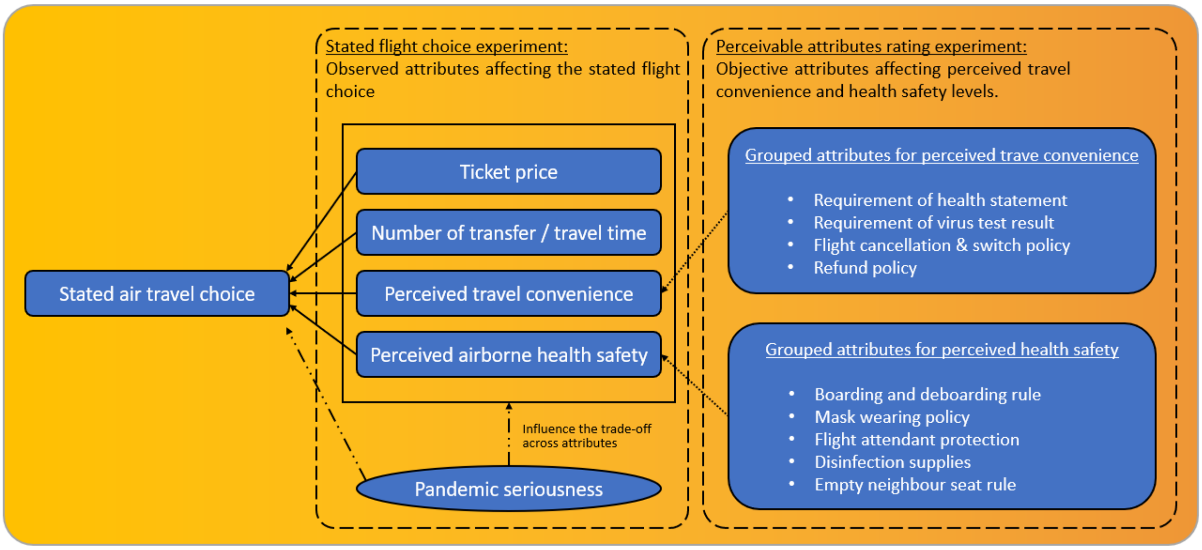


Figure 10 - Attributes inclusion of experiments and structure

The stated choice experiment consists of two levels of experiments. In the first level, stated flight choice experiment tests respondents' attribute preference for choosing preferred flight alternatives and deciding whether they want to fly. The attributes that are used to describe the performance of the flight alternative are flight ticket price, the number of transfers / total travel time, perceived travel convenience and perceived airborne health safety. Besides, pandemic seriousness is treated as the context attribute which influences the trade-off between flight attributes and therefore, the final choice. In the second level, two perception rating sub-experiments are carried out to scale the perceived attributes of travel convenience and health safety under the pandemic condition. The factors influencing perceived travel convenience are requirements of health statement and virus test result, charge policy to flight cancellation and refund policy. The attributes influencing perceived airborne health safety are boarding & disembark rule, face mask obligation, flight attendant protection, disinfection supplies and empty neighbour seat rule. Two levels of experiments are bridged by presenting perceived attributes in the stated choice experiment, where the choice between flight alternatives and flying and not flying are observed.

6.2 Attribute levels & respondent background characteristics

Attribute levels are the values that each attribute can vary from. Different levels of attribute describe the performance of an alternative in a specific aspect which can be evaluated by the respondents for giving choices.

There are several criteria that should be relied on in the design of attribute levels. The first is avoiding unnecessary increase of experiment complexity (Caussade et al., 2005). The way to do so is having as fewer attribute levels as possible, while still clearly distinguishing differences between alternatives. The second criteria is maximizing the attribute level range while keeping the levels realistic. On one hand, having a wide range of attribute levels could improve the result reliability by downsizing standard errors of parameters. Besides, a relatively extreme selection of the levels can make sure that other possible selections fall in between. Therefore, extrapolation is avoided because it is less reliable than interpolation., On the other hand, having an over-widened range of attribute level could result in unrealistic choice alternative causing unreliable results. Thirdly, having more than 2 attribute levels enables linearity test of utility contribution per unit. Finally, the difference between the nearby levels should be remained the same to guarantee the equidistance in attribute levels. This is another prerequisite for analysing linearity that is mentioned earlier.

As recommended, 3-levels attribute is a good balance which not only avoids overcomplicating the experiment design, but also allows to test the linearity of utility contributions of different attribute levels. In the following sub-sections, the level design for each attribute in the flight choice experiment and perception rating sub-experiments is specified.

6.2.1 Context attribute level

It has been decided to have 3 levels for the context attribute varying in pandemic seriousness. The level for this attribute is presented in Table 2. The elaboration of reasons that the levels are selected can be found in Appendix D.

Table 2 – Attribute level specification for pandemic seriousness

Attribute	**Levels**

Pandemic seriousness	Serious pandemic: In Europe, the virus is wide-spread and most countries are labelled in red. Cautious pandemic: In Europe, the virus starts to quickly spread and most countries are labelled in yellow. Post-COVID: The virus has largely disappeared in Europe. Only a few countries are labelled in green holding a few cases.

6.2.2 Flight attribute levels

The attribute levels for the stated choice experiment can be found in Table 3. An elaborated explanation on the reasons that attribute levels are selected can be found in Appendix D:

Table 3 – Attribute level specification for stated flight choice experiment

Attribute	Levels
Ticket price	60€ 120€ 180€
Number of transfers	0 1 2
Travel time	3 hours 5 hours 7 hours
Perceived convenience	1 out of 5 (low convenience) 3 out of 5 (medium convenience) 5 out of 5 (high convenience)
Perceived safety	1 out of 5 (high risk) 3 out of 5 (medium risk) 5 out of 5 (low risk)

6.2.3 Perceived travel convenience attribute levels

Compared with the 3-level design of flight choice experiment, two-level design will be implemented for sub-attributes influencing travel convenience in the perception rating sub-experiment. The attribute levels can be found in Table 4 below. The elaboration of the reasons that the levels are selected can be found in Appendix D.

Table 4 – Attribute level specification for perceived travel convenience experiment

Attribute	Levels
Health statement	Required: Passenger has to present a health statement issued by a general practitioner. Inessential: Health statement issued by a general practitioner is not needed.
Virus test result	Required: Passenger has to present a negative virus result. Inessential: A negative virus result is not needed.
Trip cancellation & switching	Free: Passengers can cancel or change their flight without incurring any fee. Priced: Flight cancellation and switching is not free.
Refund method	Vouchers: Passengers get their refund in vouchers. Money: Passengers get their refund in money.

6.2.4 *Perceived airborne health safety attribute levels*

Same as the attribute level design for the perceived air travel convenience rating sub-experiment, the number of levels per sub-attribute influencing health safety is set to two. Attributes and respective levels for perceived airborne health safety are presented in Table 5 below:

Table 5 – Attribute level specification for perceived health safety experiment

Attribute	Levels
Sequential boarding and deboarding	Applied: Passengers sequentially board and deboard in accordance with seat location. Unapplied: Passengers board and deboard without following any rule.
Face masks mandatory	Applied: Passengers must wear mask onboard. Unapplied: Passengers has right to decide to wear a mask or not.
Protected flight attendants	Applied: Flight attendants are fully protected by virus prevention equipment. Unapplied: Flight attendants do not take precautionary measures.
Disinfection supplies offered	Applied: Disinfection supplies are freely provided. Unapplied: Disinfection supplies are not available on board.
Empty neighbour seats	Applied: The seat next to passengers are blocked. Unapplied: The seat next to passengers can be filled with other passengers.

6.2.5 *Sociodemographic and flying preference characteristics*

The sociodemographic characteristics and flying preference of an individual can also influence the perception of travel convenience and health safety. Therefore, respondents will be asked to share this type of information as the background attributes by answering some questions. Privacy of the survey participant is foremost important. Therefore, the option that gives respondents right to preserve the privacy that they do not feel comfortable to share will be given. Such information includes gender, education and household income. The selected background attributes and their attribute levels are presented in Table 6.

Table 6 – Attribute level specification for background characteristics

Attribute	Levels
Age	Free to input the year of birth
Gender	• Male • Female • Prefer not to say
Education	• Primary school, secondary school • High school, college, professional education • Under graduate degree, BSc • Graduate degree, MA, MSc • PhD or above • Others • Prefer not to say
Household income	• Ranging from 0€-10.000€ to over 100.000€ in steps of 10.000€ • Prefer not to say
Accommodation member	Whether share the accommodation with people in following age categories: • Children (0-12 years) • Adolescences (13-18 years) • Young adults (19-39 years) • Middle-aged adults (40-59 years)

	• Senior adults (60 years and above)
Flying frequency	• Less than once per year • Once per year • 2 to 3 times per year • 3 to 5 times per year • More than 5 times per year
Date of last time flying	Free to input the date of the last-time flying

6.3 Decision-making context

Decision-making context is the environment under which the travel choices are made. It is an important element for a stated choice experiment because the choice is made under a hypothetical circumstance. Therefore, the choice question should be clearly defined with sufficient information describing the choice-making context. So that respondents' stated choices can to the most degree comply with the choices that would have been made in the real world. In this section, the context of the flight choice experiment will be discussed and determined.

Firstly, in the stated flight choice experiment, respondents will be asked to choose their preferred flight alternative for a trip between two European airports. The reason to restrict it to Europe is due to the background of the respondent group that this thesis collects the data from. The selection of the sample is explained in Chapter 2. Secondly, no specific pair of origin and destination airports will be given in this experiment because different familiarity levels can be held by respondents to the chosen pair. Therefore, respondents will be asked to choose the flight alternative for an imaginary trip between two places. Thirdly, in order to eliminate the difference in distance between the imaginary airports came up by different respondents, they will be asked to assume that the trip takes exactly 3 hours of flying in the case of direct connection without a transfer. 3-hours-flying distance should leave almost every two popular European airports within the range. Another reason for this determination is that this distance of air travel eliminates other transportation modes as an available alternative. This helps with the result of willingness to fly question (introduced in Section 6.6.3). Because in this case, if people decide to not to fly, it means they give up the travel plan rather than seeking for other transport alternatives. Fourthly, a trip purpose should also be given for the experiment because it affects how people make trade-off. For example, if an individual travels for a business trip, they normally do not care about price because it is paid by their employers. In this experiment, respondents are asked to assume they travel for a personal reason. Lastly, since the purpose of the research is to study the air travel behaviour during the pandemic. In addition, it has been concluded in Section 6.1.1 that the seriousness of the pandemic is an important factor that could influence flight preference of passengers and their willingness to fly. Therefore, the seriousness of the pandemic should also be added in the description of choice question as a context. Respondents will be asked to make their flight choice under different pandemic situations.

6.4 Alternative

Alternative is the option that the respondents make the choice for. For this research, alternatives are flights. In this section, the basis about the flight alternative in the stated choice experiment is defined.

Firstly, the categories of alternative in stated choice experiment are introduced. In a standard stated choice experiment, choice alternative can be classified into two categories: labelled and unlabelled. The criteria for discriminating them is to see whether the name of an alternative represents a particular characteristic that the other alternatives do not have. It is called labelled if the name of the alternative implies difference in characteristics. In a flight choice experiment, the name of the airline can carry some special features. For example, Ryanair represents as a Low-cost carrier, therefore, should be viewed as a labelled alternative. The difference in characteristics is often expressed by alternative specific attributes or constant in the utility model.

In this study, each alternative represents a single ticket of a 3-hours-flight between a pair of origin and destination that respondents have in mind. All alternatives are unlabelled, meaning that the difference between alternative can only be described by differences in attributes. Therefore, no other potential differences out of given attributes need to be considered. The reason for choosing unlabelled alternative is given as followed. Unlabelled alternative could avoid respondents' bias by just looking at the name or type of the airline. People could attach the characteristics of high risk or high flight cancellation fee to low-cost carrier like Ryanair or EasyJet. This situation should be avoided because there is no sufficient evidence to prove the connections.

6.5 Choice set

A choice set is the set of alternatives that the respondents make the choice from. In this section, the number of the alternatives that are included in each choice set is determined.

There are different factors to influence this decision. First, the number of alternatives in each choice set affects the amount of information that each choice question contains. In theory, the more alternatives, the more trade-off information that is included. In the statistical analysis, the trade-off information is used to estimate the parameters. High information load per question reduces the number of the choice questions that are needed. Second, from the realism perspective, when the respondents make travel choice in the the same way as they do in the real-world, the quality of the choice experiment shall be improved. Therefore, if the alternative in the choice set cannot realistically reflect respondents' experience in the real world, realism might be lost (Rose & Hersher, 2006). In the real-world flight choice, air travellers face a great number of flight options for the given route. Therefore, from the realism perspective, the number of alternatives should be sufficient to reflect the abundant flight options in the market. However, many researches also suggest that respondents lose the consistency of the choice-making criteria when the number of alternatives increases (DeShazo & Fermo, 2002; Arentze et al. 2003). Although, statistically, the increase of the number of alternatives decreases the variance at first and then increases it after reaching a threshold number (Blokland, 2008). DeShazo and Fermo argued that with more information provided, the variance with which individuals make their choices increases.

In summary, although less alternatives means more choice questions, it shall not be a problem as long as the number of choice questions is still acceptable and not making the survey difficult to finish. Therefore, the decision should be made between consistency and realism. In this case, it is decided that consistency is more important than reflecting the real-word as much as possible. Because the trade-off consistency affects the reliability of the parameter estimations. Therefore, in this research, the number of alternatives in each choice set is determined to be two. From the respondent's perspective, with 2 alternatives presented in each choice question, one can easily evaluate both options and give their preferred answer.

6.6 Experiment construction

After the detailed setup of the stated choice experiment, the NGene software (ChoiceMetrics, 2012) is used to generate the experimental designs. Stated choice experiment should be efficient and easy to follow, thus respondent fatigue as a factor (Hess, Hensher & Daly, 2012) should be put into the design. That is, if a questionnaire contains too many questions, respondents could feel overwhelmed by the information which leads to either they quitting the survey or randomly giving the answers. Both of consequences are negative to the research because the former leads to less valid responses and the latter provides unreliable data.

It has been suggested that the web-loaded questionnaire is better with a length between 10 to 20 mins (Revilla & Ochoa, 2017). Each question of perceived attribute rating sub-experiment is considered to take averagely 20 seconds. Flight choice questions are more complicated, therefore take longer up to 30 seconds. After reserving enough of time (10 mins) for answering background questions and reading the task requirements, the ideal number of questions per participant has been decided to be around 12-18 rating (6-9 per sub-experiment since there are two perceived attributes) and 8 to 10 flight choice questions. If the required number of tasks is higher than this, then the experiment should be split into several blocks that are stochastically distributed to the participants in an even way.

Ngene software allows to create an orthogonal fractional factorial design which is what this research requires. An orthogonal design makes sure that attributes are uncorrelated. This helps to reduce the standard errors and to improve reliability of the estimations. A fractional design helps to reduce the number of choice set. This can relieve respondent fatigue by reducing the number of tasks. What can be also benefited is the number of respondents needed in case the experiment blocking is needed. On the other hand, Ngene can also make sure that attribute level balanced, which means each attribute level appear an equal number of times. This guarantees the same observations of each attribute level which results in an equal probability of the estimations to become statistically significant.

In the following sections, the construction of the experiment design for both perception rating sub-experiment (Section 6.6.1.) and the flight choice experiment (Section 6.6.2.) will be introduced. The design of the questions to study the willingness to fly (Section 6.6.3.) will also be worked out.

6.6.1 Perception rating sub-experiment construction

The travel convenience experiment consists of four 2-level attributes. In order to estimate the parameters, the minimum number of degrees of freedom that is required is 5. However, 5 choice sets cannot be attribute level balanced. Therefore, the minimum 6 choice sets is needed. Nevertheless, Ngene is not able to allocate a orthogonal design in 6 choice sets, therefore the 8 choice set design is chosen.

As for the airborne health safety experiment, it consists of five 2-level attributes. The minimal requirement of degree of freedom is 6. Ngene is able to find a orthogonal design by allocating alternatives in 8 choice sets while maintain the attribute levels balanced.

A larger design shall be needed if it is aimed to study both main effects and interaction effects of the attributes. For simplicity reasons, only the main effects will be studied. The Ngene code syntax that is used to construct both sub-experiment designs can be found in Appendix B. The generated design can be found in Table 7 and Table 8 below:

Table 7 – Travel convenience perception sub-experiment orthogonal design

Sub-attribute statuses	1	2	3	4	5	6	7	8
Health statement:	0	1	1	0	0	1	1	0
Negative virus test result:	0	0	0	1	0	1	1	1
Trip cancellation:	0	0	1	0	1	0	1	1
Refund method:	0	1	0	0	1	1	0	1

Table 8 – Onboard health safety perception sub-experiment orthogonal design

Sub-attribute statuses	1	2	3	4	5	6	7	8
Sequential boarding and deboarding	1	0	1	0	0	1	0	1
Wearing masks is mandatory	1	0	0	1	1	0	0	1
Flight crew wearing protective equipment	1	0	0	0	1	1	1	0
Disinfecting supplies are offered	1	0	1	1	0	0	1	0
Free seats next to you	1	1	0	1	0	1	0	0

6.6.2 Flight choice experiment construction

The flight choice experiment consists of five 3-level attributes. In order to estimate the parameters of flight attributes, minimally 6 degrees of freedom are required. Since we decided to allocate 2 alternatives to each choice set, one choice set will add one degree of freedom. Therefore, the minimal required number of choice sets is 6.

In Ngene, both sequential construction and simultaneous construction provide orthogonal design. The difference is that sequential construction creates correlations between alternatives while the simultaneous construction eliminates both within-alternative and between-alternative correlations. However, the shortcoming of simultaneous construction is creating more choice sets which needs to be avoided. Therefore, sequential construction is applied to create the design. Another reason for choosing sequential construction is that when alternatives are unlabelled, the correlation between alternative is generally less problematic.

After implementing sequential construction, an orthogonal design has been found to allocate every 2 alternatives in 9 choice sets. The Ngene code syntax that was used to construct the experiment design can be found in Appendix B. The generated choice design can be found below in Table 9.

Table 9 – Flight choice experiment orthogonal design

Choice set	alt1.fare	alt1.stopover	alt1.convenience	alt1.safety	alt2.fare	alt2.stopover	alt2.convenience	alt2.safety
1	60	0	1	1	120	2	5	1
2	180	1	3	1	120	1	1	3
3	120	2	5	1	180	2	1	5
4	120	1	1	3	60	2	3	3
5	60	2	4	3	120	0	3	5
6	180	0	5	3	60	0	1	1
7	180	2	1	5	180	1	3	1
8	120	0	3	5	60	1	5	5
9	60	1	5	5	180	0	5	3

However, 9 is not the final profile number for the flight choice experiment design. Because at this stage, the context attribute of pandemic seriousness has not been added yet. In order to test the preference difference in air travel behaviour under 3 pandemic seriousness levels, each choice set should be presented 3 times with different seriousness levels. In this case, there will be in total 27 tasks needed for the experiment. Since it has been discussed that the ideal number of flight choice tasks is 8-12, 27 profiles should be divided into 3 blocks. And each block is randomly assigned to a respondent, meaning one participant will take 9 flight choice tasks. Ngene cannot block the experiment based on context variables. Therefore, this step should be done manually.

The method to manually block the design is as follow in Table 10. There are 9 tasks assigned to a participant and 3 seriousness levels shall be filled. It results in 3 tasks under each seriousness level. A participant will take 3 tasks under each pandemic situation. Each block can be seen as a variant of the questionnaire. The blocking result for 3 variants. The number in the cell means the number of choice set generated by Ngene.

Table 10 – Flight choice experiment blocking design

scenario	variant 1	variant 2	variant 3
serious pandemic	1,2,3	7,8,9	4,5,6
cautious pandemic	4,5,6	1,2,3	7,8,9
post-COVID	7,8,9	4,5,6	1,2,3

6.6.3 Willingness to fly questions

As a sub-research-question of this thesis, willingness to fly should be studied in the stated choice experiment. An individual's willingness to fly is consider to relate to the pandemic seriousness and the attribute performance of the flight alternative, same as the flight choice behaviour. Therefore, it is a reasonable choice to study willingness to fly while flight choices being asked. There are two ways to implement this plan.

The first is to add the opt-out alternative in the choice set that allows participants to choose none of two flight alternatives. When the opt-out is chosen, respondents declare that they will not fly under the given pandemic situation and two flight choices. However, this method has a disadvantage. If there are too many respondents choose the opt out alternative, the estimation of the model can be difficult. Because the choice of the opt-out alternative does not provide trade-off information among the flight attributes. The lack of trade-off information results in high standard-errors or inability to estimate statistically significant parameters.

In order to avoid this problem, the second way, providing the option of “none of the above flights” in a separate question is adopted. In this separate question, respondents will be asking if they want to give up the trip plan given the chosen flight alternative and the pandemic situation. In other words, respondents first make the choice between two flights, then choose either travel with the flight that they prefer or cancel the air travel plan. This solution eliminates the risk of failing to estimate the parameters due of the opt-out alternative being chosen too often.

Before the analysis of the experiment result, it is impossible to predict how often will the opt-out alternatives be chosen. Therefore, the decision could only be made when the data is analysed. which means, the decision is made in Chapter 7.

6.7 Survey questionnaire formulation

In this research, the flight choice experiment consists of three different blocks. This means that there will be 3 variants of the questionnaire needed to formulate. As introduced in Chapter 2, the data collection is finished via Qualtrics. Qualtrics offers the function to stochastically distribute questionnaire variants to the respondents. It means that not only the respondents can be randomly assigned with the questionnaire variants, but also it can guarantee that variants can be equally filled by the respondents.

In this research, variants only exist in flight choice experiment while perception rating sub-experiment do not have variants. Therefore, two perception rating sub-experiments need to be added in a flight choice experiment block to form a variant. This means each respondent will be presented with a total of 16 rating tasks (for the perception sub-experiment) and 9 choice tasks.

Before taking the perception rating sub-experiment and the stated choice experiment respondents first take the flying preference questions. Apart from the questions for which respondents have to either enter the answer in the blank or choose from the given options, the attribute priority questions will also be asked in this section. There are 7 attributes in terms of the ticket price, total travel time, airline, service, type of aircraft, safety & health and convenience & flexibility to be ranked by the respondents under two different contexts which are non-pandemic and pandemic based on their importance. The socio-demographic questions will be presented at the end of the questionnaire.

In the section of the stated choice experiment, a clear instruction for the stated choice questions will be given first, followed by an example question with informative notes annotations. Every task represents one of a choice set that is in the previously shown experiment design. For both rating and choice experiment, the questions are constructed based on the tables in Sub-chapter 6.6 in which the alternatives, attributes and attributes levels are presented. For flight choice experiment, another line is added after the example question to explain the pandemic seriousness. The sample of questionnaire formulation for the perceived rating sub-experiment (without the example question) is given in Figure 11. The sample for the flight choice experiment (without the example question) and the willingness to fly question is given in Figure 12.

The following different combinations of **air travel policies** may make your trip convenient or inconvenient during the COVID-19 pandemic. Please **rate them** on **how convenient you feel** to fly under the given policies (please consider the amount of the effort you put to prepare and proceed you trip, while keeping the flexibility that the policies give to you in mind), from 1 (very inconvenient) to 5 (very convenient).

Question 1:

A **health statement** issued by a general practitioner (doctor)	Inessential
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Free
Refund method	Money

very inconvenient — very convenient

You rate: ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯ 5

Figure 11 – Example question of travel convenience perception rating sub-experiment

Imagine you are going to take a flight for a **trip within Europe** for a private reason, which's distance takes about **3 hours of flying** (direct connection). In the following 9 choice questions, you will choose the flight you prefer to make the trip, given 3 **different pandemic situations** varying in seriousness. Each choice has a different **ticket price**, number of **stopovers**, and level of **trip convenience** and **health safety**.

Scenario 1 (serious pandemic): In Europe, the virus is **wide-spread** and most countries are labelled in **red.** Given such a situation, please give your preferred flight choice for **question 1 to 3.**

Question 1 **(serious pandemic)**:

Attributes	**Option A**	**Option B**
Ticket price	€ 60	€ 120
Number of stopovers	0	2
Total travel time	3 hours (fly: 3h + transfer: 0h)	7 hours (fly: 4h + transfer: 3h)
Your convenience rating	1 out of 5	5 out of 5
Your health safety rating	1 out of 5	1 out of 5

Which flight do you prefer?
◯ Option A
◯ Option B
Would you continue to fly, if allowed to cancel the trip?
◯ Yes
◯ No

Figure 12 – Example question of flight choice experiment and willingness to fly

The full version of the questionnaire that includes perception rating sub-experiment and one of three variants of the flight choice experiment can be found in Appendix C.

7 Data analysis and results

This chapter analyses the data collected by the stated choice experiment. Firstly, the information of the data collection, the descriptive of the sample and the analysis of attribute priority ranking questions are presented in Sub-Chapter 7.1. Then, the Linear Regression model estimations for travel convenience perception and airborne health safety perception are elaborated in Sub-Chapter 7.2. The results of MNL and ML model estimations for the flight choice behaviour and willingness to fly are discussed in Sub-Chapter 7.3.

7.1. Data collection and descriptive statistics

7.1.1. sociodemographic and flying behaviour characteristics

The data collection started from 29th of November 2020 until the 8th of December 2020. In total 250 respondents participated the survey. 143 out of the 250 respondents fully finished the questionnaire. This means that 143 responses are valid for the data analysis. The descriptive statistics of respondents' background characteristics (including socio-demographic and flying preference) are presented in Table 11 below.

Table 11 – Descriptive statistics background characteristics of the sample

Sociodemographic characteristics	Categories	% of respondents (number of respondents)
Gender	Male	45% (65)
	Female	53% (76)
	Unknown	1% (2)
Age	< 18	0% (0)
	18 - 25	66% (94)
	26 -35	29% (42)
	36 - 45	3% (5)
	46 - 55	1% (1)
	> 55	1% (1)
Education	Primary school, secondary school	0% (0)
	High school, college, professional education	3% (5)
	Under graduate degree, BSc	20% (29)
	Graduate degree, MA, MSc	71% (101)
	PhD or above	4% (6)
	Others	1% (1)
	Unknown	1% (1)

Annul gross household income (€)	< 10.000	29% (41)
	10.000 - 20.000	8% (12)
	20.001 - 30.000	6% (9)
	30.001 - 40.000	10% (14)
	40.001 - 50.000	3% (5)
	50.001 - 60.000	3% (5)
	60.001 - 70.000	1% (1)
	70.001 - 80.000	3% (5)
	80.001 - 90.000	3% (4)
	90.001 - 100.000	3% (4)
	> 100.000	5% (7)
	Unknown	25% (36)
Sharing accommodation with members in age categories:	Children (0 - 12 years)	8% (12)
	Adolescences (13 - 18 years)	6% (9)
	Young adults (19 - 39 years)	60% (86)
	Middle-aged adults (40 - 59 years)	21% (30)
	Senior adults (60 years and above)	6% (9)
Flying frequency before COVID-19	Less than once per year	6% (9)
	Once per year	13% (19)
	2 to 3 times per year	36% (51)
	3 to 5 times per year	28% (40)
	More than 5 times per year	17% (24)
Whether flew during COVID-19 (after March 2020)	Yes	43% (61)
	No	57% (82)

Some characteristics of the sample have relatively even distributions in terms of gender, flying frequency, shared accommodation members and whether having flying experience during the COVID-19 pandemic. However, some characteristics show special features of the sample group. Firstly, the sample largely consists of the generation of young-adult falling into the age between 19 to 39. This could lead to some specific travel preference tendencies due to the stage of life (Davison & Ryley, 2013). Secondly, the education level of the respondents is averagely too high because the majority of them have acquired graduate degree, MSc or equivalence. The education level affects people's risk perception and potentially other travel choice behaviour in terms of the trade-off between safety and other attributes. Thirdly, the distribution of annual gross household income tends to be a bit skewed to the lower values.

7.1.2. Flight attribute Ranking

Before analysing the stated choice data, as introduced in Sub-Chapter 6.7, the importance priority of seven selected flight attributes ranked by the respondents provides the first impression of their attribute preference. The rank under the non-pandemic period is presented in Table 12 and the rank under the pandemic period is shown in Table 13.

Table 12 – Descriptive statistics of flight attributes ranking Before the COVID-19

Attribute	Frequency							Variance	Aggregation	Overall Rank	Average Rank
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7				
Ticket price	88	29	16	6	4	0	0	995.286	238	1	1.66
Total travel time	23	75	24	6	6	6	3	654.286	356	2	2.49
Airline	7	10	29	30	23	38	6	162.952	619	4	4.33
Services	0	2	17	32	51	22	19	306.952	703	6	4.92
Type of the aircraft	1	3	6	7	14	36	76	740.286	871	7	6.09
Safety & health	21	12	21	21	26	22	20	17.619	594	3	4.15
Convenience & flexibility	3	12	30	41	19	19	19	149.286	623	5	4.36

Frequency: low – high   Variance: low – high   Aggregation: low – high   Rank: high – low

Table 13 – Descriptive statistics of flights attributes ranking During the COVID-19

Attribute	Frequency							Variance	Aggregation	Overall Rank	Average Rank
	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7				
Ticket price	41	35	31	15	14	3	2	243.476	366	2	2.56
Total travel time	18	39	37	34	8	3	2	267.81	415	3	2.90
Airline	9	12	19	27	33	35	6	137.476	615	5	4.30
Services	0	1	9	17	44	45	25	352.81	762	6	5.33
Type of the aircraft	1	2	3	6	17	33	79	804.81	874	7	6.11
Safety & health	59	24	24	10	9	12	3	354.476	357	1	2.50
Convenience & flexibility	13	28	18	32	16	10	24	65.4762	559	4	3.91

Frequency: low – high   Variance: low – high   Aggregation: low – high   Rank: high – low

How to read the tables ?

The layout of above two table is as follows. Firstly, the most left column lists the attributes that respondents ranked. Secondly, frequency columns show the number of times that each attribute have been ranked in each position. With the drop of the rank, the colour turns from green to yellow and to red. Thirdly, the variance column gives the variance of rank frequency for each attribute. The darker the green is, the larger the variance is. It describes the level of deviation of the number of times each rank being given for an attribute. According to the definition of variance, the higher the variance is, the more stable a set of data is. Since the analysed objectives are frequencies that each attribute being ranked in different positions, the high variance means that the ranks are given unequally. In other words, some rank positions are frequently given to an attribute while some other ranks are probably never given to it. Therefore, if an attribute has a high variance, it means that people tend to reach an agreement of how important an attribute is. Fourthly, aggregation describes the total rank that all respondents give to an attribute. The lighter the red is, the higher rank that population gave to it. To be more specific, the number of aggregation equal to the summation of multiplication between frequency and corresponding rank. The lower the aggregation is, the higher the rank that respondents give to an attribute. Fifthly, the column of overall rank gives the rank for aggregation. Green means high rank, while yellow means low rank. The value 1 means it is the most important aspect among all flight attributes. Lastly, average rank is another form of overall rank but more precisely showing the ranking difference across attributes. The colour rule that it applies is the same as Overall Rank. It is calculated by using aggregation divided by the number of respondents. As the rule held by overall rank, the higher the average rank is, the more important the attribute will be. After explaining the contents of the tables, the results will be discussed in the next step.

The result of two ranks

Firstly, for the flight attribute rank before the COVID-19 pandemic, ticket price and total travel time are two of the most important attributes that people consider. The average ranks of these 2 attributes also indicate that people tend to reach the agreement of their importance. For both ticket price and total travel time, more than 50% respondents rank them at the first and second place. The high variances also suggest the same conclusion. Safety & health, airline and convenience & flexibility come as follow. They are ranked from 3 to 5 places. Average ranks of them tell that the importance difference among them is very small. And three of them have very low variances, meaning that respondents could hardly reach an agreement on their importance. Services and the type of the aircraft are two least important attribute and according to their variance, respondents seem to be certain about it.

Secondly, in the case of "during the COVID-19 pandemic", changes in respondents' attribute preference are observed. While ticket price and total travel time are still very important attributes for flights-taking, safety & health becomes the most important attributes among all given aspects which used to be ranked at 3rd place before the pandemic. The importance differences across these three attributes are relatively marginal. According to variance indicators, respondents relatively agree on this preference tendency. The rank of convenience & flexibility also climbs by 1 place. However, the agreement of this new importance seems hard to be reached by the respondent group since the variance of this attribute stays relatively low. Airline, service and type of the aircraft are the 3 least important attributes during the pandemic and the importance difference are quite obvious by looking at average ranks.

The comparison of two ranks

By comparing the preference differences between two situations, some interesting trends can be found which raise some expectations for the result of stated choice experiment.

First, ticket price and total travel time are important for both conditions. This finding implies that no matter what situation it is, the respondent group always care about the ticket price and travel time of a flight while they travel. Although both of them reduce in importance during the COVID-19 pandemic and the decrease of variance suggests the raise in divergence, one can expect travel time and travel cost play important role in respondent group's flight choice.

Secondly, the importance of safety & health is observed to have a big increase during the pandemic. Two evidence support this trend. While in the situation of "before the pandemic", the extremely low variance indicates that respondents can hardly reach agreement about its importance. The numbers of people who give it rank from 1st to 7th are evenly distributed. Such divergence results in relatively low overall rank. Although staying at the 3rd place, the importance differences between safety & health and other three attributes are actually very marginal. In the pandemic case, safety & health becomes the most important attribute. And the increase in variance suggests that respondents start to be certain about this preference, highlighting its potential to be an important attribute in people's flight choice behaviour.

Thirdly, although showing improvement in importance during the pandemic, variance indicators show that convenience & flexibility as a flight attribute is not always valued the same by respondents.

Fourthly, flight attributes in terms of airline, service and type of the aircraft are also listed as objectives to be ranked. The result shows their relative importance against other four attributes which are added as variables for the stated choice experiment. According to the overall ranking result, it is confirmed that the attribute selection for stated choice experiment complies with the priority of the respondent group.

7.2. Perception rating sub-experiment data analysis

In this section, the linear regression models are used to analyse respondent's perception of travel convenience and airborne health safety based on the rating they give for each question. Apart from revealing the rating preference of the entire respondent group, the influences of sociodemographic and flying preference characteristics of different individuals on given the rates are also studied. Therefore, the analysis consists of 2 parts. The first part is the regression analysis that includes only the sub-attributes as that have been introduced in Chapter 6. The second part are the regression models that include the interaction between the background attributes and the main attributes.

As introduced in Chapter 6, owing to the privacy-protecting purpose, the questionnaire gives respondents rights not to answer some specific personal questions in terms of income, educational level, etcetera. Therefore, for some respondents, their background information is incomplete. Therefore, they cannot be studied for the second part of regression analysis. In order to keep the sample group for the 2 regression studies consistent, these respondents will be excluded. This results in a smaller sample size (n=106).

7.2.1. Linear regression model for main attributes

In this section, the linear regression models are used to analyse the effect of main attributes on people's perception of travel convenience and airborne health safety. The importance of attribute is reflected by the parameters that the model estimates. The models for travel convenience and airborne health safety are formulated below:

Travel convenience:

$$Con = C + \beta_{HS} \cdot HS + \beta_{VT} \cdot VT + \beta_{CS} \cdot CS + \beta_{RM} \cdot RM$$

Where: ***Con*** is the perceived travel convenience score that respondents rate,

C is the regression constant,

$\boldsymbol{\beta_i}$ is the parameter estimated for each level of attribute,

HS is a dummy coded variable for whether a health statement is required,

VT is a dummy coded variable for whether a virus test result is required,

CS is a dummy coded variable for whether switching or cancelling flight is charged,

RM is a dummy coded variable for whether the refund is in money or vouchers.

Airborne health safety:

$$Safety = C + \beta_B \cdot B + \beta_M \cdot M + \beta_C \cdot C + \beta_D \cdot D + \beta_S \cdot S$$

Where: ***Safety*** is the perceived travel convenience score that respondents rate,

C is the regression constant,

$\boldsymbol{\beta_i}$ is the parameter estimated for each level of attribute,

B is a dummy coded variable for whether sequential boarding and deboarding rule is applied,

M is a dummy coded variable for whether mandatory mask wearing rule is applied,

C is a dummy coded variable for whether flight attendants are well protected by prevention equipment,

D is a dummy coded variable for whether free disinfection supplies are provided,

S is a dummy coded variable for whether the empty neighbour seat policy is applied.

The reference level of each attribute is dummy coded. This means that the beta, the parameter estimated for the reference level, is fixed to zero. For the travel convenience experiment, the reference levels are set as the statuses that are logically more convenient to the passengers. In other words, since requiring health statement and virus test result, charging for flight cancelation or switching and refunding in vouchers are logically less convenient, they are coded in 1. For the airborne health safety experiment, the applied statuses of each measure are coded in 1. For both experiments, the parameters estimated for the non-reference attribute levels can be viewed as the importance of the attribute. The sign of the parameter reflects the effect to be either negative or positive. The absolute value of it indicates the total amount of contribution of an attribute.

7.2.1.1. Linear regression estimation for the perceived travel convenience

The parameter estimation result for the perceived travel convenience from the regression model together with statistic performance of the estimation are presented in Table 14 below:

Table 14 – Linear regression estimation for travel convenience (n=106)

Parameter	Estimation	Std Error	t-stat	p-value
Constant	3.8373	0.0857	44.7931	0.0000
Health statement (HS)				
Required	-0.5000	0.0766	-6.5255	0.0000
Inessential	0.0000			
Virus test (VT)				
Required	-0.2594	0.0766	-3.3859	0.0007
Inessential	0.0000			
Cancellation & Switch (CS)				
Charged	-0.6604	0.0766	-8.6186	0.0000
Free	0.0000			
Refund method (RM)				
Voucher	-0.7264	0.0766	-9.4805	0.0000
Money	0.0000			

Observations = 848

R Square = 0.2056

As previously stated, attribute levels that are considered logically inconvenient are coded as 1. Since a higher rate means a better convenience performance, it is logic to assume that the estimation of parameters should return negative values for all attributes since they have negative impacts on air travel convenience during the COVID-19 pandemic.

According to the above estimation result, it is obvious that all betas estimated are lower than 0, therefore, complying with the previous expectation of signs. And the p-values for all parameters are lower than the threshold, $\alpha = 0.05$, meaning all estimations are statistically significant.

The parameter estimation shows that the refund policy in case of flight cancellation influences the most (-0.7264) on people's convenience perception among all other attributes. The low household income of the sample group can be ascribed as a contributory factor. The second-most important is trip cancellation and flight switching policy, which is similarly important as refund method (-0.6604). The third-most important attribute is the requirement of health statement (-0.5000) followed by the requirement of virus test result (-0.2594).

Taking a closer look at the rating answers to the perceived travel convenience question, one interesting phenomenon is found. For the first rating question, 22 out of 108 respondents gave rates lower than 3 (thus, rating at 1 or 2), meaning it is either relatively inconvenient or very inconvenient, despite of the fact that the first question is logically the most convenient situation among all the questions. However, it is also found that all of these respondents have given rates higher than 3 (thus, rating at 4 or 5) for some other questions which are more logically inconvenient than question 1. This implies that there is a chance that some people have a different criteria than we previously assumed to rate travel convenience.

In order to find out the heterogeneity among the respondents, a Latent Class Analysis (LCA) will be used to identify the hidden population subgroup which is unique from the another in terms rating criteria (McCutcheon, 1987). LatentGold 6.0, a software that is able to conduct the latent class regression is used for the analysis (Vermunt & Magidson, 2013).

The 2-class latent regression model is estimated. The model fit statistics is compared with the original model in Table 15. By comparing both LL and BIC indicators, it can be concluded that 2-class model has better model fit and therefore, the respondents can be divided into 2 class.

Table 15 – Model fit comparison between 1-class model and 2-class model

Model	Npar	LL	BIC	p-value
1-Class Regression	6	-1293.55	2615.07	
2-Class Regression	13	-1199.93	2460.49	0.000

Npar = number of parameters
LL = final log-likelihood of the model
BIC = Bayesian information criterion

The parameter estimation for 2-class model is presented in Table 16 below:

Table 16 – Latent class regression estimation of the 2-class model

Parameter	Est. Class 1	z-value	Est. Class 2	z-value	Wald	p-value	mean

Constant	2.7499	57.4250	2.7853	41.1195	7487.0047	0.0000	2.7642
Health statement (HS)							
Required	-0.8400	-10.2949	0.0044	0.0344	105.9881	0.0000	-0.5000
Inessential	0.0000		0.0000				0.0000
Virus test (VT)							
Required	-1.1157	-11.7938	1.0720	7.2897	297.9614	0.0000	-0.2594
Inessential	0.0000		0.0000				0.0000
Cancellation & Switch (CS)							
Charged	-0.9258	-10.9648	-0.2666	-2.3250	126.7536	0.0000	-0.6604
Free	0.0000		0.0000				0.0000
Refund method (RM)							
Voucher	-0.7384	-9.2241	-0.7086	-6.2039	131.9122	0.0000	-0.7264
Money	0.0000		0.0000				0.0000
Class size	0.5964		0.4036				
Observations = 848							
R Square = 0.4700							

The parameters for two different classes are presented above. The class 1 accounts for 59.6% of the respondents and the class 2 accounts for 40.4% of the respondents. For the respondents in class 1, the requirement of a health statements and a virus test result are two important factors to reduce the convenience perception, which has coefficients of -0.8400 and -1.1157 respectively. For the respondents in class 2, their convenience contributions become positive with the coefficients of 0.0044 and 1.0720.

These parameters of the latent group (class 2) mean that they think health statement and virus test result bring convenience to the air trip. This mindset was explained by the interview with one of the respondents holding the preference like this. The interviewee thinks that asking for these two documents for air traveling is a threshold that guarantees the safety of everyone onboard. A flight requiring these documents makes passengers feeling safer. This adds up to relieving pressures while staying in the cabin and has potential to avoid possible inconvenience in case of getting infected while travelling. Therefore, the interviewee emphasizes that although acquiring these documents and proofs might be inconvenient. However, considering the possible inconveniences that not requiring these thresholds will cause (travel pressure) and can cause (possible infection), it is still convenient to undertake this inconvenience.

7.2.1.2. Linear regression estimation for health safety

The linear regression estimation of parameters for airborne health safety can be found in Table 17 below:

Table 17 – Linear regression estimation for airborne health safety (n=106)

Parameter	Estimation	Std Error	t-stat	p-value
Constant	0.6462	0.0781	8.2789	0.0000
Boarding & Deboarding (Boarding)				
Applied	0.5142	0.0637	8.0673	0.0000
Unapplied	0.0000			
Mandatory mask wearing (Mask)				

Applied	1.1226	0.0637	17.6147	0.0000
Unapplied	0.0000			
Protected flight attendants (Crew)				
Applied	0.6934	0.0637	10.8797	0.0000
Unapplied	0.0000			
Free disinfection supplies (Disinfection)				
Applied	0.6132	0.0637	9.6215	0.0000
Unapplied	0.0000			
Empty neighbour seats (Seat)				
Applied	0.7830	0.0637	12.2859	0.0000
Unapplied	0.0000			
Observations = 848				
R Square = 0.4668				

Looking at the estimated parameters, they again comply with the sign expectation since all estimated parameters are positive. All parameter estimations are statistically significant. This means that every precautionary measure could improve respondents' perceived airborne health safety and make them feeling more safe.

However, the differences in value between the parameters indicate that the contribution of each measure to improve health safety perception varies. As the most commonly adopted measure to prevent virus transmission, mandatory mask wearing rule appears to be the most important (1.1226) to the respondent group. The second place is taken by empty neighbour seat policy (0.7830) which reduces the transmission risk by keeping the distance between passengers. The third and fourth places are flight attendants' protection (0.6934) and free disinfection supplies (0.6132). The sequential boarding measure is considered as the least important measure among all presented measures (0.5142) probably because of low familiarity that respondents have on it as it is not widely implemented worldwide and especially rare in the Europe.

7.2.2. Linear regression model with interaction effects of background variables

Apart from the models to estimate the main effects of the observed attributes, another two models are estimated to study the possible interaction effects from the background characteristics of respondents.

There are two types of interaction effect that this analysis aims to study. The first one is the direct effect of background characteristics on the perception of travel convenience and health safety. This type of effect directly changes the constant in the model. The second type of effect refers to the indirect influence of the background characteristics on the preference of the attributes that determine the travel convenience or health safety perception. This type of effect changes the parameter of the attribute, which is later reflected by the overall perception rate.

7.2.2.1. Interaction effect estimation for travel convenience

The travel convenience linear regression model that includes the effects from the background characteristics is presented below:

$$Y = C + \beta_{HS} \cdot HS + \beta_{VT} \cdot VT + \beta_{CS} \cdot CS + (\beta_{RM} + \beta_{RM}^{Flew} \cdot Flew) \cdot RM + Gender + Age + Freq$$

Where: ***Con*** is the perceived travel convenience score that respondents rate,

C is the regression constant,

$\boldsymbol{\beta_i}$ is the parameter estimated for each level of attribute,

HS is a dummy coded variable for whether a health statement is required,

VT is a dummy coded variable for whether a virus test result is required,

CS is a dummy coded variable for whether switching or cancelling flight is charged,

RM is a dummy coded variable for whether the refund is in money or vouchers,

Gender is the gender of the respondents (= 1: female, = 0: male),

Flew is flying experience during the COVID (= 1: flew in COVID, = 0: have not flew in COVID),

Age is the age of the respondent,

Freq is the flying frequency of the respondent.

The estimation result of the final model with tested interaction effect for travel convenience can be found in the Table 18 below. The result of the model that excludes the interaction effects is also presented for the comparison.

Table 18 – Interaction effect estimation for travel convenience (n=106)

Regression with main effects only					Regression with main and interaction effects				
Parameter	Coef.	S.E	t-stat	p-value	Parameter	Coef.	S.E	t-stat	p-value
Constant	3.8373	0.0857	44.7931	0.0000	Constant	3.7696	0.2321	16.2443	0.0000
Main effects:					Main effects:				
Health statement					Health statement				
Required	-0.5000	0.0766	-6.5255	0.0000	*Required*	-0.5000	0.0763	-6.5526	0.0000
Inessential	0.0000				*Inessential*	0.0000			
Virus test					Virus test				
Required	-0.2594	0.0766	-3.3859	0.0007	*Required*	-0.2594	0.0763	-3.3999	0.0007
Inessential	0.0000				*Inessential*	0.0000			
Cancellation & Switch					Cancellation & Switch				
Charged	-0.6604	0.0766	-8.6186	0.0000	*Charged*	-0.6604	0.0763	-8.6544	0.0000
Free	0.0000				*Free*	0.0000			
Refund method					Refund method				
Voucher	-0.7264	0.0766	-9.4805	0.0000	*Voucher*	-0.6158	0.0914	-6.7349	0.0000
Money	0.0000				*Money*	0.0000			
Interaction effects:					Interaction effects:				
Refund method * Flew during COVID					Refund method * Flew during COVID				
Yes					*Yes*	-0.2444	0.1112	-2.1970	0.0283

No	*No*	0.0000			
Gender	Gender				
	Female	0.1327	0.0774	1.7140	0.0869
	Male	0.0000			
Age	Age	-0.0080	0.0066	-1.2228	0.2217
Flying Frequency	Flying Frequency	0.0634	0.0376	1.6882	0.0917
Observations = 848	Observations = 848				
R Square = 0.2018	R Square = 0.2084				

First of all, the increase of R square from 0.2018 to 0.2084 indicates that the model fit is slightly improved. Therefore, it is true that respondents' socio-demographic and flying preference characteristics influence the perception of air travel convenience.

Secondly, by comparing the estimated parameters for the main attribute with that in the original model, only the estimation for the effect of the refund policy has been found with a small difference (increases from -0.7264 to -0.6158). The constant is also changed (decreases from 3.8373 to 3.7696). These are because of the introduction of the interaction effect that takes away a bit of their importance.

Thirdly, several interaction effects are found to influence respondents' rate on travel convenience. The first is from respondent's gender. The coefficient for female respondents is 0.1327. This means females, in general, give higher rates for the travel convenience than males. This could indicate that females have higher probability of flight execution and are less afraid of inconvenience. The second is from respondents' age. The negative sign of the coefficient means that with the increase of respondents' age, travel convenience becomes more important. In other words, the sub-attributes that contribute to travel inconvenience creates more adverse effect on the perception of older people. This complies with common sense because senior groups can feel more difficult to deal with the requirement of health-related paperwork and adjusting the travel plan. Thirdly, flying frequency has a positive effect on increasing people's travel convenience perception. This can be interpreted that frequent flyers are more familiar with the air travel process. Therefore, they feel more confident to deal with inconvenience that is created by the COVID-19 pandemic. Lastly, the flying experience during the COVID-19 pandemic is found having influence on people's perception of refund policy. The coefficient of -0.2444 for those who flew during the pandemic indicates that their perception of travel convenience is more adversely impact by being refunded in vouchers (-0.8602 for people who flew during the COVID-19 compared to -0.6158 for those who did not). This is probably because their travel experience during the COVID-19 pandemic enables them to be more sensitive to the refund policy. Because they could have thought of this aspect or experienced this issue while they travel which results in the perception heterogeneity.

7.2.2.2. Interaction effect estimation for airborne health safety

The health safety linear regression model that includes the effects from the background characteristics is presented below:

$$Safety = C + \beta_B \cdot B + (\beta_M + \beta_M^{Gender} \cdot Gender) \cdot M + \beta_C \cdot C + \beta_D \cdot D + \beta_S \cdot S + Gender + Age + Freq$$

Where: ***Safety*** is the perceived travel convenience score that respondents rate,

C is the regression constant,

$\boldsymbol{\beta_i}$ is the parameter estimated for each level of attribute,

B is a dummy coded variable for whether sequential boarding and deboarding rule is applied,

M is a dummy coded variable for whether mandatory mask wearing rule is applied,

C is a dummy coded variable for whether flight attendants are well protected by prevention equipment,

D is a dummy coded variable for whether free disinfection supplies are provided,

S is a dummy coded variable for whether the empty neighbour seat policy is applied.

Gender is the gender of the respondents (= 1: female, = 0: male),

Age is the age of the respondent,

Freq is the flying frequency of the respondent.

The estimation result of the final model with tested interaction effect for airborne health safety can be found in the Table 19 below. The result of the model that excludes the interaction effects is also presented for the comparison.

Table 19 – Interaction effect estimation for airborne health safety (n=106)

Regression with main effects only					Regression with main and interaction effects				
Parameter	Coef.	S.E.	t-stat	p-value	Parameter	Coef.	S.E.	t-stat	p-value
Constant	0.6462	0.0781	8.2789	0.0000	Constant	1.2556	0.1937	6.4821	0.0000
Main effects:					Main effects:				
Boarding & Deboarding					Boarding & Deboarding				
Applied	0.5142	0.0637	8.0673	0.0000	*Applied*	0.5142	0.0621	8.2776	0.0000
Unapplied	0.0000				*Unapplied*	0.0000			
Mandatory mask wearing					Mandatory mask wearing				
Applied	1.1226	0.0637	17.6147	0.0000	*Applied*	0.9510	0.0895	10.6198	0.0000
Unapplied	0.0000				*Unapplied*	0.0000			
Protected flight attendants					Protected flight attendants				
Applied	0.6934	0.0637	10.8797	0.0000	*Applied*	0.6934	0.0621	11.1634	0.0000
Unapplied	0.0000				*Unapplied*	0.0000			
Free disinfection supplies					Free disinfection supplies				
Applied	0.6132	0.0637	9.6215	0.0000	*Applied*	0.6132	0.0621	9.8724	0.0000
Unapplied	0.0000				*Unapplied*	0.0000			
Empty neighbour seats					Empty neighbour seats				
Applied	0.7830	0.0637	12.2859	0.0000	*Applied*	0.7830	0.0621	12.6063	0.0000
Unapplied	0.0000				*Unapplied*	0.0000			

Interaction effects:	Interaction effects:				
Mask*Gender	Mask*Gender				
Female	Female	0.3308	0.1243	2.6613	0.0079
Male	Male				
Gender	Gender				
Female	Female	-0.5127	0.0885	-5.7952	0.0000
Male	Male				
Age	Age	-0.0179	0.0053	-3.3482	0.0008
Flying frequency	Flying frequency	0.0400	0.0300	1.3339	0.1826
Observations = 848	Observations = 848				
R Square = 0.4668	R Square = 0.4959				

First of all, by comparing to the original model, the improved R square from 0.4668 to 0.4959 indicates that this model has a better model fit. This result justifies the assumption that respondents' background characteristics affect their rating preference of perceived health safety and therefore should be taken into account.

Secondly, the coefficients for the main effects from the main attributes remain the same except that for the mask-wearing policy (decreases from 1.1226 to 0.9510). The constant is also changed (increases from 0.6462 to 1.2556). This is because of the introduction of the interaction effect.

Thirdly, the new model observes some interaction effects that change the importance of the attribute and the constant. The first is from the gender. It has been found that females are more likely to give a lower rate for the perceived safety level than males. Compared to the rate given by males, females tend to give 0.5127 lower. The result is consistent with Neelakantan's (2010) conclusion that females tend to be less risk-tolerant than males. Therefore, it can be expected that they might be more willing to avoid exposing themselves in risky conditions because of the COVID-19 pandemic. The second factor is respondents' age which has similar effect as gender does. Senior group tends to give lower safety rate than young people. And the more senior the respondent is, the lower rate he or she is likely to give. This can be explained by the fact that COVID-19 pandemic has a more severe impact on the health of senior people. Third, flying frequency of the respondents is found to have positive effect on the rate that respondents give. This can be explained by their flying experience which is consistent with Floyd et.al's (2004) conclusion that frequent flyers were less impacted by the risk of the 9/11 attack. Last, the coefficient of the interaction effect of gender on the importance of mask-wearing policy (0.3308) shows that compulsory mask-wearing policy creates more safety perception on females than on males. It can be also understood that females think wearing mask is more important than males do.

7.2.3. Summary of perception rating sub-experiments

The linear regression analysis results for two perception rating sub-experiment show how air travel convenience and airborne health safety are perceived by the respondents. For the perceived travel convenience, the requirement of health statement and negative virus test result, charging for flight switching or cancellation and refunding in vouchers have negative impact on travel convenience perception. As for perceived airborne health safety. All presented health safety improvement measures are helpful to increase the safety perception. Respondents' background characteristics could influence the rates that they give.

7.3. Stated flight choice experiment data analysis

In this sub-chapter, the stated flight choice experiment data will be analysed, and the results will be discussed. By analysing the data, the impact of the COVID-19 pandemic on air travellers' flight choice behaviour and willingness to fly will be revealed.

Before the estimation of any model, the decision has to be made on whether the opt-out option should be included in the choice model along with two flight alternatives. The distribution across all choice sets and variants of how often the opt-out is chosen is presented in Table 20 below:

Table 20 – The frequency of the opt-out being chosen

Question	Context	Variant 1			Variant 2			Variant 3		
		Number of choice (%)			Number of choice (%)			Number of choice (%)		
		Flight A	Flight B	Opt-out	Flight A	Flight B	Opt-out	Flight A	Flight B	Opt-out
1	Serious pandemic	12 (25%)	1 (2%)	35 (72.9%)	11 (22.9%)	6 (12.5%)	31 (64.5%)	8 (17%)	8 (17%)	31 (65.9%)
2	Serious pandemic	3 (6.2%)	13 (27%)	32 (66.6%)	11 (22.9%)	17 (35.4%)	20 (41.6%)	1 (2.1%)	28 (59.5%)	18 (38.2%)
3	Serious pandemic	3 (6.2%)	16 (33.3%)	29 (60.4%)	24 (50%)	1 (2%)	23 (47.9%)	10 (21.2%)	9 (19.1%)	28 (59.5%)
4	Cautious pandemic	8 (16.6%)	12 (25%)	28 (58.3%)	21 (43.7%)	2 (4.1%)	25 (52%)	13 (27.6%)	11 (23.4%)	23 (48.9%)
5	Cautious pandemic	4 (8.3%)	27 (56.2%)	17 (35.4%)	4 (8.3%)	22 (45.8%)	22 (45.8%)	17 (36.1%)	18 (38.2%)	12 (25.5%)
6	Cautious pandemic	13 (27%)	7 (14.5%)	28 (58.3%)	13 (27%)	12 (25%)	23 (47.9%)	24 (51%)	11 (23.4%)	12 (25.5%)
7	non-pandemic	9 (18.7%)	28 (58.3%)	11 (22.9%)	12 (25%)	30 (62.5%)	6 (12.5%)	32 (68%)	5 (10.6%)	10 (21.2%)
8	non-pandemic	13 (27%)	32 (66.6%)	3 (6.2%)	19 (39.5%)	27 (56.2%)	2 (4.1%)	4 (8.5%)	30 (63.8%)	13 (27.6%)
9	non-pandemic	37 (77%)	7 (14.5%)	4 (8.3%)	16 (33.3%)	25 (52%)	7 (14.5%)	15 (31.9%)	10 (21.2%)	22 (46.8%)

According to the result, the percentage of the opt-out being chosen in all choice sets are lower than 73%, which indicates that even under the serious pandemic context, the opt-out has never been a dominant alternative to the respondents. In this case, it can provide a decent amount of preference information between flight alternatives for the analysis of attribute trade-off.

However, as a matter of fact, the choice of the opt-out does cause information loss to a certain extent. And most importantly, because the opt-out is noticeably often chosen under the pandemic context than the non-pandemic context, it could potentially influence the estimation reliability and validity of the pandemic impacts on attribute preference. Since the study of the pandemic's impact is important to this thesis the following decisions are made:

- For revealing the changes in flight attribute preference during the pandemic, the opt-out is not taken into account for keeping the maximum trade-off information in order to give a reliable parameter estimation. In other words, the analysis is only based on the first choice, which is the choice of flight alternative.

- For revealing the changes in willingness to fly during the pandemic, the opt-out will be taken into account because it makes the study feasible. In other words, for those who decide not to fly, the choice of the opt-out given for the second task will be considered regardless whichever flight alternative they choose for the first task.

7.3.1. Estimation results for analysing Flight attribute preference

In this section, three models are estimated in a sequence that is proven to gradually improve the model fit. The first estimated model is the Multinomial Logit model as the basis. The second model is the Mixed Logit model. It is estimated for its ability to capture the attribute preference heterogeneity of the respondents which has potential to improve the model fit. Another reason is, unlike the MNL model that regards a set of choices made by the same individual independent, ML model sees them correlated, which reflects the special taste of the individual. This feature also has potential to improve the model fit since it is closer to the reality. The third model is still a ML model but with the quadratic effects for the perceived attributes in terms of travel convenience and health safety. In some previous researches, it has be found that the quadratic effect could exist in the attributes that need to be perceived (Molin et al., 2017) & (Ting, 2004). This means the importance of perceived attribute matters more when the level of it is low but less when the level of it is high.

7.3.1.1 Utility model formulation

MNL model

The utility function for the MNL model includes the main effects of the flight attributes and the context effects on the flight attributes that are created by different levels of the pandemic. It consists of 4 parts contributed by 4 different flight attributes: Ticket price, the number of transfers, perceived travel convenience and perceived airborne health safety. Each attribute has 3 parameters to influence its utility contribution. The parameters in terms of β_{Fare}, β_{Trans}, β_{Conv} and β_{Safety} represent the basic utility of the attribute regardless of the pandemic context. The parameters in terms of $\beta_{PanFare1}$, $\beta_{PanFare2}$ etcetera. represent the impact of the pandemic context on the attributes' utility contribution. These represent the influence of serious pandemic when the index equals to 1 and the influence of the cautious pandemic when the index equals to 2. The context attribute is dummy coded. Which means the attribute equals 0 when the pandemic level is not true. If the context attributes for both levels of the pandemic equal 0, the pandemic situation is non-pandemic. The coding method of the context attribute is listed in Table 21 below:

Table 21 – Dummy coding of context attribute

Attribute level	Pan_1	Pan_2
Serious pandemic	1	0
Cautious pandemic	0	1
Non-pandemic	0	0

The formulation of the utility model for the MNL model is presented below:

$$V_i = (\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i +$$
$$(\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i +$$
$$(\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i +$$
$$(\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i$$

Where $\boldsymbol{Fare_i}$ stands for the ticket price of the flight,

$\boldsymbol{Trans_i}$ stands for the number of transfer,

$\boldsymbol{Conv_i}$ stands for the respondents' rate of the flight convenience

$\boldsymbol{Safety_i}$ stands for the respondents' rate of the airborne health safety measures

$\boldsymbol{Pan_1, Pan_2}$ stand for different pandemic seriousness levels.

$\boldsymbol{PanFare_1}$, $\boldsymbol{PanTrans_1}$, $\boldsymbol{PanConv_2}$ and $\boldsymbol{PanSafety_2}$ stand for the context effects from different seriousness levels of the pandemic on above observable flight attributes. The index number represent the effect from different pandemic seriousness levels.

$\boldsymbol{\beta_{Fare}}$, $\boldsymbol{\beta_{Trans}}$, $\boldsymbol{\beta_{Conv}}$, $\boldsymbol{\beta_{Safety}}$, $\boldsymbol{\beta_{PanFare1}}$, **etcetera.** represent the coefficient of each attribute.

ML model

The utility function for the ML model is largely the same as for the MNL model except the difference in parameters for the main attribute effects. In the ML model, the estimated parameter is not constant, but a stochastic value. This means the estimated parameter contains a distribution represented by a σ to stand for the variation in respondents' preference of attributes. In order to keep the model estimation efficient, only the parameters for the main attribute effects are added with a sigma to check the preference heterogeneities among the sample. The formulation of the utility model for the ML model is presented below:

$$\begin{aligned} V_i = &(\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i + \\ &(\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i + \\ &(\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i + \\ &(\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i \end{aligned}$$

Where $\beta_{Fare} \sim N(\beta_{Fare}, \sigma_{\beta_{Fare}}),\ \beta_{Trans} \sim N(\beta_{Trans}, \sigma_{\beta_{Trans}})$

$\beta_{Conv} \sim N(\beta_{Conv}, \sigma_{\beta_{Conv}}),\ \beta_{Safety} \sim N\left(\beta_{Safety}, \sigma_{\beta_{Safety}}\right)$

ML model with quadratic effect

In this model, the quadratic effects are added to perceived attributes in terms of air travel convenience and airborne health safety. This model upgrade is based on the previous ML model. The formulation of the utility model for the ML model with the quadratic effects is presented below:

$$\begin{aligned} V_i = &(\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i + \\ &(\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i + \\ &(\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i + \beta_{ConvSqu} * Conv_i^2 + \\ &(\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i + \beta_{SafetySqu} * Safety_i^2 \end{aligned}$$

Where $\beta_{Fare} \sim N(\beta_{Fare}, \sigma_{\beta_{Fare}}),\ \beta_{Trans} \sim N(\beta_{Trans}, \sigma_{\beta_{Trans}})$

$$\beta_{Conv} \sim N(\beta_{Conv}, \sigma_{\beta_{Conv}}),\ \beta_{Safety} \sim N\left(\beta_{Safety}, \sigma_{\beta_{Safety}}\right)$$

7.3.1.2 Estimation result

The results of three estimated models are presented in the Table 22 below:

Table 22 - Estimation of three flight choice models

Attribute category	Parameter	MNL model				ML model				ML model with quadratic effect			
		Coef.	S.E	t-val.	p-val.	Coef.	S.E	t-val.	p-val.	Coef.	S.E	t-val.	p-val.
Main attributes	Ticket price (TP)	-0.0156	0.0019	-8.2100	0.0000	-0.0229	0.0028	-8.0600	0.0000	-0.0258	0.0030	-8.5300	0.0000
	Number of transfers (NT)	-0.6340	0.1210	-5.2200	0.0000	-0.9950	0.1890	-5.2800	0.0000	-1.1000	0.1880	-5.8700	0.0000
	Perceived convenience (PC)	0.1780	0.0532	3.3500	0.0008	0.2830	0.0746	3.8000	0.0001	0.6190	0.2020	3.0600	0.0022
	Quadratic convenience (PC^2)									-0.0567	0.0311	-1.8200	0.0687
	Perceived safety (PS)	0.2290	0.0565	4.0500	0.0001	0.3510	0.0858	4.0800	0.0000	1.4100	0.2650	5.3200	0.0000
	Quadratic safety (PS^2)									-0.1710	0.0394	-4.3300	0.0000
Context Attributes	TP - Serious pandemic	0.0019	0.0030	0.6440	0.5200	0.0051	0.0038	1.3500	0.1760	0.0046	0.0038	1.2200	0.2240
	TP - Cautious pandemic	0.0060	0.0027	2.2600	0.0237	0.0083	0.0034	2.4100	0.0160	0.0088	0.0035	2.5500	0.0108
	NT - Serious pandemic	-0.7770	0.2540	-3.0600	0.0022	-0.8890	0.3260	-2.7300	0.0063	-0.7660	0.3190	-2.4000	0.0163
	NT - Cautious pandemic	-0.5130	0.2080	-2.4700	0.0135	-0.7490	0.2850	-2.6300	0.0087	-0.5860	0.2780	-2.1100	0.0348
	PC - Serious pandemic	0.0305	0.0835	0.3660	0.7140	-0.0312	0.1160	-0.2680	0.7890	-0.0800	0.1160	-0.6900	0.4900
	PC - Cautious pandemic	0.0645	0.0790	0.8170	0.4140	0.1120	0.1120	0.9960	0.3190	0.0852	0.1110	0.7690	0.4420
	PS - Serious pandemic	0.4780	0.0958	4.9900	0.0000	0.6190	0.1350	4.5900	0.0000	0.6020	0.1350	4.4400	0.0000
	PS - Cautious pandemic	0.2550	0.0860	2.9700	0.0030	0.3850	0.1230	3.1400	0.0017	0.3570	0.1220	2.9300	0.0034
Taste variance	Sigma - TP					0.0124	0.0021	-5.8600	0.0000	0.0126	0.0021	6.0600	0.0000
	Sigma - NT					0.7740	0.1420	5.4300	0.0000	0.6990	0.1460	4.7700	0.0000
	Sigma - PC					0.1370	0.0810	1.6900	0.0903	0.1580	0.0715	2.2100	0.0271
	Sigma - PS					0.4150	0.0747	5.5600	0.0000	0.4270	0.0751	5.6900	0.0000
Model Descriptive	Null log-likelihood	-892.080				-1499.146				-1541.907			
	Final log-likelihood	-708.071				-673.201				-663.522			
	rho-square	0.206				0.551				0.570			
	Number of observations	1287				1287				1287			

Model fit

In order to check if the model fit is statistically improved, the likelihood ratio test is conducted. This test tells whether the better model fit is due to a coincidence. To conduct the likelihood ratio test, the likelihood ratio statistic (LRS) should be first calculated by the function below:

$$LRS = 2 \times (Log\_Likelihood\ B - Log\_Likelihood\ A)$$

The next step is to compare LRS with χ^2 probability value for the difference in the degrees of freedom (which is the difference of the number of estimated parameters) between two models. By comparing the ML model with the MNL model, ML model has 4 extra estimated parameters which means there are 4 degrees of freedom. The LRS between two models is $2 * (-673.2014 - (-708.0710)) = 69.74$. By comparing to χ^2 table, the LRS is higher than 18.467 which is a confidence level of 0.001. This means that the chance that ML model has a better model fit than MNL model is because of a coincidence is lower than 0.1%. Therefore, it is safe to conclude that ML model improve the model fit.

By comparing the quadratic effect ML model with the normal ML model, the quadratic effect ML model has 2 extra estimated parameters which means there are 2 degrees of freedom. The LRS between two model is $2 * (-663.5219 - (-673.2014)) = 19.359$. the LRS is higher than 13.816 which is the threshold of the significance at 0.1% level. Therefore, it is safe to conclude that the ML model that includes the quadratic effect has a solid model fit improvement.

Parameter interpretation

Because the quadratic effect ML model has the best model fit, the interpretation of the parameters will be based on it.

Firstly, the estimation for the main attributes effect provides a promising result. The coefficients of ticket price (-0.0258) and number of transfers (-1.1000) are minus. Which means that they have negative effects on the flight utility. In other words, with the increase of the ticket price and the number of transfers, the probability to choose the flight decreases. On the other hand, the coefficients for travel convenience (0.6190) and health safety (1.4100) are positive. Which means that a flight with higher levels of these attributes has higher chance to be chosen. The parameters for convenience square (-0.0567) and safety square (-1.1710) confirms the quadratic effects. This results in non-linear utility contribution of these two attributes. The negative signs of the coefficients mean that with the levels of the attributes increase, the importance of them reduces. In other words, these attributes matter more when they are at a low level than a high level.

Secondly, the parameter estimation for the effects of the context attributes also provides some interesting results. The coefficients for both levels of context effect on ticket price (0.0046 during a serious pandemic and 0.0088 during a cautious pandemic) are positive. This means that the negative contribution of the ticket price becomes less negative during the COVID-19 pandemic. In other words, the importance of the ticket price becomes less important during the COVID-19 pandemic. It can be understood that respondents are willing to accept a higher price in exchange for the improvement of other attributes. On the other hand, the results suggest that, during the COVID-19 pandemic, number of transfers and travel time become more important (-0.7660 for the serious pandemic and -0.5860 for the cautious pandemic). This complies with the previous expectation because more transfers and longer travel time increase exposure of travellers under the health risk. Therefore, people are more willing to reduce them during the pandemic period than the non-pandemic period. The parameters of context effects on travel convenience are abnormal because it is firstly positive (0.0852) when there is a cautious pandemic, but with the seriousness increases, it becomes negative (-0.0800). Considering their p-values are much higher than the threshold (0.05), these effects might be questionable because of their statistical insignificance. As the last context effects, the pandemic's impacts on health safety is consistent with the expectation. During the COVID-19 pandemic, people would pay more attention to this attribute. And the importance of it becomes higher when the seriousness of the pandemic increase (0.6020 for the serious pandemic compared with 0.3570 for the cautious pandemic).

Third, the attribute preference heterogeneity part of the ML model is believed to largely contribute to the model fit improvement. All 4 parameters are statistically significant meaning that the attribute taste heterogeneity does exist in the sample group. It is worth to mention that due to the quadratic effect on travel convenience and heath safety, the means of the normal distribution of these two attributes vary along with the attribute levels, which result in different heterogeneity range.

7.3.1.3 Willingness to pay

The absolute value of the parameters in the flight choice models in the previous section cannot be intercompared with each other. Willingness to pay (WTP) provides a good tool to compare their relative importance in the form of monetary value. An example of WTP calculation is presented below:

$$WTP = \frac{Coeff.\ of\ Trans}{Coeff.of\ Fare} = \frac{Utiltiy\ contribution}{Number\ of\ transfers} / \frac{Utiltiy\ contribution}{Ticket\ price\ (euro)} = \frac{euro}{number\ of\ transfer}$$

The WTP for improving attribute performance by one level under different pandemic contexts are listed in the Table 23 below.

Table 23 – WTP to improve attribute performance by one level

Pandemic context	WTP for transfer (travel time) reduction			
	2 to 1		1 to 0	
Serious pandemic	€ 87.9		€ 87.9	
Cautious pandemic	€ 99.2		€ 99.2	
Non-pandemic	€ 42.6		€ 42.6	
Pandemic context	WTP for health safety improvement			
	1 to 2	2 to 3	3 to 4	4 to 5
Serious pandemic	€ 70.6	€ 54.5	€ 38.4	€ 22.3
Cautious pandemic	€ 73.8	€ 53.6	€ 33.5	€ 13.4
Non-pandemic	€ 34.8	€ 21.5	€ 8.3	€ -5.0
Pandemic context	WTP for travel convenience improvement			
	1 to 2	2 to 3	3 to 4	4 to 5
Serious pandemic	€ 21.2	€ 15.8	€ 10.5	€ 5.1
Cautious pandemic	€ 26.4	€ 19.7	€ 13.1	€ 6.4
Non-pandemic	€ 17.4	€ 13.0	€ 8.6	€ 4.2

According to the table above, the WTP for transfer reduction shows that the respondents are willing to pay more under the pandemic context. Compared to the non-pandemic period in which a price of 42.6 euro is willing to pay to reduce the number of transfer by one, respondents are willing to pay 99.2 euro during the cautious pandemic period. However, during the serious pandemic period, the WTP for that becomes 11.3 euro lower. This is because the coefficient for the pandemic's impact on the ticket price during the serious pandemic is less positive than that during the cautious pandemic. Therefore, even if the coefficient for the number of transfer is larger during the serious pandemic, the willingness to pay is still lower during the serious pandemic after the division. However, it is worth to mention that this result might not hold because the parameter of the context effect on the ticket price during the serious pandemic is not statistically significant (P-value = 0.22).

The higher WTP for attribute improvement during the pandemic period also apply to health safety and travel convenience. During the COVID-19 pandemic, respondents are willing to pay more than they were during the non-pandemic period. During the serious pandemic period, respondents are willing to pay higher price than in a cautious pandemic to improve the health safety at higher level (€ 22.3 compared to € 13.4 for improving from 4/5 to 5/5). Another interesting phenomenon is that respondents would rather keep the health safety to an acceptable level during the non-pandemic period. Because their WTP for improving it from 4/5 to 5/5 becomes €-5, which means that they do not want to pay for this improvement. The willingness to pay for travel convenience improvement is also higher during the pandemic because the coefficient for the ticket price becomes less negative due to the context effect.

The quadratic effects reflect on WTP for both travel convenience and health safety. That is, people prefer to pay more to improve these perceived attributes from low-levels to mid-levels than from mid-levels to high-levels. This trend is illustrated by the Figure 13 below:

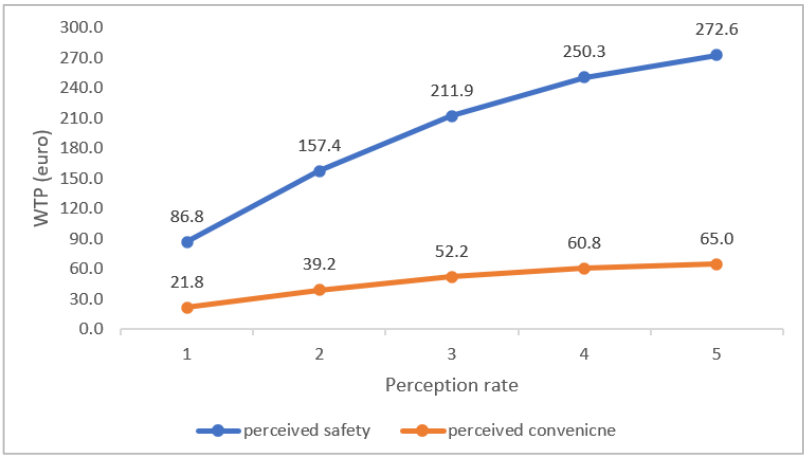


Figure 13 – The trend of WTP for perceived attribute improvement (serious pandemic)

7.3.2. Estimation results for analysing willingness to fly

The model for analysing respondents' willingness to fly is estimated in this section by the ML model with the quadratic effects because this model has the best model fit performance in flight choice analysis. The data that considers the opt-out option as a choice alternative together with flight alternatives will be analysed.

7.3.2.1 Utility model formulation

The utility function for this ML model is similar to the previous one. The only difference is that this model has 2 extra constant parts. The first part represents the attribute difference between flight alternatives and the opt-out option. The second part of the constants reflects the context influence on the above utility difference. This part of the constant is expected to be negative because the pandemic is assumed to reduce the utility of the flight alternative which makes the opt-out more often to be chosen. As the reference alternative, the utility of the opt-out is fixed to 0. The utility function of the flight alternative is presented below:

$$V_i = (\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i +$$
$$(\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i +$$
$$(\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i + \beta_{ConvSqu} * Conv_i^2 +$$
$$(\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i + \beta_{SafetySqu} * Safety_i^2$$

Where $\boldsymbol{Fare_i}$ stands for the ticket price of the flight,

$\boldsymbol{Trans_i}$ stands for the number of transfer combined with the duration of the trip that the flight involves

$\boldsymbol{Conv_i}$ stands for the respondents' rate of the flight convenience

$\boldsymbol{Safety_i}$ stands for the respondents' rate of the airborne health safety measures

$\boldsymbol{Pan_1}, \boldsymbol{Pan_2}$ stand for different pandemic seriousness levels.

$\boldsymbol{\beta_{Fare}}$, $\boldsymbol{\beta_{Trans}}$, $\boldsymbol{\beta_{Conv}}$, $\boldsymbol{\beta_{Safety}}$ represent the coefficient of each attribute.

$\beta_{PanFare1}$, $\beta_{PanTrans_1}$, $\beta_{PanConv_2}$, $\beta_{PanSafety_2}$, **etcetera.** stand for the context effects from different seriousness levels of the pandemic on above observable flight attributes. The index number represent the effect from different pandemic seriousness levels.

β_{fly} stands for the constant utility of flight alternatives

β_{pan1} , β_{pan2} stand for the constant utility of different pandemic seriousness levels, which represent their impacts on flight alternatives.

7.3.2.2 Estimation result

The estimation result of the ML model that considers the opt-out is presented in the Table 24. The result of the model that does not consider the opt-out is also listed for the preparation.

Table 24 – The estimation of the ML model that considers the opt-out option

Attribute category	Parameter	ML model (does not consider the opt-out)				ML model (consider the opt-out)			
		Coef.	S.E	t-val.	p-val.	Coef.	S.E	t-val.	p-val.
Main attributes	Ticket price (TP)	-0.0258	0.0030	-8.5300	0.0000	-0.0195	0.0020	-9.6200	0.0000
	Number of transfers (NT)	-1.1000	0.1880	-5.8700	0.0000	-0.7760	0.1370	-5.6800	0.0000
	Perceived convenience (PC)	0.6190	0.2020	3.0600	0.0022	0.5730	0.1900	3.0200	0.0025
	Quadratic convenience (PC^2)	-0.0567	0.0311	-1.8200	0.0687	-0.0540	0.0299	-1.8000	0.0714
	Perceived safety (PS)	1.4100	0.2650	5.3200	0.0000	0.3430	0.1960	1.7500	0.0799
	Quadratic safety (PS^2)	-0.1710	0.0394	-4.3300	0.0000	-0.0093	0.0301	-0.3080	0.7580
Context Attributes	TP - Serious pandemic	0.0046	0.0038	1.2200	0.2240	0.0084	0.0029	2.8700	0.0041
	TP - Cautious pandemic	0.0088	0.0035	2.5500	0.0108	0.0105	0.0027	3.9400	0.0001
	NT - Serious pandemic	-0.7660	0.3190	-2.4000	0.0163	0.0847	0.1850	0.4580	0.6470
	NT - Cautious pandemic	-0.5860	0.2780	-2.1100	0.0348	0.0455	0.1780	0.2560	0.7980
	PC - Serious pandemic	-0.0800	0.1160	-0.6900	0.4900	-0.3510	0.0900	-3.9000	0.0001
	PC - Cautious pandemic	0.0852	0.1110	0.7690	0.4420	-0.1680	0.0846	-1.9800	0.0474
	PS - Serious pandemic	0.6020	0.1350	4.4400	0.0000	0.2710	0.1000	2.7000	0.0070
	PS - Cautious pandemic	0.3570	0.1220	2.9300	0.0034	0.0972	0.0934	1.0400	0.2980
Constants	Pan1 - Serious pandemic					-3.8200	0.4810	-7.9300	0.0000
	Pan2 - Cautious pandemic					-3.0800	0.4600	-6.6900	0.0000
	Fly - Flight specific constant					2.6600	0.4170	6.3700	0.0000
Taste variance	Sigma - TP	0.0126	0.0021	6.0600	0.0000	0.0068	0.0015	4.6200	0.0000
	Sigma - NT	0.6990	0.1460	4.7700	0.0000	0.5320	0.1070	4.9500	0.0000
	Sigma - PC	0.1580	0.0715	2.2100	0.0271	0.2550	0.0483	5.2900	0.0000
	Sigma - PS	0.4270	0.0751	5.6900	0.0000	0.3330	0.0497	6.6900	0.0000
Model Descriptive	Null log-likelihood	-1541.907				-2371.349			
	Final log-likelihood	-663.522				-1097.009			
	rho-square	0.570				0.537			
	Number of observation	1287				1287			

Parameter interpretation

The estimation result for the ML model that bases on the data that considers opt-out as an alternative shows several features in common with the previous estimation result. The signs of the coefficients for the main attributes are the same as for the previous estimation. However, the p-values for perceived health safety and its quadratic coefficient are higher than the threshold.

There are some differences in attribute context effects that can be found. In the estimation considering the opt-out option, the coefficients for the context impact on the number of the transfer become positive. This is contradictory to common sense because it suggests that during the pandemic period, respondents would prefer to take flights that have a higher number of transfers. The coefficients for the context impact on travel convenience are negative, meaning that respondents prefer to take flights that have poorer travel convenience performance during the pandemic, which is also contradictory to the logical expectation. These differences can be attributed to the different amount of trade-off information included in the model estimation, which results in some unreliable estimations.

The constant of β_{fly} is the utility base of the flight alternatives regardless the pandemic context. When there is no pandemic, this is the only constant in the utility model. Because it has a relatively large positive coefficient (2.66), it gives a high chance to choose either of the flight alternative during the non-pandemic period. However, when there is the COVID-19 pandemic, the above utility advantage is offset by the impact of the pandemic. β_{pan2} represents the impact of the cautious pandemic on the constant, which is -3.08. This could strongly reduce the choice probability of the flight alternatives. The negative impact becomes even larger when the pandemic escalates to serious, which has a coefficient of -3.82.

8 Scenario study

In this chapter, two scenario studies will be conducted to demonstrate the influence of the COVID-19 pandemic on potential passengers' air travel behaviour. The choice environment will be constructed to test both flight choice behaviour and willingness to fly using the models and estimated parameters discussed in Chapter 7.

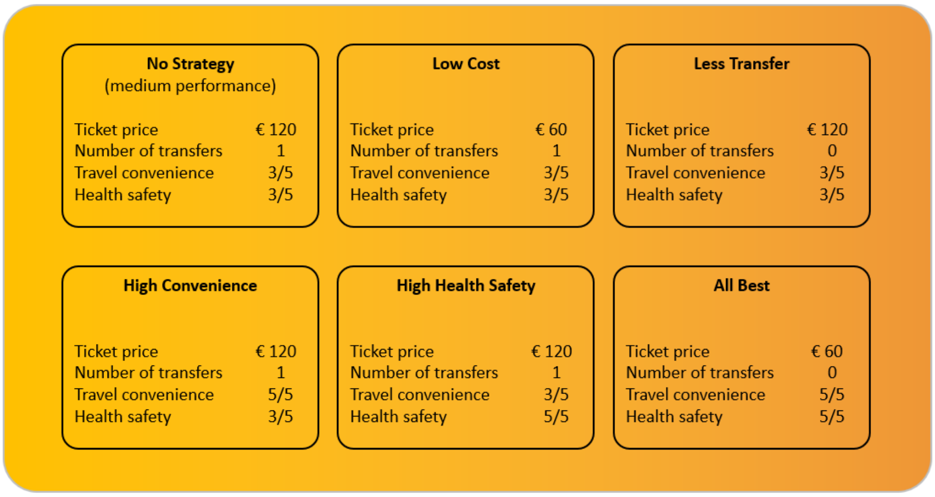
8.1. Flight choice behaviour

In this sub-chapter, the scenario study checks the effect of improving different flight attributes on attracting air travellers under different pandemic situations. The choice probability increment will be used to express the consequence of the attribute improvement. The parameter estimation from the ML model with the quadratic effects is used for this study. Which means that there will be no opt-out option. Therefore, the basic assumption for this scenario study is that the decision-makers have already decided to have an air travel. The result of this study reflects their choice on which flight they prefer to take.

In this scenario study, it is assumed that there are 4 flights in the competition, in which 3 flights are references that have the same attribute performance. The last flight is the variable flight which sequentially takes 6 different strategies (represented by different levels of attribute) which are Medium Performance, Low-price, Less-transfer, High-convenience, High-health-safety and All Best to compete against other 3 rival flights.

The attribute performance of the flights for different strategies in the scenario study has to be determined. The reference flights are set to have the medium attribute performance, i.e. they are priced at 120 euro, transferring once, having total travel time of 5 hours and medium travel convenience and health safety levels. The variable flight will have the highest performance of the attribute that corresponds to the respective competition strategy. For example, for the Low-price strategy, the variable flight will have a lower price (60 euro), while the other attributes are the same as the reference flights. Two pandemic contexts will be compared, which are non-pandemic and cautious pandemic. The tested strategies are presented in the Figure 14 below:

Figure 14 – Tested strategies and respective flight attributes performance



The choice probabilities of the variable flight which applies different strategies under different pandemic contexts are presented in the Table 25 below.

Table 25 – Choice probability of the variable flight under 2 pandemic seriousness levels

	Market share	
Attribute strategy	Post-COVID	Cautious pandemic
Medium Performance	25.0%	25.0%
Low-price	61.0%	48.0%
Less-transfer	50.0%	64.3%
High-convenience	31.7%	31.7%
High-health-safety	26.6%	42.5%
All Best	85.9%	94.0%

As it can be seen above, the choice probability can be increased by improving all attributes that are included in this research during whatever pandemic context. However, their effectiveness is different. Under the post-COVID situation, reducing price of the ticket is the most effective way to improve the choice probability, from 25% to 61.0% when reducing price from 120 euro to 60 euro. Low travel time / Less-transfer strategy is the second effective competition strategy which increases the choice probability to 50% when reducing 1 transfer time. Improving health safety measure during the Post-COVID period has very marginal effect on increasing the choice probability. While implementing high travel convenience strategy has the same result in choice probability improvement under both pandemic situations, which increases it by 6.7%. During the Cautious pandemic situation, the effectiveness of Low-price strategy becomes less. The choice probability increment reduced by 13% to 48%. On the contrary, reducing travel time and the number of transfers can significantly improve the choice probability to 64.3%. The usefulness of improving health safety measures also increases dramatically to about 16%.

8.2. Willingness to fly

The willingness to fly scenario study will use the estimated parameters of the ML model that considers the opt-out option along with the other two flight alternatives. The goal of this study is to see to what extent the COVID-19 pandemic would reduce the chance to fly. The sub-goal is to check whether the improvement of flight attributes could mitigate the negative effect because of the COVID-19 pandemic on willingness to fly.

This scenario study will simulate a situation in which an individual faces 2 flight options and an opt-out option just like the choice experiment. The choice probability of choosing either of the flight alternatives will be calculated under different pandemic contexts. The choice probability reduction under the pandemic context would tell the impact of the pandemic on willingness to fly. On the other hand, by changing the attribute performance and checking the increase of choice probability of the flight alternatives, the sub-goal of this study can be achieved.

The 2 flight alternatives are set to have the same attribute performance. As the previous scenario study for the flight choice behaviour, they will firstly have a medium attribute performance to test the impact of the COVID-19 pandemic on willingness to fly. Three choice probabilities of flying will be given under the non-pandemic, cautious pandemic and serious pandemic context respectively. Then, the effect of improving different attribute on increasing the chance of flying will be tested. Again, 5 other strategies (Low Cost, Less-transfer, High-convenience, High-health-safety and All Best) will be respectively implemented on the 2 flight alternatives to check their contribution to the willingness to fly increment. The result of scenario study is given in the Table 26 below:

Table 26 – Flying probability under different pandemic seriousness levels

Attribute strategy	Choice probability of flying		
	non-pandemic	Cautious pandemic	Serious pandemic
Medium Performance	83.5%	55.0%	37.6%
Low-price	92.3%	61.9%	47.0%
Less-transfer	89.7%	65.5%	48.4%
High-convenience	87.2%	57.7%	34.4%
High-health-safety	88.0%	68.3%	60.9%
All Best	97.6%	83.3%	75.5%

As it can be observed above, no matter what attribute strategy is adopted, the choice probability of flying decreases considerably due to the pandemic getting worse. When the flight alternatives have medium attribute performance, the flying probability decrease from 83.5% when there is no pandemic to 55.0% when there is a cautious pandemic and further to 37.6% when the pandemic get serious.

The effectiveness of improving different flight attributes on increasing willingness to fly varies with the pandemic context. During the non-pandemic situation, The Low-price strategy has the best outcome in improving the chance that people fly (83.5% to 92.3%), which is followed by the Less-transfer strategy (to 89.7%). The third and fourth places are high safety and high convenience respectively. However, during the cautious pandemic, improving health safety becomes the best way to increase willingness to fly (55.0% to 68.3%), which is followed by Less-transfer strategy (to 65.5%), Low-price (to 61.9%) and high convenience (to 57.7%). During the serious pandemic, the order of the effectiveness of different attribute strategies remains the same as the cautious pandemic. When all the flight attributes are set to the best level, the probability of flying is at a very high level. Under the serious pandemic context, the flights with the best attribute performance increase the flying chance from 37.6% to 75.5%.

8.3. Summary

According to both scenario studies, it is rather obvious that the COVID-19 pandemic has a huge impact on how air travel choices are made. In the scenario study for the flight choice behaviour, it is found that once being the most effective way to attract customers, reducing price during the pandemic period becomes less effective. The pandemic also highlighted the importance of the number of transfers and virus precautionary measures due to the safety concerns. In the scenario study for the willingness to fly, a similar trend is also observed. During the pandemic situation, safety performance and the number of transfers are more important attributes than the ticket price to determine willingness to fly of air travellers. Another interesting finding is that respondent preference revealed by their stated choices on both flight alternatives and willingness to fly is largely consistent with their rank of important flight attribute in the questionnaire.

9 Conclusions

This thesis studies air travel behaviour during the COVID-19 pandemic. It firstly studies the context of the COVID-19 pandemic influencing the air travel behaviour. Secondly, as two important travel choices which are found to be influenced by the pandemic, the choice between flight alternatives and between flying and not flying during the pandemic were studied by the stated choice experiment. In this chapter, the conclusions are drawn based on the formulated research questions and the results of the study.

The main research question is:

> ***What is the difference in air travel behaviour between the COVID-19 period and the non-pandemic period?***

To this end, three sub-questions below were formulated:

SQ1: What is the context of the COVID-19 pandemic influencing air travel behaviour?

- **SQ1a: What are the context aspects that are affected by the pandemic and may influence air travel behaviour?**
- **SQ1b: What air travel behaviour could be changed by these context aspects?**

SQ2: How does COVID-19 pandemic influence willingness to fly?

- **SQ2a: To what extent is the willingness to fly influenced by the COVID-19 pandemic?**
- **SQ2b: To what extent can the willingness to fly be increased by improving the flight attributes?**

SQ3: How does COVID-19 pandemic influence flight choice behaviour?

- **SQ3a: How are flight attributes in terms of travel convenience and health safety perceived by air travellers during the pandemic?**
- **SQ3b: To what extent does the pandemic influence the trade-off across flight attributes when choosing the flight for travelling?**

The first sub-question is researched by means of a literature review. The conceptual model constructed after the literature review organizes the answer to the question.

Three aspects that are greatly impacted by the COVID-19 pandemic were identified to influence air travel behaviour the most. Firstly, the policy environment is changed during the pandemic when national or regional authorities impose a series of policies, including travel restrictions and travel recommendations. Under the new policy environment, passengers are either forced or nudged to avoid travelling, in order to slow down the global virus transmission. Secondly, the COVID-19 pandemic creates a new risk to public health. Such situation stimulates the risk perception of the public. The increase in risk perception could trigger a set of health-protective behaviours that can be reflected by the changes in making travel choices. The mindset behind these behaviour changes is often related to risk reduction and avoidance. Therefore, the safety aspect of a flight trip is underscored so that air passengers might choose a safer destination and flight for the trip or simply postpone or cancel the trip. Thirdly, the COVID-19 pandemic heavily impacts the way that airlines operate. Facing the low travel demand, airlines are forced to retrench their operation by reducing offered capacity. On the other hand, in order to attract air passengers to fly, many strategies including price reduction and improvements on onboard health safety measures and travel convenience have been put into place. All these changes in airline operation could potentially affect passengers' choices between flight alternatives and flying or not.

Sub-questions 2 and 3 were studied by discrete choice modelling using stated choice data provided by a sample size of 143 adults. The survey for collecting stated choice data consists of two experiments. The first is a perception rating sub-experiment to measure the importance of perceived flight attributes including perceived travel convenience and onboard health safety. This experiment gives the answer to sub-question 3a. The second experiment incorporates these attributes into a flight choice experiment. This model estimation through the choice data reveals the attribute preference of the respondents under different pandemic context, which gives the answer to sub-question 3b. In the flight choice experiment, the respondent's willingness to fly is tested through the choice of the opt-out. The answers to sub-question 2a and 2b are given through the choice model estimation for the willingness to fly.

The perceived attribute rating sub-experiment shows two important findings. Firstly, the perception of air travel convenience is related to the amount of effort to make the trip. For example, the requirement of a health statement or a virus test result for the trip can lead to more complicated trip preparation, which can be understood as an inconvenience. However, there is also another group of respondents that presents a different type of preference. This group considers the inconvenience expectation which makes them accept the inconvenience of acquiring the paperwork to fly. To be more specific, they think the requirement of this paperwork improves the potential safety of the cabin environment which avoid travel anxiety and possible inconvenience after accidentally getting infected. What is also important to travel convenience is the rescheduling flexibility that is provided by the airlines. Due to the uncertainties of the COVID-19 pandemic, air travellers think more rescheduling flexibility equals higher travel convenience. The measures that can improve include allowing travellers to cancel or switch the flight for free and making refunds in money instead of vouchers. Secondly, the health safety perception is related to the virus precautionary measures that are imposed in the cabin. According to the 5 measures tested in the experiment, the use of virus protection, hygiene products and retaining the socio-distancing rule onboard are effective to improve health safety perception.

The results of the stated choice experiment show that both flight choice behaviour and willingness to fly of the respondent group are considerably influenced by the COVID-19 pandemic.

For the preference of flight attributes, the change in flight choice behaviour can be ascribed to air passengers' safety concerns. Firstly, the importance of perceived onboard health safety for choosing the flight has been highly increased during the COVID-19 pandemic. Compared to the non-pandemic situation, respondents are willing to pay more (from 18.4 euro up to 39.0 euro) to improve the perceived health safety by one level during the pandemic context. The willingness to pay for the perceived health safety improvement increases when the seriousness of the pandemic increases. Secondly, extra transfers and time spent on the flight journey are considered to be dangerous during the pandemic. Because extra transfers would involve sitting with a new set of travellers on the connecting flight, which increases the risk of infection. Longer travel and waiting time make it even worse. Therefore, the number of transfers and travel time become more important during the pandemic situation, so that people are willing to pay more to reduce them. The willingness to pay for reducing one transfer and 2 hours of travel time during the pandemic period is 56.6 euro more than during the non-pandemic period. Thirdly, travel cost, represented by flight ticket price becomes less important during the pandemic. That is, reducing the same amount of price of a flight ticket during the pandemic could not improve as much choice probability as it can be done during the non-pandemic situation. This can be explained by the trade-off made by the passengers that they would rather pay more in exchange for improving other attributes in terms of increasing perceived health safety and reducing the number of transfer or travel time. Perceived travel convenience is also important for travellers to make flight choices. However, the willingness to pay for improving it by one level is only slightly increased (maximum 10 euro when increasing if from 1/5 to 2/5) compared to the other attributes.

With respect to the willingness to fly, it is dramatically reduced because of the COVID-19 pandemic. And the negative impact on the willingness to fly increases along with the seriousness of the pandemic. For instance, a cautious pandemic could reduce people's willingness to fly by 28.5% when the flight attributes are set at the medium level, whereas a serious pandemic situation reduces it by 45.9%. However, it is worth mentioning that the negative impact of the pandemic on the willingness to fly can be to a certain extent be offset by the improvement of the flight attribute performance. Improving health safety perception and reducing the number of transfer and travel time are effective to increase willingness to fly. Reducing the ticket price can do as well, but it would be not as effective during the pandemic as it was when there is no pandemic.

10 Discussion

In this chapter, a reflection of this study including some research decision makings and methodology limitations is given. Some interesting future research directions are also given.

Perception rating sub-experiment

In this research, perceived travel convenience and health safety are considered as the attributes that air travellers would additionally consider during the COVID-19 pandemic. Therefore, they are added as attributes for the flight choice experiment. However, in this case, they are presented together with other attributes that are normally more important and therefore, included in almost every other flight choice experiment. This could have led to an overestimation of the importance of them. Because there might be other attributes that are more influential to flight choice-making but not included in the experiment.

Perceived convenience is assumed to be influenced by sub-attributes including the requirement of the health statement and the virus test result. After the perception rating sub-experiment, it is present in the flight choice experiment as an attribute. Therefore, the level of this attribute does not represent the status of a particular sub-attribute influencing perceived convenience. This is based on the theory of hierarchical information integration by definition. However, in almost all cases, it is the authorities of the destination countries to determine whether entering their border requires a negative virus test result. Therefore, when two flight alternatives have different performance in terms of perceived travel convenience during the flight choice experiment, respondents have to assume that the difference is not coming from the requirement of the virus test result but from elsewhere. Because the flight alternatives should be assumed to fly to the same destination, therefore, the status of the virus test requirement should be according. However, it is hard to judge whether the respondents have followed the above logic which leaves this point to improve in future researches.

Perceived health safety is assumed to be influenced by 5 virus precautionary measures. However, the actual number of applied measures in the real world could be more than 5. This could create different problems across respondents. Respondents that expect more health-protective measures would think these measures are insufficient even though all of them are applied. This group of the respondent should give a low safety rate. However, to those who think in the way that if all measures are applied, 5 out of 5 shall be rated, the importance of each individual measure, therefore, is overestimated. However, if all possible measures are included in the experiment, same as the problem of having too many attributes to the flight choice experiment, it will make the choice set lacking overview, which results in more rating error and a worse model fit. Thus, this is a dilemma that future research should consider.

In this research, the attribute statuses that determine perceived travel convenience and health safety are directly presented and therefore, obvious to the respondents. This might be unrealistic because this information normally is not integrated as good as in this experiment and presented to the customers when booking the flights. In the real world, this information can be more difficult to noticed unless airlines or ticket booking platform deliberately present it to the consumers. Therefore, this setup could result in an overestimation of the importance of perceived attributes. However, the story can be told from the opposite side that if airlines and ticket booking platform present the good performance of the flight on these aspects, their importance to influencing air travellers' flight choice behaviour can be shown.

Flight choice & willingness to fly experiment

In the stated choice experiment, the decision is made that the seriousness of the pandemic is depicted by the verbal description. The reason to do so is because of the heterogeneity of the respondents in regards to the pandemic situation familiarity. Therefore, the interpretation of the pandemic statistics from different respondents could vary. However, the verbal description, since it is a method based on subjective language understanding, has the disadvantage that it is unable to scientifically refer to the objective pandemic situation. Because there could still be a variance of seriousness perception based on the verbal description. Therefore, this study can be benefited from future studies which investigate the interpretation of the pandemic seriousness based on the pandemic statistics.

The context attribute, which is the seriousness of the pandemic, is considered by the respondent for giving the answer to the willingness to fly question. The description of the pandemic seriousness is made with the literal expression of the situation. However, no further information is given which indicates the travel recommendation from the government. Therefore, it is up to the respondents to decide if the government would give travel advice under a particular pandemic situation. This could create two problems. First, for those who have not assumed the existence of governmental travel recommendation, they give their WTF answer without the influence of the travel policy. Therefore, what they have considered is the pure pandemic situation described by the seriousness. For those who have, the influence of the policy should be taken into account, which is not in this research. Second, for those who have considered the travel policy, to what extent their WTF choice reflects their willing because of the pandemic situation and the imposed policy is unknown.

In the flight choice experiment, both the number of transfers and total travel time which are correlated are presented to the respondents. Although in the discrete choice modelling, only one attribute is added in the utility function, respondents could not be able to notice the fact that the amount of travel time always increases with the number of transfers. Therefore, they could assume that they are independent attributes. This might create a cross strengthening effect that the importance of one attribute is emphasized by another which results in the over-estimated attribute importance.

The number of transfers is incorporated in the flight choice experiment. In the case when it is higher than zero, it means people have to transfer. However, this research assumes that the connecting flight(s) have the same performance in terms of travel convenience and health safety, which could be conflicting to the reality when the connecting flight could be from different airlines. Therefore, this setup can tell the general idea of the importance of these perceived attributes but they might not be able to reflect the complexity that air travelling has.

11 Recommendations & implications

11.1. Recommendations

According to the result of the thesis, there are some recommendations for policy makers:

Airlines and the industry

- Air passengers' perception of travel convenience of a flight trip is positively influenced by the airlines' free flight cancellation policy and money refund (instead of in vouchers) policy but adversely influenced by requirement of health statement and virus test result. Airlines could improve the convenience performance of their flights by using the above result despite the fact that the requirement of the virus test result is often charged by the authority of the destination country.
- Air passengers' perception of the health safety of a flight is positively influenced by the applied virus precautionary measures onboard. The more infection preventive measures are taken, the safer passengers will feel. Face mask-wearing obligation and onboard social-distancing measures in terms of empty neighbour sit policy have an outstanding performance on improving health safety perception. Airlines could improve the health safety levels of their flights by applying useful measures including the above two.
- Facing the low travel demand because of passengers' reduced willingness to fly due to the pandemic, airlines could implement a set of measures to reduce the impact including making their service cheaper, faster, safer and more convenient. However, all those efforts combined are unlikely to totally offset the negative impact on willingness to fly that is brought by the pandemic itself. In addition, imposing all attribute improvement measures could lead to poorer profitability. In that case, the sustainability of the operation can be questionable. Therefore, airlines receiving impact from the low travel demand during the COVID-19 pandemic is unfortunately inevitable.
- With respect to airline competition, although making flight cheaper, faster, safer and more convenient all contribute to improving airline market share, The COVID-19 pandemic makes the transfer, travel time and onboard health safety measures extra important to the competition. Airlines could gain more market share by offering their customer safer and non-stop flight. Low-price operating strategy may not be as effective as it could be in the non-pandemic situation.
- The safety aspect has been underscored during the COVID-19 pandemic and has played an important role in passengers' air travel behaviour. The need for safe travel should not only be paid attention by airlines but also the entire industry including plane manufacturers, airports and the governments.

Government

- Air passengers' travel behaviour is a complex consequence of many different socio-economic aspects including travel policy, public risk perception and airline operation. Therefore, when governments focus on the influence of pandemic travel policies on restricting population mobility, influences from other aspects should not be overlooked.
- Governments need to be aware of the influence of airline operation strategies on encouraging the public to travel, especially considering the fact that air transport facilitates the pace of global transmission.
- Public risk perception translate the actual risk of the COVID-19 pandemic and results in health-protective behaviours in terms of trip cancellation and postponement. Governments could use this connection to influence public travel behaviour to reduce population movement for the good of controlling the pandemic.
- Passengers' willingness to fly has a strong connection to the seriousness of the pandemic. Therefore, policy decision-makers should never underestimate the rebound of travel motivation in order to avoid the uncontrollability of the pandemic when the situation gets better.
- The low travel demand during the COVID-19 pandemic can be largely ascribed to the high sensitivity of the air travellers to the risk of the virus. So as long as the pandemic continues, it will have a major impact on the demand for air travel and thus the survival of airlines. Combined with the expectation for the continuation of the pandemic, the government can use this knowledge to work out a more sustainable supporting contract with airlines for a longer period of time.

The COVID-19 pandemic changes many different socioeconomic aspects which influence air passenger's travel behaviour. The change in air travel behaviour does not only affect the development of the aviation industry but also impact many different aspects. Therefore, relevant stakeholders should pay attention to these changes for the good of their objectives.

11.2. Insights in a bigger picture

There are several points to be generated out from this research in the light of existing knowledge and the author's considerations.

- The reduced willingness to fly of the air travellers does not only show its impact on airline operation and the development of the COVID-19 pandemic but also influence the accessibility of the destination. Although this thesis only considers the seriousness of the pandemic as an aggregated context in Europe, which does not take the pandemic situation of the exact destination of the air trip into account, willingness to fly still shows a dramatic decrease. This willingness to fly reduction can be understood as the consequence of reduced accessibility from the perspective of the destination. On the other hand, the ability of flight attributes to improve the willingness to fly shows that the accessibility level can be improved by the overall performance of the travel mode.

- Governments in dealing with the COVID-19 pandemic situation, in general, are facing the dilemma between saving people and saving the economy. Advance on one side could lead to a setback on the other side. This dilemma also reflects on decision-making in air transport. On one hand, it facilitates virus propagation globally. On the other hand, air transport keeps every destination accessible. This supports global trade and national tourism which carry on the economy. Some governments want to keep a balance between two ends, for example, keeping the air transport operating to a certain extent and funding the airlines to survive. But it becomes more and more clear that this strategy results in a longer suffering for both the airline industry and the national economy.
- COVID-19 pandemic as the crisis to the society also brings opportunities for the changes. It provides the political window for the implementation of some policies that have not been able to execute. One example is working from home policy, although it has been proposed and discussed for decades in Dutch society. It had never been able to be massively promoted. COVID-19 pandemic reduces the resistance to conducting the try-out. The same could happen in the air transport industry. The air transport industry has been argued to create too much population (Colvile et al., 2001) therefore, to be one of the biggest contributors to the process of global warming. The crisis that the COVID-19 pandemic creates for the airline industry provides such a chance to improve the situation. As previously concluded, as long as the pandemic does not disappear, the low travel demand will retain, therefore, the industry will be suffering and relying on the governmental bailout. As the rescuer of the airlines and therefore, the industry, this gives governments a better position to work out a resolution. Therefore, policy-maker should not waste this chance to make the development of the economy more sustainable.

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Appendix A: Academic paper

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Analysing the influence of the COVID-19 pandemic on air travellers' flight choice behaviour and willingness to fly: An approach of stated choice experiment

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ARTICLEINFO

Article history:
Received 29 March 2021

Keywords:

COVID-19
Air travel behaviour
Flight choice
Willingness to fly
Stated choice experiment

ABSTRACT

COVID-19 has greatly impacted the development of the passenger air transport industry. This paper studies the impact of the pandemic on two air travel choices, the flight choice and the choice between flying or not flying during the pandemic. A stated choice experiment was carried out to analyse the changes in trading-off across flight attributes for the decision-making of the above two choices under three pandemic seriousness levels. It was found out that the COVID-19 pandemic changes the importance of attributes. The importance of the flight ticket reduces during the pandemic while the importance of layover, travel time and the perception of health safety (influenced by the intensity of the precautionary measures onboard) increase. By adjusting operational and marketing strategy in accordance with the results from this research, airlines have the potential to attract more customers to fly. On the other hand, the government should be aware of this and the strong connection between low willingness to fly and high pandemic seriousness to have better control of the global transmission.

1. Introduction

The COVID-19 pandemic which broke out in 2019 shows its impact on the air transport industry. A dramatic scale-down of air transport capacity was observed in 2020 when the number of seats offered by airlines reduced by 51% worldwide (ICAO, 2020). This result can be ascribed to two reasons. First, after the outbreak, many governments imposed stricter travel regulations to restrain population movement and to slow down international air transport (Sun et al., 2020). Second, the travel demand was reduced by the pandemic. The public generally expressed their concerns about the threat of the virus. Gerhold (2020) found in his research that people are particularly worried about possible infection in places with a high density of crowd such as public transportation.

As a result, the number of people who took flights in 2020 considerably decreased compared to previous years. According to the statistics (ICAO, 2020), a 2,887 to 2,892 million air passenger reduction worldwide was caused because of the COVID-19 pandemic in 2020.

Because the COVID-19 pandemic has heavily interfered with the development of the air transport industry, this research assumes that one of the contributors to such a heavy impact is the changes in the air travel behaviour of people during the pandemic.

However, air travel behaviour under the context of a pandemic has not been sufficiently studied by current literature. Some previous researches associated public risk perception with risk avoidance actions in order to explain the changes in how people behave during a pandemic (Bayham et al., 2015) & (Eiser et al., 2012). Their theories to some extent lay the foundation to explain air travel behaviour changes during a pandemic. There were also researches that observed some specific travel behaviour changes during a pandemic. Such changes include starting to wear masks and consulting doctors for recommendations (Lau et al., 2004), and postponing or cancelling trip plans (Fenichel et al., 2013). However, the impact of a pandemic on the way that air travellers make travel choices has been rarely studied. The incompletion of this knowledge makes it difficult to analyse the impact of the COVID-19 pandemic on passengers to explain the influence they create on the industry. This research dedicates itself to study the behaviour of two travel choices which are the choice between different flight alternatives (flight choice behaviour) and the choice between flying or not flying (willingness to fly) during the COVID-19 pandemic.

There are two important attributes of flights considered to be more influential on the above two travel choices, which are travel convenience and health safety. During the COVID-19, the development of the pandemic evolves rapidly. Governments impose or release travel policies over time which is hard to predict. This crates uncertainties on travel planning. On the other hand, in order to secure the safety of the cabin, some airlines also require their customers to present relevant safety proof before the check-in. These make air travelling more inconvenient during the pandemic. On the other hand, As a closed space, the cabin provides an ideal environment for the spread of the virus. Travellers could feel too risky to travel by planes which results in health-protective behaviours (Bermúdez, 1999). These behaviours can result in several changes in how people travel (Bish & Michie, 2010). Therefore, the roles of the perception of travel convenience and health safety in influencing air travel behaviour will be studied by this research.

The following research questions are formulated for this study:

- How do people perceive travel convenience and cabin health safety?
- How does the COVID-19 pandemic influence travellers' flight choice behaviour and willingness to fly?
- What are the best way for airlines to attract customers by improving flight attributes during the pandemic?

In order to answer the above research questions, the stated choice experiment will be applied. The two travel choice behaviours will be analysed by panel effect Mixed Logit (ML) model using stated choice data. This method has not been used to study the travel behavioural impact of an emergency incident such as a pandemic. This thesis will provide an example of using the stated choice experiment to study changes in travel choice behaviour during a global incident.

In the remainder of the thesis, a literature review about the possible impact of the global incidents on air travel behaviour is presented in Chapter 2. The methodology that the study used to answer the research questions and the design of the stated choice experiment is introduced in Chapter 3. Chapter 4 lists the result of the data analysis with necessary interpretations. Chapter 5 presents the result of a scenario study to more directly demonstrate the impact of the COVID-19 pandemic on the studied two air travel choices. The conclusions of the findings of the research and the discussion of some limitations can be found in Chapter 6 which is followed by some recommendations for the industry and the governments in Chapter 7.

2. Literature review

The airline industry is vulnerable to global incidents and has always been threatened by emergency context throughout history. Such emergencies and incidents are various in terms of armed conflict, terrorist attack, political unrest, economic recession, global pandemic and etc. These incidents generate uncertainties and bring a lot of impact on the industry and society. In this case, airlines are forced to take countermeasures including downsizing schedule, unloading asset, furloughing crews and retrenching budget which often results in industry downturns (Sobieralski, 2020).

The 9/11 incident, the terrorist attack that occurred in The United States in 2001, provides an example to understand the negative impacts of global incidents on air travel demand. Although temporarily, the terrorist attack in New York and Washington caused a complete shut-down of the national commercial aviation system. This created a short-term but massively strong setback on airline operation (Guzhva & Pagiavlas, 2004). The attack not only forced many travellers to reduce or avoid air travel because of a newly-perceived risk associated with it but also caused many companies to put a temporary freeze on business trip plans (Goodrich, 2002). Despite the fact that the immediate shock of September 11 is largely dissipated after 5 months, the attack created aftershocks imposing a more lasting impact on the demand for airline services.

It was suggested that this incident resulted in both a negative transitory shock of over 30% and a long-term negative demand influence amounting to roughly 7.4% of pre-September 11 demand in the US (Ito & Lee, 2005). The impacts of 9/11 overshadowed the travel demand in the U.S. for nearly 3 years. Until July 2004, the American air transport industry finally surpasses the pre 9/11 level of the number of passengers carried (USDOT, 2012).

In order to understand the long-term shock of the 9/11 event on the air transport industry, scientists took different perspectives to research travel behavioural factors laying behind the lasting low demand. One study ascribes this shock to the accumulation of travel anxiety due to terrorism's impact on the safety perception of air travellers (Baker, 2014). This phenomenon was particularly observed in the tourism industry. In consequence, trip makers' choice behaviour changed in choosing transportation modes and determining travel destinations. The public fear of being hijacked and attacked is attributed as the main reasons for such change. In order to improve the safety perception of air passengers, deploying more security facilities and implementing more security measures were adopted as a solution. However, redundant security measures made travelling by air more time-consuming and far less convenient than before. A further study notes that the implementation of such security equipment in the US's busiest airport could lead to 9% of air travel demand decrease (Blalock et al., 2007). Such an effect is especially noticeable on the demand for short-haul trips. For example, the number of passengers for the trip distance shorter than 250 miles was 26.2% fewer in June 2003 than in June 2001 (Ito & Lee, 2005).

A more detailed travel intention study (Floyd et.al, 2004) in the aftermath of the 9/11 event also adds up to understand the lasting low travel demand. The research presented more evidence to prove the negative impact of the attack on people's risk perception and linked it up to passengers' travel behaviour. It was found out that people's intention of making a flight trip for leisure purpose in 12 months after the 9/11 event was related to safety concerns, perceived social risk, travel experience and income level. The research team suggested that there is a strong correlation between high safety concerns and low travel intention. In other words, individuals who prioritize safety show less interest in travelling by plane after the attack. Secondly, social risk, represented by the disapproval of vacation plans by family and friends was also associated with a lower likelihood of taking a leisure trip after the attack. Other factors like air travel experience and income of passengers lay as positive contributors to the high intention of flying. Through their study, it has been highlighted the connection between global incidents and passengers' change in travel behaviour (in terms of the intention of travel by planes in this case).

The case of the 9/11 attack and its impact on the aviation industry shows that global incidents have the ability to greatly influence airline operation and to cause a huge financial loss by causing low air travel demand. One of the reasons for the weak market demand can be ascribed to a change in passenger's air travel behaviour. During the period of the COVID-19 pandemic, much evidence indicates that due to the fear of the potential infection and the effect of governmental actions, the air travel demand decreased dramatically. In the light of travel behavioural changes as the consequence of previous global incidents in terms of the 9/11 attack, the assumption is made that the industry downtrend that happens during the COVID-19 pandemic can be partly ascribed to changes in air travel behaviour.

3. Methodology

3.1 The Hierarchical Information Integration approach

As discussed in Introduction, travel convenience and cabin health safety are considered important as flight attributes during the pandemic. However, it is hard to objectively quantify them. Besides, if the experiment presents every objective indicator that could influence these two attributes in the experiment, it will end up having too many attributes overwhelming the respondents. Therefore, a way has to be found to measure and scale these two perceivable attributes.

A method inspired by Hierarchical Information Integration (HII) proposed by Louviere (1984), which was applied to study the perception of flight safety (Molin et al., 2017) provides a good example to avoid the issues. In Molin et al.'s research, it suggests that the perceived flight safety is influenced by the objective sub-attributes that influence safety perception. Therefore, they conducted a rating sub-experiment to presents objective safety performance of a flight that is described by several sub-attributes. Based on this, participants were asked to rate flight safety performance from 1 to 7 on a Likert Scale depending on how safe they perceive the given flight. This step enables them to get the scale of passengers' risk perception. After the rating sub-experiment, the perceived attribute is presented in the flight stated choice experiment to integrate the study for analysing the attribute trade-off between flight safety perception and other attributes.

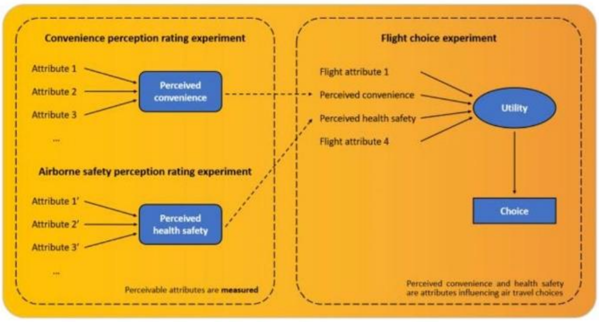


Figure 1: Graphical display of the structure of the experiment

In this study, the above method is adopted to overcome the issue of incorporating perceived attributes into stated choice experiment. This means, two perception rating sub-experiments will be conducted in order to obtain the scale and attribute value of perceived travel convenience and perceived cabin health safety. According to the main idea of HII, factors that could influence these two attributes should be grouped and presented as the sub-attributes in the perception rating sub-experiments. This rating sub-experiment is one-level-lower than the stated flight choice experiment. Two experiments will be bridged by the presenting of perceived attributes with other attributes in the stated flight choice experiment. The relationship between the two experiments is presented in Figure 1.

3.2 Sub-attributes for perception rating experiment

As discussed in Introduction, the requirement of paperwork that proves the travellers healthy could adversely influence travel convenience because, in order to fly, the health proof has to be acquired which costs time and possibly money. On the other hand, airlines also implement new policies to ease travellers' concern by providing more travel flexibility. Based on the above two aspects, the following sub-attributes for perceived travel convenience are determined:

- Requirement of a health statement issued by a general practitioner for checking-in.
- Requirement of a negative virus test result for checking-in.
- Charge policy for flight switching and cancellation.
- Refund policy for flight cancellation.

The sub-attributes and their levels are presented in Table 1.

Table 1: Attribute level specification for perceived travel convenience

Attribute	Levels
Health statement	Required: Passenger has to present a health statement issued by a general practitioner. Inessential: A health statement is not needed.
Virus test result	Required: Passenger has to present a negative virus result. Inessential: A negative virus result is not needed.
Trip cancellation & switching	Free: Passengers can cancel or change their flight without incurring any fee. Priced: Flight cancellation and switching are charged.
Refund method	Vouchers: Passengers get their refund in vouchers. Money: Passengers get their refund in money.

Due to the risk of possible spread of the COVID-19 in flight cabins, the implementation of virus precautionary measures is expected to improve travellers' health safety perception. Therefore, the following sub-attributes for perceived cabin health safety are determined:

- The implementation of a specially designed boarding strategy to minimize the human contact.
- The obligation of wearing mask onboard.
- The protection of cabin crews
- The supply of disinfection products
- The seat allocation method to keep social-distance

The sub-attributes and their levels are presented in Table 2.

Table 2: Attribute level specification for perceived health safety

Attribute	Levels
Sequential boarding and deboarding	Applied: Passengers sequentially board and disembark in accordance with seat location. Unapplied: Passengers board and deboard without following any rule.
Face masks mandatory	Applied: Passengers must wear mask onboard. Unapplied: Wearing mask is not an obligation
Protected flight attendants	Applied: Flight attendants are fully protected by virus prevention equipment. Unapplied: Flight attendants do not take precautionary measures.
Disinfection supplies offered	Applied: Disinfection supplies are provided free of charge. Unapplied: Disinfection supplies are not available on board.
Empty neighbour seats	Applied: The seats next to passengers are empty. Unapplied: The seat next to passengers can be taken by other passengers.

3.3 Attribute for flight stated choice experiment

In order to study flight choice behaviour and willingness to fly during the pandemic, the attributes of flight alternatives and the attribute of the choice context need to be defined.

The seriousness of the COVID-19 pandemic is added as the context attribute. Because it influences travellers' risk perception which leads to the health-protective behaviour to change the way of making air travel choices. The more severe the pandemic is, the heavier impact on choice behaviour is expected. The seriousness of the pandemic will be presented in 3 levels described by literal descriptions which are presented in Table 3.

Table 3: Attribute level specification of pandemic seriousness

Attribute	Levels
Pandemic seriousness	Serious pandemic: In Europe, the virus is wide-spread and most countries are labelled in red.
	Cautious pandemic: In Europe, the virus starts to quickly spread and most countries are labelled in yellow.
	Post-COVID: The virus has largely disappeared in Europe. Only a few countries are labelled in green holding a few cases.

The number of flight attribute is limited under five because presenting more than five attributes could result in overloading the respondents which could adversely affect the reliability of the model estimation (Caussade et al., 2005).

As the result, in total 4 attributes are selected to enter the stated choice experiment which is discussed below:

- Ticket price: Travel cost is one of the most important attributes to consider when people make travel choices. It also allows comparing the importance of the flight attributes by converting the importance of the attributes into the monetary cost.
- The number of transfer and total travel time: They are important because they represent the non-monetary costs of a trip, including the spending of effort and time. In this study, both attributes will be used to describe flight alternatives. However, they are set correlated because in reality they hardly vary independently.
- Perceived travel convenience: As discussed in Introduction COVID-19 pandemic creates more uncertainties which make air travelling less convenient. Therefore, this attribute is assumed to have an important role to affect passengers' flight choice and willingness to fly.
- Perceived cabin health safety: This attribute is selected for three reasons. First, it is a fact that COVID-19 can be spread in the cabin. Second, a large number of people are afraid of getting infected by the virus. Third, airlines implement a variety of precautionary measures to convince people that flying is still safe during the pandemic.

The flight attributes will be presented in 3 levels which are presented in Table 4.

Table 4: Attribute level specification for stated flight choice experiment

Attribute	Levels
Ticket price	60€ 120€ 180€
Number of transfers	0 1 2
Travel time	3 hours 5 hours 7 hours
Perceived convenience	1 out of 5 (low convenience) 3 out of 5 (medium convenience) 5 out of 5 (high convenience)
Perceived safety	1 out of 5 (high risk) 3 out of 5 (medium risk) 5 out of 5 (low risk)

3.4 Experiment structure and attributes inclusion

The stated choice experiment consists of two levels of experiments. In the first level, the stated flight choice experiment tests respondents' attribute preference for choosing preferred flight alternatives and deciding whether they want to fly. The attributes that are used to describe the performance of the flight alternative and the choice-making context are discussed in Chapter 3.3. In the second level, two perception rating sub-experiments are carried out to scale the perceived attributes of travel convenience and health safety under the pandemic condition. The factors influencing them are determined in Chapter 3.2. Two levels of the experiments are integrated by presenting perceived attributes in the stated choice experiment, where the choice between flight alternatives and flying and not flying are observed. The structure of the experiment is illustrated in Figure 2.

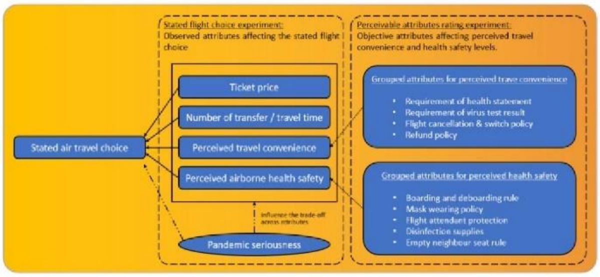


Figure 2 - The experiment structure and attribute inclusion

3.5 Stated choice question design

The design of the perception rating sub-experiment presents the combination of the sub-attributes that influence the perceived attributes including air travel convenience and cabin health safety. The rates that the respondents are allowed to give start from 1 to 5, which range from "very inconvenient" or "very unsafe" to "very convenient" or "very safe". An example question is presented in Figure 3.

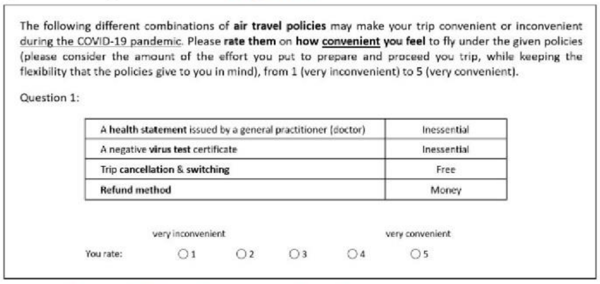
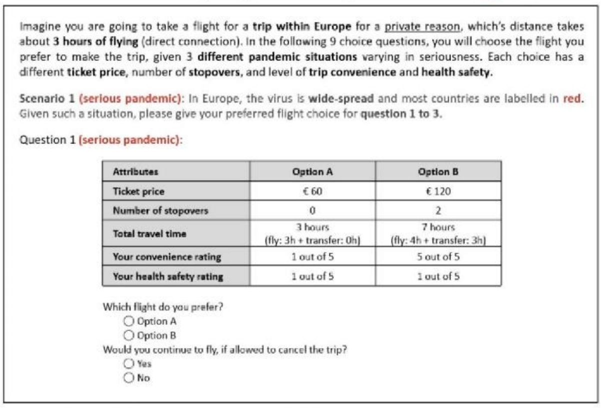


Figure 3: Example question of travel convenience perception

The design of the flight choice and willingness to fly questions has to assure that respondents give their choice answer based on the same context. Therefore, an instruction is given before the stated flight choice questions to specify the choice-making context which defines the purpose of the trip, the distance of the trip that the flight choice is for and the seriousness level of the COVID-19 pandemic. Each flight choice question includes 2 alternatives. Respondents give their preferred flight choice and then declare if they will choose the opt-out if they are allowed not to fly based on the given pandemic seriousness and the attributes of the chosen flight alternative. An example question is presented in Figure 4.


Imagine you are going to take a flight for a **trip within Europe** for a private reason, which's distance takes about **3 hours of flying** (direct connection). In the following 9 choice questions, you will choose the flight you prefer to make the trip, given 3 **different pandemic situations** varying in seriousness. Each choice has a different **ticket price**, number of **stopovers**, and level of **trip convenience** and **health safety**.

Scenario 1 (serious pandemic): In Europe, the virus is **wide-spread** and most countries are labelled in **red**. Given such a situation, please give your preferred flight choice for **question 1 to 3**.

Question 1 **(serious pandemic)**:

Attributes	Option A	Option B
Ticket price	€ 60	€ 120
Number of stopovers	0	2
Total travel time	3 hours (fly: 3h + transfer: 0h)	7 hours (fly: 4h + transfer: 3h)
Your convenience rating	1 out of 5	5 out of 5
Your health safety rating	1 out of 5	1 out of 5

Which flight do you prefer?
- Option A
- Option B

Would you continue to fly, if allowed to cancel the trip?
- Yes
- No

Figure 4: Example question of flight choice and willingness to fly

Each respondent faces 8 perception rating sub-experiment questions for air travel convenience and cabin health safety respectively and 9 flight choice and willingness to fly questions.

3.6 Model estimation methods

Although the rate given by the respondents for the For the perception rating sub-experiment, the linear regression models are used to analyse respondents' perception of travel convenience and airborne health safety based on the rates they give. In order to apply linear regression for the perceived attributes, the assumption is made that the scaling of perceived attributes is of interval measurement. In other words, the interpolation for unselected intermediate values is possible.

Since it is assumed that there is a linear relationship between the dependent variables and the independent variables, the models for travel convenience and health safety can be represented by the functions formulated below which also include the interaction effects from respondents' background characteristics:

Perceived travel convenience

$$Con = C + \beta_{HS} \cdot HS + \beta_{VT} \cdot VT + \beta_{CS} \cdot CS + (\beta_{RM} + \beta_{RM}^{Flew} \cdot Flew) \cdot RM + Gender + Age + Freq$$

Where: Con = perceived travel convenience score that respondents rate, C = regression constant, β_i = the parameter estimated for each level of sub-attributes, HS = dummy coded variable for whether a health statement is required, VT = dummy coded variable for whether a virus test result is required, CS = dummy coded variable for whether switching or cancelling flight is charged, RM = dummy coded variable for whether the refund is in money or vouchers, $Flew$ = if the respondent has flew during the COVID, Age = Respondent's age, $Freq$ = respondent's frequency of flying

Perceived cabin health safety

$$Safety = C + \beta_B \cdot B + (\beta_M + \beta_M^{Gender} \cdot Gender) \cdot M + \beta_C \cdot C + \beta_D \cdot D + \beta_S \cdot S + Gender + Age + Freq$$

Where: Y = perceived health safety score that respondents rate, C = regression constant, β_i = the parameter estimated for each level of sub-attributes, B = dummy coded variable for whether sequential boarding and disembarking rule is applied, M = dummy coded variable for whether wearing mask is obligatory onboard, C = dummy coded variable for whether cabin crews are well protected by precautionary equipment, D = dummy coded variable for whether the disinfection products are freely supplied. S = dummy coded variable for whether the neighbour seats are empty, Age = Respondent's age, $Freq$ = respondent's frequency of flying.

For analysing the stated choice data, the Random Utility Theory is used as the criteria that respondents rely on to determine the best choice. As for the choice model, the panel effect Mix Logit (ML) model is applied for choice modelling.

The study of willingness to fly choice behaviour needs to consider respondents' choice of the opt-out. However, when the number of respondents who choose the opt-out increase, it will result in less trade-off information across flight attributes which influence the study of flight choice behaviour. Therefore, the following decidison are made: for studying the flight choice behaviour, the choice of the opt-out will not be considered while for studying the willingness to fly, the choice of the opt-out is considered. The utility models that are used to study flight choice behaviour and willingness to fly are presented below:

Flight choice behaviour:

$$\begin{aligned} V_i =& (\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i + \\ & (\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i + \\ & (\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i + \beta_{ConvSqu} * Conv_i^2 + \\ & (\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i + \beta_{SafetySqu} * Safety_i^2 \end{aligned}$$

Willingness to fly:

$$\begin{aligned} V_i =& (\beta_{Fare} + \beta_{PanFare1} * Pan_1 + \beta_{PanFare2} * Pan_2) * Fare_i + \\ & (\beta_{Trans} + \beta_{PanTrans1} * Pan_1 + \beta_{PanTrans2} * Pan_2) * Trans_i + \\ & (\beta_{Conv} + \beta_{PanConv1} * Pan_1 + \beta_{PanConv2} * Pan_2) * Conv_i + \beta_{ConvSqu} * Conv_i^2 + \\ & (\beta_{Safety} + \beta_{PanSafety1} * Pan_1 + \beta_{PanSafety2} * Pan_2) * Safety_i + \beta_{SafetySqu} * Safety_i^2 \\ & + \beta_{Fly} + \beta_{Pan1} + \beta_{Pan2} \end{aligned}$$

Where: $\beta_{Fare} \sim N(\beta_{Fare}, \sigma_{\beta_{Fare}})$, $\beta_{Trans} \sim N(\beta_{Trans}, \sigma_{\beta_{Trans}})$, $\beta_{Conv} \sim N(\beta_{Conv}, \sigma_{\beta_{Conv}})$, $\beta_{Safety} \sim N\left(\beta_{Safety}, \sigma_{\beta_{Safety}}\right)$, $Fare_i$ = ticket price, $Trans_i$ = number of transfer, $Conv_i$ = respondents' rate of the flight convenience, $Safety_i$ = respondents' rate of the airborne health safety measures. Pan_1, Pan_2 = different pandemic seriousness level. β_{Fare} , β_{Trans} , β_{Conv} , β_{Safety} = coefficients of each attribute. $\beta_{PanFare1}$, $\beta_{PanTrans_1}$, $\beta_{PanConv_2}$, $\beta_{PanSafety_2}$, *etc.* = context effects from different pandemic seriousness levels on the above flight attributes. The index number represent the effect from different pandemic seriousness levels. β_{fly} stands for the constant utility of flight alternatives. β_{pan1} , β_{pan2} stand for the constant utility of different pandemic seriousness levels, which represent their impacts on flight alternatives.

The context attribute is dummy coded. The coding method of the context attribute is listed in Table 5 below:

Table 5: Coding rule of context attribute

Attribute level	Pan_1	Pan_2
Serious pandemic	1	0
Cautious pandemic	0	1
Non-pandemic	0	0

3.7 Data collection and sample

The recruitment of the sample should comply with the design of the experiment. Because the stated choice questions are based on air travel within Europe, the population was defined as individuals aged 18 years or older who have living and air travelling experience in the EU. The sample recruitment was accomplished via the author's social network. The questionnaires were handed out through several social-networking applications. Secondary forward was also encouraged which means experiment participants can also send the invitation by sharing the questionnaire link. This resulted in a sample of in total of 143 respondents who completely filled out the survey in December 2020.

Table 6 present the frequency distribution of the background variables. Some characteristics in terms of gender, flying frequency, shared accommodation members and whether having flying experience during the COVID-19 pandemic have a relatively even distribution. However, some characteristics show the special features of the sample group. Firstly, the sample largely consists of the generation of young-adult falling into the age between 19 to 39. This could lead to some specific travel preference tendencies due to the stage of life (Davison & Ryley, 2013). Secondly, the education level of the respondents is averagely too high because the majority of them have acquired a graduate degree, MSc or equivalence. The education level affects people's risk perception and potentially other travel choice behaviour in terms of the trade-off between safety and other attributes. Thirdly, the distribution of annual gross household income tends to be a bit skewed to the lower values.

Table 6: Distribution of background characteristics (n=143)

Characteristics & Categories	% of respondents (number of people)
Gender	
Male	45% (65)
Female	53% (76)
Unknown	1% (2)
Age	
< 18	0% (0)
18 - 25	66% (94)
26 -35	29% (42)
36 - 45	3% (5)
46 - 55	1% (1)
> 55	1% (1)
Education	
Primary school, secondary school	0% (0)
High school, college, professional education	3% (5)
Under graduate degree, BSc	20% (29)
Graduate degree, MA, MSc	71% (101)
PhD or above	4% (6)
Others	1% (1)
Unknown	1% (1)
Annul gross household income (€)	
< 10.000	29% (41)
10.000 - 20.000	8% (12)
20.001 - 30.000	6% (9)
30.001 - 40.000	10% (14)
40.001 - 50.000	3% (5)
50.001 - 60.000	3% (5)
60.001 - 70.000	1% (1)
70.001 - 80.000	3% (5)
80.001 - 90.000	3% (4)
90.001 - 100.000	3% (4)
> 100.000	5% (7)
Unknown	25% (36)
Sharing accommodation with members in age categories:	
Children (0 - 12 years)	8% (12)
Adolescences (13 - 18 years)	6% (9)
Young adults (19 - 39 years)	60% (86)
Middle-aged adults (40 - 59 years)	21% (30)
Senior adults (60 years and above)	6% (9)
Flying frequency before the COVID-19	
Less than once per year	6% (9)
Once per year	13% (19)
2 to 3 times per year	36% (51)
3 to 5 times per year	28% (40)
More than 5 times per year	17% (24)
Whether flew during COVID-19	
Yes	43% (61)
No	57% (82)

4. Results

4.1 Linear regression estimation for attribute perception

For studying the influence of respondents' background characteristics on their perception of attributes, respondents who chose "prefer not to say" for some personal questions in terms of income, education and etc. have not been included in this analysis. This results in a relatively smaller sample group (n=106).

The result of the linear regression analysis for the air travel convenience perception is presented in Table 6.

Table 7: Linear regression result for air travel convenience (n=106)

Parameter	Coef.	S.E	t-stat	p-value
Constant	3.7696	0.2321	16.2443	0.0000
Main effects:				
Health statement				
Required	-0.5000	0.0763	-6.5526	0.0000
Inessential	0.0000			
Virus test				
Required	-0.2594	0.0763	-3.3999	0.0007
Inessential	0.0000			
Cancellation & Switch				
Charged	-0.6604	0.0763	-8.6544	0.0000
Free	0.0000			
Refund method				
Voucher	-0.6158	0.0914	-6.7349	0.0000
Money	0.0000			
Interaction effects:				
Refund method * Flew during COVID				
Yes	-0.2444	0.1112	-2.1970	0.0283
No	0.0000			
Gender				
Female	0.1327	0.0774	1.7140	0.0869
Male	0.0000			
Age	-0.0080	0.0066	-1.2228	0.2217
Flying Frequency	0.0634	0.0376	1.6882	0.0917
Observations = 848				
R Square = 0.2084				

The parameter estimation shows that charging for cancelling or switching flights has the highest influence on people's convenience perception with a coefficient of -0.6604. The second important attribute is voucher refund policy (-0.6158). The coefficient of requirement of a health statement is -0.5000 which make it the third important main effect followed by the requirement of a virus test result (-0.2594). Note that a group of respondents who view the requirement of a virus test result positive to the perceived convenience was found by the latent class analysis. The result details of it is not discussed in this research. This explanation for this is they think the requirement of a virus test result makes travelling safer which helps to avoid the potential inconvenience in case of accidently being infected. Therefore, it is accepted to sacrifice the short-term inconvenience for acquiring a negative virus test result.

Some interaction effects are observed. The first is from the respondent's gender. The constant coefficient for female respondents is 0.1327. Meaning females give higher rates for travel convenience than males. The second is from respondents' age. The negative sign of the coefficient means that with the increase in respondents' age, travel convenience becomes more important. This is reasonable because the senior group can feel more difficult to deal with complicated procedure for air travel. Third, flying frequency has a positive effect on increasing people's travel convenience perception. Last, the flying experience during the COVID-19 pandemic is found to have an influence on people's perception of refund policy. The coefficient of -0.2444 for those who flew during the pandemic indicates that their convenience perception is more adversely impacted by refunding in vouchers. Their flying experience during the pandemic can be attributed to this preference difference.

The result of the linear regression analysis for the health safety perception is presented in Table 7.

Table 8: Linear regression result for cabin health safety (n=106)

Parameter	Coef.	S.E.	t-stat	p-value
Constant	1.2556	0.1937	6.4821	0.0000
Main effects:				
Boarding & Deboarding				
Applied	0.5142	0.0621	8.2776	0.0000
Unapplied	0			
Mandatory mask wearing				
Applied	0.9510	0.0895	10.6198	0.0000
Unapplied	0			
Protected flight attendants				
Applied	0.6934	0.0621	11.1634	0.0000
Unapplied	0			
Free disinfection supplies				
Applied	0.6132	0.0621	9.8724	0.0000
Unapplied	0			
Empty neighbour seats				
Applied	0.7830	0.0621	12.6063	0.0000
Unapplied	0			
Interaction effects:				
Mask*Gender				
Female	0.3308	0.1243	2.6613	0.0079
Male				
Gender				
Female	-0.5127	0.0885	-5.7952	0.0000
Male				
Age	-0.0179	0.0053	-3.3482	0.0008
Flying frequency	0.0400	0.0300	1.3339	0.1826
Observations = 848				
R Square = 0.4959				

The coefficient of the main effect of the sub-attributes suggests that every precautionary measure could improve respondents' perceived health safety and make them feel safer. However, the value differences between parameters indicate that the contribution of each is different. As the most commonly adopted measure to prevent virus transmission, the mandatory mask-wearing rule appears to be the most important (0.9510). Empty neighbour seat policy takes second place (0.7830) which reduce transmission risk by keeping the distance between passengers. The third and fourth places are flight attendants' protection (0.6934) and free disinfection supplies (0.6132). The sequential boarding measure is considered to be the least important measure among all presented measures (0.5142).

Some interaction effects are also observed. The first is from gender. Females averagely give a 0.5127 lower rate for the perceived safety than males. This result can be linked to the assumption that females are more risk-conservative than males. The second factor is respondents' age which has a similar effect as gender does. With the growth of age, people tend to give lower rate for health safety. This can be explained by the fact that the COVID-19 pandemic has a more severe impact on the health of senior people. Third, flying frequency of the respondents is found to have a positive effect on giving a higher safety rate. This can be explained by their flying experience which has similarities with Floyd et.al's (2004) conclusion that frequent flyers were less impacted by the fear of the 9/11 attack. Last, a positive coefficient of 0.3308 for the interaction effect of gender on the importance of mask shows that compulsory mask-wearing policy creates more safety perception for females than males. It can be also understood that females think wearing a mask is more important than males.

4.2 Choice model estimation for flight choice behaviour

The data analysis for flight choice behaviour only considers the respondents' choice of flight alternatives regardless of the choice of the opt-out. The COVID-19's impact on the trade-off that respondents make across the flight attributes will be analysed.

Table 9: ML model estimation without considering the opt-out

Parameter	Coef.	S.E.	t-stat	p-value
Main attributes				
Ticket price (TP)	-0.0258	0.0030	-8.5300	0.0000
Number of transfers (NT)	-1.1000	0.1880	-5.8700	0.0000
Perceived convenience (PC)	0.6190	0.2020	3.0600	0.0022
Quadratic convenience (PC^2)	-0.0567	0.0311	-1.8200	0.0687
Perceived safety (PS)	1.4100	0.2650	5.3200	0.0000
Quadratic safety (PS^2)	-0.1710	0.0394	-4.3300	0.0000
Context Attributes				
TP - Serious pandemic	0.0046	0.0038	1.2200	0.2240
TP - Cautious pandemic	0.0088	0.0035	2.5500	0.0108
NT - Serious pandemic	-0.7660	0.3190	-2.4000	0.0163
NT - Cautious pandemic	-0.5860	0.2780	-2.1100	0.0348
PC - Serious pandemic	-0.0800	0.1160	-0.6900	0.4900
PC - Cautious pandemic	0.0852	0.1110	0.7690	0.4420
PS - Serious pandemic	0.6020	0.1350	4.4400	0.0000
PS - Cautious pandemic	0.3570	0.1220	2.9300	0.0034
Taste variance				
Sigma - TP	0.0126	0.0021	6.0600	0.0000
Sigma - NT	0.6990	0.1460	4.7700	0.0000
Sigma - PC	0.1580	0.0715	2.2100	0.0271
Sigma - PS	0.4270	0.0751	5.6900	0.0000
Model Descriptive				
Null log-likelihood	-1541.907			
Final log-likelihood	-663.522			
rho-square	0.57			
Number of observation	1287			

First, the estimation of the main attribute effect complies with the expectation. The coefficients of ticket price (-0.0258) and number of transfers (-1.1000) are minus. Which means the increase in these attributes results in a lower utility leading to a lower choice probability of the alternative. On the other hand, the coefficients for travel convenience (0.6190) and health safety (1.4100) are positive. Which means that a flight with higher levels of these attributes has a higher chance to be chosen. The parameters for convenience square (-0.0567) and safety square (-1.1710) verify the quadratic effects on these two attributes. The negative signs of the coefficients mean that as the levels of the attributes increase, the importance of them reduces. In other words, these attributes matter more when they are at a low level than a high level.

Second, the parameter estimation for the effects of the context attributes also provides some interesting results. The coefficients for both levels of context effect on ticket price (0.0046 during a serious pandemic and 0.0088 during a cautious pandemic) are positive. This means that the negative contribution of the ticket price becomes smaller during the COVID-19 pandemic. In other words, the importance of the ticket price reduces during the COVID-19 pandemic. It can be understood that respondents are willing to accept a higher price in exchange for the improvement of other attributes. On the other hand, the results suggest that, during the COVID-19 pandemic, number of transfers and travel time become more important (-0.7660 for the serious pandemic and -0.5860 for the cautious pandemic). This complies with the previous expectation because more transfers and longer travel time increase the exposure under the infection risk. Therefore, people are more willing to reduce them during the pandemic period than the non-pandemic period. The parameters of the context effects on travel convenience have high p-values which makes their estimation unreliable. As the last context effects, the pandemic's impacts on health safety is consistent with the expectation. People care this attribute more during the pandemic. And the importance of it becomes higher when the seriousness of the pandemic increases (0.6020 for the serious pandemic and 0.3570 for the cautious pandemic).

4.3 Choice model estimation for willingness to fly

The data analysis for the willingness to fly considers both the respondents' choice of flight alternatives and the opt-out. When the opt-out is chosen, the respondent's choice of the flight will be ignored. In other words, respondents are seen as making choices among three alternatives.

Table 10: ML model estimation with considering the opt-out

Parameter	Coef.	S.E.	t-stat	p-value
Main attributes				
Ticket price (TP)	-0.0195	0.0020	-9.6200	0.0000
Number of transfers (NT)	-0.7760	0.1370	-5.6800	0.0000
Perceived convenience (PC)	0.5730	0.1900	3.0200	0.0025
Quadratic convenience (PC^2)	-0.0540	0.0299	-1.8000	0.0714
Perceived safety (PS)	0.3430	0.1960	1.7500	0.0799
Quadratic safety (PS^2)	-0.0093	0.0301	-0.3080	0.7580
Context Attributes				
TP - Serious pandemic	0.0084	0.0029	2.8700	0.0041
TP - Cautious pandemic	0.0105	0.0027	3.9400	0.0001
NT - Serious pandemic	0.0847	0.1850	0.4580	0.6470
NT - Cautious pandemic	0.0455	0.1780	0.2560	0.7980
PC - Serious pandemic	-0.3510	0.0900	-3.9000	0.0001
PC - Cautious pandemic	-0.1680	0.0846	-1.9800	0.0474
PS - Serious pandemic	0.2710	0.1000	2.7000	0.0070
PS - Cautious pandemic	0.0972	0.0934	1.0400	0.2980
Constant				
Pan1 - Serious pandemic	-3.8200	0.4810	-7.9300	0.0000
Pan2 - Cautious pandemic	-3.0800	0.4600	-6.6900	0.0000
Fly - Flight specific constant	2.6600	0.4170	6.3700	0.0000
Taste variance				
Sigma - TP	0.0068	0.0015	4.6200	0.0000
Sigma - NT	0.5320	0.1070	4.9500	0.0000
Sigma - PC	0.2550	0.0483	5.2900	0.0000
Sigma - PS	0.3330	0.0497	6.6900	0.0000

Model Descriptive	
Null log-likelihood	-2371.349
Final log-likelihood	-1097.009
rho-square	0.537
Number of observation	1287

Because the data for the model considers the choice of the opt-out, the trade-off information is not provided as much as the previous model. Therefore, there are some noticeable differences between the parameters that the two models estimate. The constant of β_{fly} is the utility base of both flight alternatives regardless of the pandemic context. When there is no pandemic, this is the only constant in the utility model. Because it has a relatively large positive coefficient of 2.66, it gives a high chance to choose either of the flight alternatives during the non-pandemic period. However, when there is a pandemic, the above utility advantage is offset by the impact of the pandemic. β_{pan2} represents the impact of the cautious pandemic on the utility of flight alternatives as a constant, which is -3.08. This could reduce the choice probability of flight alternatives. The negative impact becomes even larger when the pandemic escalates to serious, which has a coefficient of -3.82. These constant effects result in the reduction of the willingness to fly during the pandemic period.

5. Scenario studies

In order to show the impact of the COVID-19 pandemic on studied two choices better, two scenario studies were carried out using the estimated parameters of the first and second choice model respectively. The impact on flight choice behaviour will be represented by the changes in the choice probability of a flight alternative. And the willingness to fly will be represented by the changes in the probability of choosing either of flight alternatives.

5.1 Flight choice behaviour

In this scenario study, a choice situation that has 4 flight alternatives is created. Three of them are reference flights that have a medium level performance of all attributes (€120, 1 layover, 3/5 travel convenience, 3/5 health safety). The last flight is a variable flight that respectively applies different competition strategies by improving the level of each attribute to the highest level in the experiment to test their effects on improving the choice probability of the flight. Two pandemic contexts are tested, which are post-COVID and cautious pandemic. Note that because the opt-out option is not included, the assumption for this study is that people have already determined to make the trip. The result is presented in Table X.

Table 11: Choice probability of the variable flight

Attribute strategy	Post-COVID	Cautious pandemic
Medium Performance	25.0%	25.0%
Low Price	61.0%	48.0%
Less Transfer	50.0%	64.3%
High Convenience	31.7%	31.7%
High Health Safety	26.6%	42.5%
All Best	85.9%	94.0%

When the variable flight has the same attribute performance as the other 3 reference flights, the choice probability are the same as 25%. The choice probability of the variable flight can be increased by improving all attributes during whatever pandemic context. However, their effects are different. Under the post-COVID situation, reducing the price of the ticket from €120 to €60 is the most effective way to improve the choice probability. Less transfer strategy takes the second place to increases the choice probability to 50% when reducing by 1 transfer. Improving health safety measure during the Post-COVID period has a very marginal effect on increasing the choice probability. While implementing a high travel convenience strategy has the same result in choice probability improvement under both pandemic situations. During the cautious pandemic situation, the effectiveness of the low price strategy becomes less useful. The choice probability increment reduced by 13% to 48%. On the contrary, reducing travel time and the number of transfers can significantly improve the choice probability to 64.3%. The usefulness of improving health safety measures also increases the choose probability dramatically by about 16%.

5.2 Willingness to fly

In this scenario study, a choice situation with 2 flight alternatives having the same attribute performance and an opt-out alternative is created. The same operational strategies as the previous study will be applied to flight alternatives to test their effects on improving willingness to fly under 3 pandemic seriousness levels. The result is presented in Table X.

Table 12: Flying probability under different pandemic seriousness levels

Attribute strategy	non-pandemic	Cautious pandemic	Serious pandemic
Medium Performance	83.50%	55.00%	37.60%
Low Price	92.30%	61.90%	47.00%
Less Transfer	89.70%	65.50%	48.40%
High Convenience	87.20%	57.70%	34.40%
High Safety	88.00%	68.30%	60.90%
All Best	97.60%	83.30%	75.50%

As can be observed above, no matter what attribute strategy is adopted, the choice probability of flying is considerably decreased because of the pandemic. When the flight alternatives have medium attribute performance, the flying probability decrease from 83.5% when there is no pandemic to 55.0% when there is a cautious pandemic and further to 37.6% when the pandemic get serious.

The effectiveness of improving different flight attribute on increasing willingness to fly varies with the pandemic context. During the non-pandemic situation, the low price strategy has the best outcome in improving the chance that people fly (83.5% to 92.3%), which is followed by the less transfer strategy (to 89.7%). The third and fourth places are high safety and high convenience respectively. However, during the cautious pandemic, improving health safety becomes the best way to increase willingness to fly (from 55.0% to 68.3%), which is followed by less transfer strategy (to 65.5%), low price (to 61.9%) and high convenience (to 57.7%). During a serious pandemic, the order of the effectiveness of different attribute strategies remains the same as the cautious pandemic. When all the flight attributes are set to the best, the probability of flying is at a very high level. Under the serious pandemic context, the flights with the best attribute performance increase the flying chance from 37.6% to 75.5%.

6. Conclusions & discussions

This study uses the stated choice experiment to study the impact of the COVID-19 pandemic on travellers' flight choice behaviour and willingness to fly. It firstly identified air travel convenience and cabin health safety as two flight attributes that are important to travel choices during the pandemic. Then, a perception rating experiment was conducted to research how these two attributes are perceived and measured. The perception of air travel convenience is decreased by the requirement of the health-related documents, such as health statement and virus test result, and increased by the airline policies that improve travel flexibility, which includes free flight cancellation and money refund policies. The perception of cabin health safety is influenced by the adoption of virus precautionary measures. The obligatory rule of wearing a mask and regulations that maintain the social-distance are helpful to increase travellers' perception of health safety in the cabin.

Secondly, by conducting a stated choice experiment, it has been found that travellers' flight choice behaviour and the willingness to fly are heavily impacted by the COVID-19 pandemic. For the flight choice behaviour, travellers' sensitivity to the ticket price is reduced by the pandemic. They are more willing to spend more money for non-stop flights which apply high-level health precautionary measures. As for the willingness to fly, the chance of people making a flight trip decreases along with the pandemic getting serious.

Thirdly, the results of the scenario studies show that airlines could attract their customers by improving every attribute that is studied by this experiment during the COVID-19 pandemic. However, improving passengers' health safety perception onboard and providing non-stop flights are the best way to increase both willingness to fly and the choice probability of their services.

Although having outputted some interesting conclusions, this research also has some limitations which can be improved in the future. Firstly, the seriousness of the pandemic is presented in verbal description without showing any objective statistics in terms of the number of infection cases. This decision was made for the reason that people could interpret numbers differently because of the heterogeneity of their familiarity with the pandemic situation. However, this results in the inability to measure and scale the pandemic seriousness perception by the objective indicators, which could affect the extrapolation of the results of this research. Therefore, it leaves a research gap for future studies to fill. Secondly, the government's travel restrictive policies are considered to have a correlation to the pandemic seriousness and thus have an impact on air travel behaviour. In this experiment, there is no segmentation between the pandemic situation and the public travel policy. This results in respondents unavoidably associate these two factors. In other words, their choice could also to a certain extent reflect the impact of the travel recommendation given by the government. Such interfere can be isolated or filtered out by future researches.

7. Recommendations

Both the airline industry and the government can be benefited from this research. For airlines, it is possible to attract more customers to fly during the pandemic by improving their services. A precise demand forecast on routes is worth to be pursued because it allows airlines to better deploy their resources to offer non-stop flights to the market as much as possible. As it would help to considerably improve both travellers' willingness to fly and preference over their services. Improving the health-improving measures onboard and marketing them and making them transparent is another way for airlines to mitigate the negative impact created by the COVID-19 pandemic. On the other hand, governments need to be aware of the influence of airline operation strategies on encouraging the public to travel, especially considering the fact that air transport facilitates the pace of global transmission. Last but not least, passengers' willingness to fly has a strong connection to the seriousness of the pandemic. Therefore, policy decision-makers should never underestimate the rebound of travel motivation in order to avoid the uncontrollability of the pandemic when the situation gets better.

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Appendix B: Ngene syntax for the experiment design

Travel convenience perception sub-experiment design

```
Design
;alts = alt1,base
;rows = 6
;orth = seq
;model:
U(alt1)=b1*A[0,1]+b2*B[0,1]+b3*C[0,1]+b4*D[0,1]
$
```

Airborne health safety perception sub-experiment design

```
Design
;alts = alt1,base
;rows = 8
;orth = seq
;model:
U(alt1)=b1*A[0,1]+b2*B[0,1]+b3*C[0,1]+b4*D[0,1]+b5*F[0,1]
$
```

Flight choice experiment design experiment design

```
Design
;alts=alt1,alt2
;rows=9
;orth=seq
;model:
U(alt1)=b1*Fare[60,120,180]+b2*stopover[0,1,2]+b3*convenience[1,4,7]+b4*safety[1,4,7]/
U(alt2)=b1*Fare+b2*stopover+b3*convenience+b4*safety
$
```

Appendix C: SC experiment (variant 1)

preface

Dear respondent,

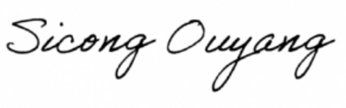
Thank you very much for taking the time to fill in this survey.

This questionnaire is a part of my master graduation thesis at the TU Delft. It aims to study air travel behaviour during the COVID-19 pandemic.

By answering the questions in this survey, you help us to understand the demands and preferences of air passengers during the pandemic, which could be used to improve the services of the airlines and the policy design of the government.

Note that this survey is fully anonymous and only for academic purpose. None of the data in this survey will be shared with others. Please feel free to contact me at Ouyang.sicong@gmail.com for any question regarding this research.

Best regards,



Part 1: Flying preference

We first ask you to answer a few questions about your flight behaviour.

1. How often did you travel by plane BEFORE the COVID-19 pandemic?

- Less than once per year
- Once per year
- 2 to 3 times per year
- 3 to 5 times per year
- More than 4 times per year

2. When was the last time you took a flight? (Please enter in mm-yyyy, for example: 01-2020 for January 2020)

____

3. If you take a flight for private reasons (not for work), please rank the following aspects based on their importance **BEFORE** the COVID-19 pandemic (drag and sort the options from the top to the bottom).

______Ticket price

______Total travel time

______Airline

______Services (entertainment, food, legroom, seating comfort)

______Type of the aircraft

______Safety & health

______Convenience & flexibility (booking, cancellation, refund)

4. If you take a flight for private reasons (not for work), please rank the following aspects based on their importance **DURING** the COVID-19 pandemic (drag and sort the options from the top to the bottom).

______Ticket price

______Total travel time

______Airline

______Services (entertainment, food, legroom, seating comfort)

______Type of the aircraft

______Safety & health

______Convenience & flexibility (booking, cancellation, refund)

Part 2.1: Travel convenience perception rating sub-experiment

The following different combinations of **air travel policies** may make your trip convenient or inconvenient during the COVID-19 pandemic. Please **rate them** on **how convenient you feel** to fly under the given policies (please consider the amount of the effort you put to prepare and proceed you trip, while keeping the flexibility that the policies give to you in mind), from 1 (very inconvenient) to 5 (very convenient).

An example question is presented below with the instruction of individual policy:

Policy	Setup
A **health statement** issued by a general practitioner (doctor)	Required
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Priced
Refund method	Money

1. You need to acquire a health statement for taking the flight.
2. You don't need to acquire a virus test result for taking the flight.
3. You will be charged if you cancel or change your flight.
4. You will be refunded in money rather than the vouchers in case of cancellation.

☆ Rate this air travel policy on how convenient you feel to make a trip

Your rate:

(very inconvenient) 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ (very convenient)

Question 1:

A **health statement** issued by a general practitioner (doctor)	Inessential
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Free
Refund method	Money

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 2:

A **health statement** issued by a general practitioner (doctor)	Required
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Free

Refund method	Vouchers

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 3:

A **health statement** issued by a general practitioner (doctor)	Required
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Priced
Refund method	Money

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 4:

A **health statement** issued by a general practitioner (doctor)	Inessential
A negative **virus test** certificate	Required
Trip **cancellation** & **switching**	Free
Refund method	Money

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 5:

A **health statement** issued by a general practitioner (doctor)	Inessential
A negative **virus test** certificate	Inessential
Trip **cancellation** & **switching**	Priced
Refund method	Vouchers

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 6:

A **health statement** issued by a general practitioner (doctor)	Required
A negative **virus test** certificate	Required

Trip **cancellation** & **switching**	Free
Refund method	Vouchers

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 7:

A **health statement** issued by a general practitioner (doctor)	Required
A negative **virus test** certificate	Required
Trip **cancellation** & **switching**	Priced
Refund method	Money

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Question 8:

A **health statement** issued by a general practitioner (doctor)	Inessential
A negative **virus test** certificate	Required
Trip **cancellation** & **switching**	Priced
Refund method	Vouchers

(very inconvenient) ☐1 ☐2 ☐3 ☐4 ☐5 (very convenient)

Part 2.1: airborne health safety perception rating sub-experiment

The following questions show different combinations of **precautionary measures** taken by an airline during the pandemic. Please **rate them** on **how safe you feel** to fly by their plane, from 1 (very unsafe) to 5 (very safe).

An example question is presented below with the instruction of individual precautionary measures:

Measures	status
Sequential **boarding** and **deboarding**	Applied
Passenger wearing a mask is mandatory	Unapplied
Flight crews wear protective equipment	Applied
Disinfecting suppliers are offered	Unapplied
Empty seats next to you	Applied

1. Passengers sequentially board in accordance with their seats location and fill up the cabin from the tail to the front to maximally avoid human contact.
2. Passengers don't have to wear a mask onboard.
3. Flight crews wear mask, gloves, visor etc.
4. No disinfection suppliers are offered onboard.
5. The neighbour seats are blocked so that no passenger sit directly next to you.

☆ Rate this trip policy package on how safe you feel to travel with this flight

Your rate:

(very unsafe)	1	2	3	4	5	(very safe)
	O	O	O	O	O	

Question 1

Sequential **boarding** and **deboarding**	Applied
Passenger wearing a mask is mandatory	Applied
Flight crews wearing protective equipment	Applied
Disinfecting supplies are offered	Applied
Empty seats next to you	Applied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 2

Sequential **boarding** and **deboarding**	Unapplied
Passenger wearing a mask is mandatory	Unapplied

Flight crews wearing protective equipment	Unapplied
Disinfecting supplies are offered	Unapplied
Empty seats next to you	Applied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 3

Sequential **boarding** and **deboarding**	Applied
Passenger wearing a mask is mandatory	Unapplied
Flight crews wearing protective equipment	Unapplied
Disinfecting supplies are offered	Applied
Empty seats next to you	Unapplied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 4

Sequential **boarding** and **deboarding**	Unapplied
Passenger wearing a mask is mandatory	Applied
Flight crews wearing protective equipment	Unapplied
Disinfecting supplies are offered	Applied
Empty seats next to you	Applied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 5

Sequential **boarding** and **deboarding**	Unapplied
Passenger wearing a mask is mandatory	Applied
Flight crews wearing protective equipment	Applied
Disinfecting supplies are offered	Unapplied
Empty seats next to you	Unapplied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 6

Sequential **boarding** and **deboarding**	Applied
Passenger wearing a mask is mandatory	Unapplied
Flight crews wearing protective equipment	Applied
Disinfecting supplies are offered	Unapplied
Empty seats next to you	Applied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 7

Sequential **boarding** and **deboarding**	Unapplied
Passenger wearing a mask is mandatory	Unapplied
Flight crews wearing protective equipment	Applied
Disinfecting supplies are offered	Applied
Empty seats next to you	Unapplied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Question 8

Sequential **boarding** and **deboarding**	Applied
Passenger wearing a mask is mandatory	Applied
Flight crews wearing protective equipment	Unapplied
Disinfecting supplies are offered	Unapplied
Empty seats next to you	Unapplied

(very unsafe) ☐1 ☐2 ☐3 ☐4 ☐5 (very safe)

Part 3: Flight choice experiment and willingness to fly questions

Imagine you are going to take a flight for a **trip within Europe** for a <u>private reason</u>, which's distance takes about **3 hours of flying** (direct connection). In the following 9 choice questions, you will choose the flight you prefer to make the trip, given 3 **different pandemic situations** varying in seriousness. Each choice has a different **ticket price**, number of **stopovers**, and level of **trip convenience** and **health safety**.

An example question with the answering instruction is presented below:

Question 1 **(serious pandemic)** → You answer this choice question under this pandemic seriousness situation

Attributes	Option A	Option B
Ticket price	€60	€120
Number of stopovers	0	2
Total travel time	3 hours (fly: 3h + transfer: 0h)	7 hours (fly: 4h + transfer: 3h)
Your convenience rating	3 out of 5	5 out of 5
Your health safety rating	1 out of 5	1 out of 5

→ Option B costs **120 euro.**

→ Option B makes **2 stops** in the trip.

→ Option B consists of **4h of flying time** and **3 h of transfer time.**

→ Option B has your **highest convenience rate.**

→ Option B has your **lowest health safety rate.**

Which flight do you prefer? ← ☆ Choose your **preferred flight** based on the attribute performance of two options.

- Option A
- Option B

Would you continue to fly, if allowed to cancel the trip? ← ☆ Indicate if you really want to make this trip given the selected flight option and the pandemic situation. (the trip plan will be aborted if choose **No**)

- Yes
- No

Scenario 1 (serious pandemic): In Europe, the virus is **wide-spread** and most countries are labelled in **red.**

Given such a situation, please give your preferred flight choice for **question 1 to 3.**

Question 1 **(serious pandemic)**

Attributes	Option A	Option B
Ticket price	€60	€120
Number of stopovers	0	2
Total travel time	3 hours (fly: 3h + transfer: 0h)	7 hours (fly: 4h + transfer: 3h)

Your convenience rating	1 out of 5	5 out of 5
Your health safety rating	1 out of 5	1 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 2 **(serious pandemic)**

Attributes	Option A	Option B
Ticket price	€180	€120
Number of stopovers	1	1
Total travel time	5 hours (fly: 3.5h + transfer: 1.5h)	5 hours (fly: 3.5h + transfer: 1.5h)
Your convenience rating	3 out of 5	1 out of 5
Your health safety rating	1 out of 5	3 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 3 **(serious pandemic)**

Attributes	Option A	Option B
Ticket price	€120	€180
Number of stopovers	2	2
Total travel time	7 hours (fly: 4h + transfer: 3h)	7 hours (fly: 4h + transfer: 3h)

Your convenience rating	5 out of 5	1 out of 5
Your health safety rating	1 out of 5	5 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Scenario 2 (cautious pandemic): In Europe, the virus **starts to quickly spread** and most countries are labelled in **yellow.**

Given such a situation, please give your preferred flight choice for **question 4 to 6.**

Question 4 **(cautious pandemic)**

Attributes	Option A	Option B
Ticket price	€120	€60
Number of stopovers	1	2
Total travel time	5 hours (fly: 3.5h + transfer: 1.5h)	7 hours (fly: 4h + transfer: 3h)
Your convenience rating	1 out of 5	3 out of 5
Your health safety rating	3 out of 5	3 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 5 **(cautious pandemic)**

Attributes	Option A	Option B
Ticket price	€60	€120

Number of stopovers	2	0
Total travel time	7 hours (fly: 4h + transfer: 3h)	3 hours (fly: 3h + transfer: 0h)
Your convenience rating	3 out of 5	3 out of 5
Your health safety rating	3 out of 5	5 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 6 **(cautious pandemic)**

Attributes	Option A	Option B
Ticket price	€180	€60
Number of stopovers	0	0
Total travel time	3 hours (fly: 3h + transfer: 0h)	3 hours (fly: 3h + transfer: 0h)
Your convenience rating	5 out of 5	1 out of 5
Your health safety rating	3 out of 5	1 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Scenario 3 **(post-COVID)**: The virus has **largely disappeared** in Europe. Only a few countries are labelled in **green** holding a few cases.

Given such a situation, please give your preferred flight choice for **question 7 to 9.**

Question 7 **(post-COVID)**

Attributes	Option A	Option B
Ticket price	€180	€180
Number of stopovers	2	1
Total travel time	7 hours (fly: 4h + transfer: 3h)	5 hours (fly: 3.5h + transfer: 1.5h)
Your convenience rating	1 out of 5	3 out of 5
Your health safety rating	5 out of 5	1 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 8 **(post-COVID)**

Attributes	Option A	Option B
Ticket price	€120	€60
Number of stopovers	0	1
Total travel time	3 hours (fly: 3h + transfer: 0h)	5 hours (fly: 3.5h + transfer: 1.5h)
Your convenience rating	3 out of 5	5 out of 5
Your health safety rating	5 out of 5	5 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Question 9 **(post-COVID)**

Attributes	Option A	Option B
Ticket price	€60	€180
Number of stopovers	1	0
Total travel time	5 hours (fly: 3.5h + transfer: 1.5h)	3 hours (fly: 3h + transfer: 0h)
Your convenience rating	5 out of 5	5 out of 5
Your health safety rating	5 out of 5	3 out of 5

Which flight do you prefer?

□ Option A

□ Option B

Do you really want to take this flight under this pandemic situation?

□ Yes

□ No

Part 4: Sociodemographic questions

Finally, we kindly ask you to answer a few sociodemographic questions (You answers is anonymous and will only be used for this research and not be shared with others):

1. Gender:

□ Male

□ Female

□ Prefer not to say

2. Year of the birth:

____

3. Do you share your accommodation with others in the following age categories?

	Yes	No
Children (0~12 years)	□	□
Adolescences (13~18 years)	□	□
Young adults (19~39 years)	□	□
Middle-aged adults (40~59 years)	□	□
Senior adults (60 years and above)	□	□

4. Highest Education:

□ Primary school, secondary school

□ High school, college, professional education

□ Undergraduate degree, BSc

□ Graduate degree, MA, MSc, PhD or above

□ Other, please specify:

□ Prefer not to say

5. Annual gross household income

□ €10,000 or less

□ €10,001 - €20,000

□ €20,001 - €30,000

□ €30,001 - €40,000

□ €40,001 - €50,000

□ €50,001 - €60,000

□ €60,001 - €70,000

□ €70,001 - €80,000

□ €80,001 - €90,000

□ €90,001 - €100,000

□ €100,001 or above

□ Prefer not to say

Part 5: Epilogue

Thank you! You have finished all the questions in this survey, I will be glad to hear any feedback from you.

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____

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Thank you very much for your help with this research. If you have any question regarding this research, please feel free to contact me at ouyang.sicong@gmail.com

Appendix D: Decision making of attribute levels

Flight choice attributes:

- Ticket price (TP): The selection of attribute levels for TP is highly influenced by the reference tickets searched by Skyscanner (a flight ticket order platform). Since the flight choice is made for the single not return, the median ticket price is selected as 120 euros which is about the average price of flight ticket for such distance of flying. However, considering the services and options offered by Low-Cost Carriers (LCC), the minimum ticket price is set as 60 euros (the lowest option found is 39 euros). Therefore, given the rule of equidistance rule for attribute levels, the maximum price should be 60 euros higher than the median price too. Thus, the maximum price is 180 euros. The flight searching is done in October 2020 when COVID-19 is still severe in some European countries.
- Number of transfer (NT): For most pairs of origin and destination within European continent, the direct flight and one-stop-flight can be found. However, sometimes two-stop-flight with a considerable discount can also be found, making them as an appealing option for those who have a low budget and a less sensitivity to time. In short, direct flight, one-stop-flight and two-stop-flight will be offered.
- Travel time (TT): As introduced in Chapter 6, travel time and number of transfers have strong correlation in reality. In the majority of cases, higher number of transfer equals to longer travel time. In this flight choice experiment, such reality will be reflected by a travel time fully correlated to number of transfers. The correlation rule between these two attributes has been set as each transfer adds 0.5 hour of transfer and 1.5 hour of extra flying time (because of extra approach, departure and detour). In other words, if it is a direct flight, the travel time should be 3 hours. Each extra transfer add another 2 hours to the total travel time. In short, the attribute levels of travel time comply with the number transfer. Levels of travel time are 3, 5 and 7 hours.
- Perceived convenience (PC): In the sub experiment, the convenience perception is expressed by a rate on a 5-point scale. The 5-point scale is selected for 2 reasons. The first one is because it offers the middle option that 6-point scale cannot provide. The second reason is because, comparing to 7-point scale, it avoids potential confusion among respondents as people might think the differences between 2 and 3 or 5 and 6 are not significant enough, which can create extra subjective rating errors. In the end, the minimum, average and maximum rates stood by 1, 3 and 5 are selected to enter the stated choice experiment.
- Perceived safety (PS): Same as perceived convenience, the 5-point scale is again used for expressing attribute level of perceived airborne health safety. The minimum, average and maximum rates stood by 1, 3 and 5 are selected to present to respondents in the flight choice survey.

Context attribute:

- Seriousness of pandemic: In Chapter 6, it has been determined that respondents grasp idea about the seriousness of the pandemic through literal description. Therefore, the proper way should be found to describe different levels to make sure that respondents can easily perceive the pandemic situation by reading the literal description. Since all of the respondents have residential experience in Europe and mostly in The Netherlands. The Dutch standard adopted by National Institute for Public Health and the Environment (RIVM) is taken to define the attribute levels of pandemic seriousness. According to RIVM Coronavirus Dashboard, the determination of a region's risk level is influenced by many factors. the level of risk is sorted into 4 levels: caution, concern, serious, and severe. Each level implies different intensity of countermeasures to deal with the virus. Since all above levels that are used by Dutch government refer the situation during the pandemic and none of which can actually describe the situation when the pandemic is largely vanished, a Post-COVID Level is introduced to describe the situation that most of world has successfully dealt with the virus and the risk of the pandemic is largely disappeared. As another extreme end of the spectrum, Serious Pandemic situation is selected to describe the situation when the pandemic is out of control. At last, Cautious pandemic is selected to describe the situation when the pandemic is propagation but still largely under control as the middle level. Since the positive effect of colour in helping people to better understand the literal description, red yellow and green will be used on font of respective seriousness levels to help the information delivery.

Perceived travel convenience:

- Requirement of health statement: As the special policy implemented during the pandemic, a health statement issued by a GP is sometimes required. The level of this attribute is binary which can only be required or not required.
- Requirement of virus test result: Same as the health statement, there is no middle value can be chosen for this attribute. Therefore, the level for this attribute can be either required to unessential.
- Charge of flight cancellation or change: In this experiment, two levels of the attribute will be presented to the respondents. Therefore, the selection of either free or changed that flight cancellation or change are made.
- Refund: During the COVID-19 pandemic, two refund methods are commonly applied, which are refunding in vouchers or in money.

Appendix E: Biogeme syntax for the final ML models

Mixed Logit model with 2 flight alternatives

```
import pandas as pd
import biogeme.database as db
import biogeme.biogeme as bio
import biogeme.models as models
import biogeme.version as ver
import biogeme.messaging as msg
from biogeme.expressions import Beta, DefineVariable, bioDraws, PanelLikelihoodTrajectory,
MonteCarlo, log
# Read the data
df = pd.read_excel('MNL_EXC_OPT_OUT.xlsx')
database = db.Database('CHOICE', df)
# They are organized as panel data. The variable ID identifies each individual.
database.panel("ID")
# The following statement allows you to use the names of the
# variable as Python variable.
globals().update(database.variables)
# Parameters to be estimated
B_COST = Beta('B_COST', 0, None, None, 0)
B_COST_SIGMA = Beta('B_COST_SIGMA', 1, None, None, 0)
B_COST_RND = B_COST + B_COST_SIGMA * bioDraws('B_COST_RND','NORMAL')
B_PanCost1 = Beta('B_PanCost1', 0, None, None, 0)
B_PanCost2 = Beta('B_PanCost2', 0, None, None, 0)
B_TRANS = Beta('B_TRANS', 0, None, None, 0)
B_TRANS_SIGMA = Beta('B_TRANS_SIGMA', 1, None, None, 0)
B_TRANS_RND = B_TRANS + B_TRANS_SIGMA * bioDraws('B_TRANS_RND','NORMAL')
```

```
B_PanTran1 = Beta('B_PanTran1', 0, None, None, 0)
B_PanTran2 = Beta('B_PanTran2', 0, None, None, 0)
B_TRANS_SQU = Beta('B_TRANS_SQU', 0, None, None, 0)
B_CONVE = Beta('B_CONVE', 0, None, None, 0)
B_CONVE_SIGMA = Beta('B_CONVE_SIGMA', 1, None, None, 0)
B_CONVE_RND = B_CONVE + B_CONVE_SIGMA * bioDraws('B_CONVE_RND','NORMAL')
B_PanConve1 = Beta('B_PanConve1', 0, None, None, 0)
B_PanConve2 = Beta('B_PanConve2', 0, None, None, 0)
B_CONVE_SQU = Beta('B_CONVE_SQU', 0, None, None, 0)
B_SAFE = Beta('B_SAFE', 0, None, None, 0)
B_SAFE_SIGMA = Beta('B_SAFE_SIGMA', 1, None, None, 0)
B_SAFE_RND = B_SAFE + B_SAFE_SIGMA * bioDraws('B_SAFE_RND','NORMAL')
B_PanSafe1 = Beta('B_PanSafe1', 0, None, None, 0)
B_PanSafe2 = Beta('B_PanSafe2', 0, None, None, 0)
B_SAFE_SQU = Beta('B_SAFE_SQU', 0, None, None, 0)
# Definition of option avaialbility
FLIGHTA_AV_SP = 1
FLIGHTB_AV_SP = 1
# Definition of the utility functions
V1 = (B_COST_RND + B_PanCost1 * PAN1 + B_PanCost2 * PAN2) * TP1 + \
    (B_TRANS_RND + B_PanTran1 * PAN1 + B_PanTran2 * PAN2) * TT1 + \
    (B_CONVE_RND + B_PanConve1 * PAN1 + B_PanConve2 * PAN2) * CON1 + B_CONVE_SQU
* CON1 * CON1 + \
    (B_SAFE_RND + B_PanSafe1 * PAN1 + B_PanSafe2 * PAN2) * SAF1 + B_SAFE_SQU * SAF1
* SAF1
V2 = (B_COST_RND + B_PanCost1 * PAN1 + B_PanCost2 * PAN2) * TP2 + \
    (B_TRANS_RND + B_PanTran1 * PAN1 + B_PanTran2 * PAN2) * TT2 + \
    (B_CONVE_RND + B_PanConve1 * PAN1 + B_PanConve2 * PAN2) * CON2 + B_CONVE_SQU
* CON2 * CON2 + \
    (B_SAFE_RND + B_PanSafe1 * PAN1 + B_PanSafe2 * PAN2) * SAF2 + B_SAFE_SQU * SAF2
* SAF2
# Associate utility functions with the numbering of alternatives
V = {1: V1,
    2: V2}
# Associate the availability conditions with the alternatives
```

```
av = {1: FLIGHTA_AV_SP,
    2: FLIGHTB_AV_SP}
# Definition of the model. This is the contribution of each
# observation to the log likelihood function.
obsprob = models.logit(V, av, CHOICE)
# Conditional to the random parameters, the likelihood of all observations for
# one individual (the trajectory) is the product of the likelihood of
# each observation.
condprobIndiv = PanelLikelihoodTrajectory(obsprob)
# We integrate over the random parameters using Monte-Carlo
logprob = log(MonteCarlo(condprobIndiv))
# Define level of verbosity
logger = msg.bioMessage()
#logger.setSilent()
#logger.setWarning()
#logger.setGeneral()
logger.setDetailed()
#logger.setDebug()
# Create the Biogeme object
biogeme = bio.BIOGEME(database, logprob, numberOfDraws=150)
biogeme.modelName = 'ML_PANEL_Taste_Heterogeneity'
# Estimate the parameters
results = biogeme.estimate()
# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
print(pandasResults)
```

Mixed Logit model with 2 flight alternatives + 1 opt-out

```
import pandas as pd
import biogeme.database as db
import biogeme.biogeme as bio
import biogeme.models as models
import biogeme.version as ver
```

```
import biogeme.messaging as msg
from biogeme.expressions import Beta, DefineVariable, bioDraws, PanelLikelihoodTrajectory, MonteCarlo, log
# Read the data
df = pd.read_excel('MNL_INC_OPT_OUT.xlsx')
database = db.Database('CHOICE', df)
# They are organized as panel data. The variable ID identifies each individual.
database.panel("ID")
# The following statement allows you to use the names of the
# variable as Python variable.
globals().update(database.variables)
# Parameters to be estimated
ASC_FLY = Beta('ASC_FLY', 0, None, None, 0)
ASC_Pan1 = Beta('ASC_Pan1', 0, None, None, 0)
ASC_Pan2 = Beta('ASC_Pan2', 0, None, None, 0)
B_COST = Beta('B_COST', 0, None, None, 0)
B_COST_SIGMA = Beta('B_COST_SIGMA', 1, None, None, 0)
B_COST_RND = B_COST + B_COST_SIGMA * bioDraws('B_COST_RND','NORMAL')
B_PanCost1 = Beta('B_PanCost1', 0, None, None, 0)
B_PanCost2 = Beta('B_PanCost2', 0, None, None, 0)
B_TRANS = Beta('B_TRANS', 0, None, None, 0)
B_TRANS_SIGMA = Beta('B_TRANS_SIGMA', 1, None, None, 0)
B_TRANS_RND = B_TRANS + B_TRANS_SIGMA * bioDraws('B_TRANS_RND','NORMAL')
B_PanTran1 = Beta('B_PanTran1', 0, None, None, 0)
B_PanTran2 = Beta('B_PanTran2', 0, None, None, 0)
B_CONVE = Beta('B_CONVE', 0, None, None, 0)
B_CONVE_SIGMA = Beta('B_CONVE_SIGMA', 1, None, None, 0)
B_CONVE_RND = B_CONVE + B_CONVE_SIGMA * bioDraws('B_CONVE_RND','NORMAL')
B_PanConve1 = Beta('B_PanConve1', 0, None, None, 0)
B_PanConve2 = Beta('B_PanConve2', 0, None, None, 0)
B_CONVE_SQU = Beta('B_CONVE_SQU', 0, None, None, 0)
B_SAFE = Beta('B_SAFE', 0, None, None, 0)
B_SAFE_SIGMA = Beta('B_SAFE_SIGMA', 1, None, None, 0)
B_SAFE_RND = B_SAFE + B_SAFE_SIGMA * bioDraws('B_SAFE_RND','NORMAL')
```

```
B_PanSafe1 = Beta('B_PanSafe1', 0, None, None, 0)
B_PanSafe2 = Beta('B_PanSafe2', 0, None, None, 0)
B_SAFE_SQU = Beta('B_SAFE_SQU', 0, None, None, 0)
# Definition of new variables
FLIGHTA_AV_SP = 1
FLIGHTB_AV_SP = 1
OPTOUT_AV_SP = 1
# Definition of the utility functions
V1 = (B_COST_RND + B_PanCost1 * PAN1 + B_PanCost2 * PAN2) * TP1 + \
    (B_TRANS_RND + B_PanTran1 * PAN1 + B_PanTran2 * PAN2) * TT1 + \
    (B_CONVE_RND + B_PanConve1 * PAN1 + B_PanConve2 * PAN2) * CON1 + B_CONVE_SQU
* CON1 * CON1 + \
    (B_SAFE_RND + B_PanSafe1 * PAN1 + B_PanSafe2 * PAN2) * SAF1 + B_SAFE_SQU * SAF1
* SAF1+\
    ASC_Pan1 * PAN1 + ASC_Pan2 * PAN2 + ASC_FLY
V2 = (B_COST_RND + B_PanCost1 * PAN1 + B_PanCost2 * PAN2) * TP2 + \
    (B_TRANS_RND + B_PanTran1 * PAN1 + B_PanTran2 * PAN2) * TT2 + \
    (B_CONVE_RND + B_PanConve1 * PAN1 + B_PanConve2 * PAN2) * CON2 + B_CONVE_SQU
* CON2 * CON2 + \
    (B_SAFE_RND + B_PanSafe1 * PAN1 + B_PanSafe2 * PAN2) * SAF2 + B_SAFE_SQU * SAF2
* SAF2+\
    ASC_Pan1 * PAN1 + ASC_Pan2 * PAN2 + ASC_FLY
V3 = 0
# Associate utility functions with the numbering of alternatives
V = {1: V1,
    2: V2,
    3: V3}
# Associate the availability conditions with the alternatives
av = {1: FLIGHTA_AV_SP,
     2: FLIGHTB_AV_SP,
     3: OPTOUT_AV_SP}
# Definition of the model. This is the contribution of each
# observation to the log likelihood function.
obsprob = models.logit(V, av, CHOICE)
# Conditional to the random parameters, the likelihood of all observations for
```

```
# one individual (the trajectory) is the product of the likelihood of
# each observation.
condprobIndiv = PanelLikelihoodTrajectory(obsprob)
# We integrate over the random parameters using Monte-Carlo
logprob = log(MonteCarlo(condprobIndiv))
# Define level of verbosity
logger = msg.bioMessage()
#logger.setSilent()
#logger.setWarning()
#logger.setGeneral()
logger.setDetailed()
#logger.setDebug()
# Create the Biogeme object
biogeme = bio.BIOGEME(database, logprob, numberOfDraws=150)
biogeme.modelName = 'ML_PANEL_Taste_Heterogeneity_Include_OPT-OUT'
# Estimate the parameters
results = biogeme.estimate()
# Get the results in a pandas table
pandasResults = results.getEstimatedParameters()
print(pandasResults)
```