HEC MONTRÉAL

An air transportation risk assessment tool estimating the risk of global vector and vector-borne disease dissemination

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THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF REQUIREMENTS
FOR MASTER OF SCIENCE
IN ADMINISTRATION (M. Sc.)

December 2017

Résumé

L'objectif de cette thèse de maîtrise est de développer un outil d'évaluation du risque en aviation civile sur la base de critères de santé publique. Les événements de santé publique, tels que des épidémies, devenant de plus en plus communs, la propagation des maladies à l'échelle mondiale par le réseau de transport aérien constitue désormais un élément perturbateur pour les chaînes d'approvisionnement, les opérations des compagnies aériennes et les flux de passagers et de marchandises. En conséquence, l'Organisation de l'Aviation Civile Internationale (OACI) préconise le développement d'un outil scientifique et standardisé d'évaluation du risque pour les acteurs de l'aviation civile, de la santé publique et des gouvernements pour mesurer le risque que représente l'importation de vecteurs de maladies et de maladies à transmission vectorielle.

Nous avons développé un outil d'évaluation du risque en quatre étapes, comme projet-pilote. Premièrement, nous avons utilisé les indicateurs de risque développés par un précédent groupe de travail de l'OACI, et y avons ajouté d'autres indicateurs identifiés par une revue de la littérature. Deuxièmement, nous avons interrogé des acteurs de l'aviation civile et de la santé publique pour affiner les indicateurs initiaux, et déterminer une liste définitive d'indicateurs. Troisièmement, nous avons incorporé la liste d'indicateurs dans une méthodologie de hiérarchie multicritère (MHM), et l'avons organisée pour que les participants répondent à un questionnaire de comparaisons par paires. Quatrièmement, nous avons extrait les poids des résultats du questionnaire basé sur la MHM, et les avons compilés dans un tableur Excel permettant aux utilisateurs d'utiliser l'outil d'évaluation du risque.

L'exploitabilité de cet outil est également démontrée dans cette thèse de maîtrise par la mesure de niveaux de risque dans des paires d'aéroports origine-destination, entre l'une à haut risque et l'autre à bas risque. Nous discutons des résultats et de l'interprétation de la démonstration, et nous élaborons sur les objectifs et les utilisateurs potentiels de cet outil. Finalement, nous discutons de la validation de l’outil par divers acteurs, et ses développements futurs.

Mots clés : aviation civile, santé publique, perturbations de la chaîne d’approvisionnement, évaluation du risque, vecteurs de maladie, maladies à transmission vectorielles, méthodologie de hiérarchie multicritère

Abstract

The purpose of this master thesis is to develop a civil aviation risk assessment tool using public health and vector control criteria. As public health events, such as disease outbreaks, become increasingly common, global dissemination of diseases through the air transportation network have become disruptive to the global supply chain, airline operations, and the movement of people and cargo. As a result, the International Civil Aviation Organization (ICAO) is pushing for the development of a common, scientifically-based risk assessment tool for civil aviation, public health, and government stakeholders to assess the potential importation risk of vectors and vector-borne diseases.

We developed a risk assessment tool in four steps as a pilot project. First, we used the risk indicators developed by a previous ICAO working group and added other indicators identified through a literature review. Second, we interviewed civil aviation and public health stakeholders to refine the initial indicators and determined the final list of indicators. Third, we incorporated the list of indicators into an Analytical Hierarchy Process (AHP) methodology, and organized it for respondents to participate in an pair-wise comparison questionnaire. Fourth, we derived the weights from the results of the AHP questionnaire, and packaged them into an Excel spreadsheet that allowed users to use the risk assessment tool.

The usability of the tool is also demonstrated in this master thesis by assessing the risk levels between a low risk and high risk origin-destination airport pairs. We discuss the results and interpretation of the demonstration, and we elaborate on the potential purposes and users of the tool. Finally, we discuss the validation of the tool by various stakeholders, and future developments for the tool.

Key words: Civil aviation, public health, supply chain disruptions, risk assessment, vector, vector-borne diseases, Analytical Hierarchy Process

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Acknowledgements

First and foremost, I would like to thank my two advisors: Professor Julie Paquette and Professor Marie-Ève Rancourt. Professor Rancourt, our fateful meeting at the conference in Mexico City led me to HEC Montréal. I probably would not have ended up here if it was not for you. Professor Paquette, thank you for taking the time to introduce to me the Global Supply Chain Management program, and becoming my advisor. Your email to me to confirm my attendance prior to my start at HEC made me realize that I made the right choice for school. I want to thank both of you for the support and guidance (and your patience!) in the last two years, and helping me make my master thesis a success. I am forever grateful.

I want to thank Dr. Ansa Jordaan and the Aviation Medicine section at ICAO for giving me this opportunity to create this risk assessment tool. It is not very often that a student gets to work on an ICAO resolution-related project that may have an impact globally. I also want to thank all the civil aviation and public health stakeholders for participating in the interview and questionnaire process. Your inputs made my thesis possible!

To my friends at HEC. Shoma, thank you for being my truest thesis buddy and friend. I'm glad you are here to push each other to the finish line. Charlotte, thanks for lending me your apartment so I can be in Montréal to put the finishing touches on this thesis. Cathy, your help with the math equations from Sri Lanka made my thesis even more presentable. Valentin, your can-do attitude with the French translation is the first impression every reader of my thesis will see. To the rest of the thesis buddies, good luck! And Nicole Hoff, you are welcome.

Lastly, I want to thank my family. Thank you for letting me choose my path and my passion. Your unwavering support in my endeavors allowed me to flourish and grow. I hope this degree (and the other educational investment you've made) will allow me to contribute back to humanity, and make a meaningful and positive impact on others.

Chapter 1 : Introduction

> *In a world in which carriers of disease can spread with speed of an aeroplane. A typhus louse or a plague flea, brushed off the rags of a beggar in an eastern bazaar, can be in Tokyo or Oslo, New York or Moscow, London or Sydney, in a matter of few hours.*
>
> - *Dr. Brock Chisholm, first Director-General of World Health Organization*

1.1 Research Problem

Human-kind lived in a world immersed in infectious diseases (Wang, et al., 2012). But as civilization and trading began to expand, trade routes brought – along with traders and their merchandise – new diseases and exotic species to and from faraway land, often with disastrous consequences (McNeill, 1976). This paradigm of international trade and global spread of disease continues to persist today, but at a much greater pressure due to the acceleration of globalization, complex supply chain and trade, and an explosion in travel and population mobility (Tatem, Rogers, & Hay, 2006).

One of the challenges in containing diseases is aviation and air transportation. As modern airplanes are able to fly longer, farther, and faster, modern long-haul airplanes are able to cover most of the globe within 36 hours (Bij & Pitout, 2012). With approximately 4,000 airports worldwide that have international destinations and routes (Gould, 1999), the world has shrunk with immense exchange in goods, ideas, cultures, and people (Smith, Sax, Gaines, Guernier, & Guegan, 2007). Add the increasingly affordability and convenience of air travel, large populations globally – including from those in the developing, low-income countries – have access to air travel and the world (Mangili & Gendreau, 2005).

The above attributes of aviation pose many challenges for governments and health agencies in terms of containing the spread of disease. As airplanes begin to fly farther and faster, disease carriers from Asia can now find themselves in Europe or North America in less than 24 hours (Webster, 2010). Further, the growth of trade and cultural exchanges made possible by international airports now allows historically localized diseases to become internationally mobile along with people and goods (McNeill, 1976). And as people and goods start arriving from anywhere in the world, policy makers need to decide what regulations should be enacted that balance between public health safety and ensuring that the global supply chain remains uninterrupted (Fidler, 2001). Lastly, disease-carrying insects and animals can be accidentally brought on-board airplanes as passengers or cargo which could subsequently be introduced into a foreign country with negative repercussions (Budd, Bell, & Brown, 2009). Aviation is one the most efficient, effective, and rapid vehicles to transport disease globally.

1.2 History, purpose and objectives of this study

The Zika virus outbreak declared in February 2016 forced many governments and public health agencies to re-examine whether the current regulations to prevent the spread of vector and vector-borne disease were effective. Vectors are defined as living organisms that can transmit disease, and vector-borne diseases are diseases that are carried and transmitted by vectors (WHO, 2017). The Zika virus is a vector-borne disease that was widely accepted to be primarily carried and transmitted by the *Aedes Aegypti* and *Aedes Albopictus* mosquito vectors (World Health Organization, 2016). Advisory groups formed by various aviation and public health stakeholders began to examine this issue.

In April 2016, an ad hoc World Health Organization (WHO) advisory group concluded that countries should begin to conduct risk assessments on the existing presence and potential risk of importation of mosquito vectors in their countries (World Health Organization, 2016). At the International Civil Aviation Organization (ICAO), a specialized United Nations agency responsible for regulating civil aviation worldwide, the issue of importation has surfaced prior to the Zika outbreak. At the 37th ICAO assembly in 2010, a resolution was passed urging collaboration with WHO on exploring alternative methods to chemical disinsection – using chemicals to kill vectors on-board aircrafts – as well as developing performance-based criteria for aircraft disinsection (ICAO Resolution A37-14). There was a bigger push in the 39th ICAO Assembly in 2016 to be more expansive.

Led by the United States delegation to ICAO, the delegation assembled a task group of experts in August 2016 prior to the 39th ICAO Assembly to discuss the efficacy of current WHO regulations on the potential importation of vectors. Several issues were raised by the group. First, the WHO still had not expanded their recommended vector control strategy beyond chemical disinsection on-board airplanes. Second, chemical disinsection was becoming less reliable as vectors became resistant to the chemicals used. Third, acceptable performance standard (e.g. kill rate) for vector control methods outside of chemical disinsection still had not been established. Fourth, chemical disinsection was recommended by the WHO but there was still no global standard or protocol regarding when disinsection should be conducted by individual countries. This lack of global standard created negative consequences for airlines when countries began to unilaterally impose new disinsection requirements due to Zika that were not medically or scientifically-based (United States Delegation, 2016). Airlines scrambled to meet sudden regulatory changes in the disinsection requirements which adversely impacted fleet deployment and plane utilizations (Slepski, 2017). The task force (personal communication, August 11, 2016) concluded the following:

> The current strategy of aircraft chemical disinsection relies on a reactive strategy to kill vectors once on board. We need a pro-active risk based alternative to effectively prevent vectors from entering aircraft at the origin and/or exiting aircraft at the destination. (p. 1)

As a result of the work and research done by the task group and the United States delegation, the 39th ICAO Assembly voted and accepted to include these recommendations as an official resolution of ICAO. In the resolution as *A39-28: Performance-based criteria and guidance material on aircraft disinsection and vector control measures (2016)*, the Assembly:

1. Directs that the [ICAO] Council engage with the World Health Organization to develop:

    a) Performance-based criteria to evaluate all disinsection methods, including non-chemical means of disinsection;
    b) Recommendations regarding non-chemical disinsection methods; and
    c) Guidance on the components of a scientifically-based risk assessment model for Contracting States to use in determining whether to employ vector control measures that include but are limited to aircraft disinsection. (p. 92)

It is on the basis of subsection (c) where we derive our purpose and objectives of this study. The Contracting States are composed of countries that are members of ICAO. The principal objective of this thesis is to develop and present a risk assessment tool that is scientific and holistic in its approach to evaluate the risk of vector importation into another country. ICAO wants to develop this risk tool to be corroborated with WHO as another measure to mitigate the potential spread of disease through aviation. Finally, as a solution to the fourth issue pointed above, creating a global standard risk assessment tool reduces unilateral decisions by governments, and gives all the stakeholders – governments, civil aviation authorities, public health agencies, and air operators – a basis of discussion when developing or implementing regulations against the spread of disease.

1.3 Research questions

In order to develop the risk assessment model, there are research questions to be answered:

1. What are the correct and necessary vector control and public health indicators to be included in a holistic and scientific-based aviation risk assessment tool?

2. What is the relative importance of each indicator and the weights that should be used in the risk assessment tool?

3. What is the accuracy and usefulness of the risk assessment tool?

The remainder of this thesis is organized as follows: Chapter 2 presents the literature review that examines the relationship of public health and global trade, the negative economic consequences of imported disease outbreaks, vectors and vector-borne diseases, rules and regulations regarding vectors, vector control methods, and addressing the current knowledge gap. Chapter 3 details the methodology that explains the four steps in creating the risk assessment tool. We start by examining the original indicator list that was first developed by the ICAO working group in August 2016. Then we begin the steps of modifying the original indicator list, conduct expert interviews, finalizing the indicators, use the Analytical Hierarchy Process (AHP) methodology and questionnaire for weighting, and receive final validation with stakeholders. Chapter 4 presents the results that coincide with the four steps in the methodology chapter and the five major indicator categories. Chapter 5 presents the discussion of the pilot project phase of the risk assessment tool, its potential users, supply chain disruption mitigation, limitation of our research, and demonstrates the usability of the risk tool by comparing the risk scores between two origin-destination airport pairs. Chapter 6 concludes the thesis and its current juncture.

Chapter 2 : Literature Review

The literature review chapter provides an overview of the various topics that encompass the prevention of the global spread of disease, global trade and supply chain, and civil aviation. This chapter first examines the relationship of air transportation and global trade as the impetus to global spread of disease. Second, we discuss how disease pandemics, in turn, negatively impact the economy and disrupts the global trade and supply chain. Third, we explore the most common-types of vectors and the vector-borne diseases. Fourth, we review the current rules, regulations and recommendations implemented by international or national law. Fifth, we look at various vector control methods that prevent or eliminate the spread of disease. Lastly, we look at how this thesis addresses current knowledge gaps.

2.1 Global movement of goods and people, and the global spread of disease

Human activity is one of the great contributors to the spread of global disease. Compared to non-human diseases that stay localized, infectious diseases harmful to humans have been globalized by human activities (McNeill, 1976). This phenomenon is not new, and we can trace major disease pandemics, such as the Black Death in the 14^{th} century, to trading ships and trading routes that brought onshore infected rats that killed upwards to half the population in Europe (Ziegler P. , 2013). Today, the increasing spread of disease coincides with increasing globalization, and there are many factors within it that contribute to the global spread of disease.

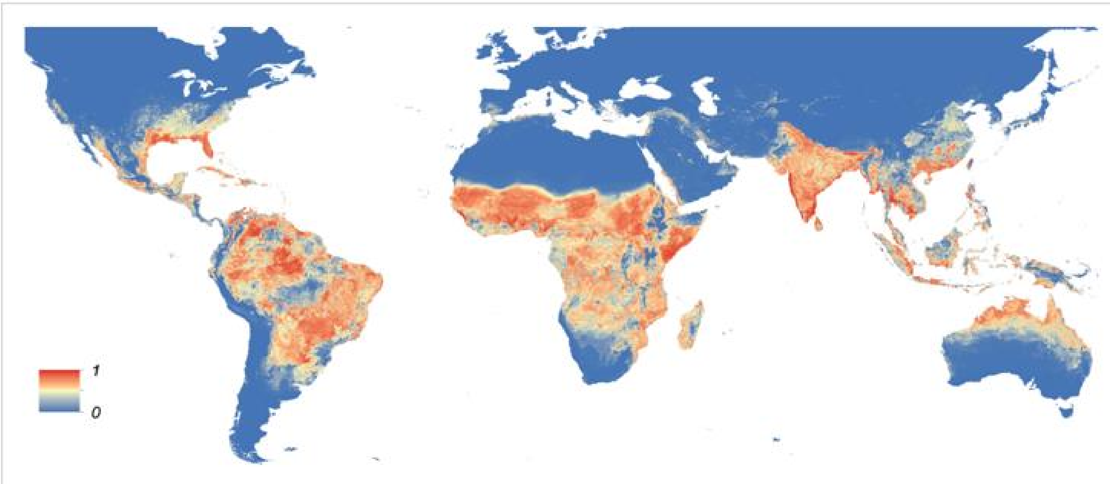
2.1.1 Increased global transportation and trade

There are correlations between human activities in globalizing trade and supply chain and the global spread of disease. In one study comparing the possibility of vector importation at global seaports, the model predicted that the chance of vectors entering African sea ports are significantly lower than other international ports simply due to the lower volume of trade and cargo in Africa (Tatem, Hay, & Rogers, 2006). And as cities and countries become more interconnected into the global trade network, the risk becomes higher (Huang & Tatem, 2013). There are many examples in which global trade increases the chances of the globalization of disease.

As stated prior, non-human diseases are more localized. But as humans begin to trade wildlife species and livestock internationally, the importation of animals begins to spread diseases into the local animal population (Lowe, et al., 2014). For example, the speed of air transportation enables male horse studs to be flown around the world for breeding. Since artificial insemination is forbidden in the breeding of thoroughbreds, what was once long and hard to transport a horse to a foreign destination, the studs can now be flown year-round for breeding. But, in turn, flying these horses around have introduced and caused several new disease outbreaks in the local horse population (Timoney, 2000). Furthermore, the cramped conditions of transporting animals internationally induce stress on the animals, thus lowering their immunity to potential disease while being transported (Cutler, Fooks, & van der Poel, 2010). Also, there is the possibility of zoonosis, where imported animals can transmit animal diseases to humans (Morse, et al., 2012).

Vectors are also introduced into new countries courtesy of global trade and transportation. One way that mosquito vector species arrived in the Americas was through ships transporting used tires for disposal. With the bottoms of used tires being able to collect water, the still water became breeding grounds for mosquitos to survive the long voyage, and establish residence in new countries (Craven, et al., 1988). Mosquito species spread throughout the world in similar fashion. The spread of *Aedes Aegypti* mosquitos from Africa to the world may have started as early as 18^{th} century, where the water stored on-board ships became breeding grounds for mosquitos (Carey, 1971). The *Aedes* family of mosquitos were introduced throughout the Pacific Islands and Asia during World War 2 when warships and military airplanes were islandhopping in the Pacific theatre of the war (Lambrechts, Scott, & Gubler, 2010). Figure 1 shows the present global presence of the Aedes Aegypti mosquitos that originally only inhabited Africa.

Figure 1. Current global presence of Aedes Aegypti mosquitos that originated from Africa. Blue denotes no presence, and red denotes high presence (Kraemer, et al., 2015)



Even if *Aedes Aegypti* is unsuitable for the Canadian climate, it was reported in August 2017 that surveillance mosquito traps in Windsor, Ontario found these mosquitos in Canada. It was believed that ships originating from south of the Great Lakes region carried these mosquitos to Canada (Doherty, 2017). Vectors also become more adaptive to human environments as cities around the world become more homogenized. Meaning that our urban environment (e.g. infrastructure, buildings, sewage) is easily adaptable to vectors now because cities around the world are now so similar (Smith et al., 2007). Furthermore, the increase growth in the north-south trade have again increased the exposure of disease-free areas to ships and airplanes that may be harboring disease or vectors (Sutherst, 2004).

Lastly, global trade and public health security should not be treated as separated matters. In trade treaties, public health concerns such as the global spread of disease are usually not part of the trade language. Often, neither trade negotiators nor public health experts have the expertise or experience to understand each other's concerns. There needs to be more engagement on both sides to advance trade while protecting public health safety (Smith, 2006).

In the case of North American Free Trade Agreement (NAFTA), a study noted that there was no mechanism to discuss public health issues between the United States and Mexico even though NAFTA had exponentially grown the trade between the two countries (Homedes & Ugalde, 2003).

2.1.2 Increased air travel

Aircrafts and air transportation are changing the dynamics of global disease dissemination in several ways. First, airplanes compress time and space. While the world sailing record for ships to circumvent the globe is approximately 40 days (Trophée Jules Verne, 2017), a modern, jet aircraft can reach most points on earth within 36 hours (Bij & Pitout, 2012). This efficiency is a rapid departure from the past, when slow-moving ships on long voyages can either easily identify and quarantine infected persons or let the disease pass and die off (Ali & Keil, 2006). Due to the fast velocity of aircrafts, diseases and vectors are better able to survive the short journey time, and asymptomatic passengers can arrive at destinations undetected (Naylor, 2003). This makes air transportation an efficient vehicle for global disease transmission (Budd, Bell, & Brown, 2009).

In Figure 2, we demonstrate the efficiency of modern aircrafts by sampling an Emirates Cargo 777 aircraft, registered as A6-EFE, and all of its routings and destinations for one week from August 16, 2017 to August 24, 2017. In an one-week span, Emirates utilized this particular cargo aircraft to fly to 11 airports in five continents. Stationed in Dubai, this aircraft flew twice through North America and Europe. A6-EFE also made two milk runs through Singapore, Australia, and Hong Kong. Lastly, it made another run in Africa by the ways of Malawi, Zambia, and Kenya in this one-week period (flightradar24, 2017).

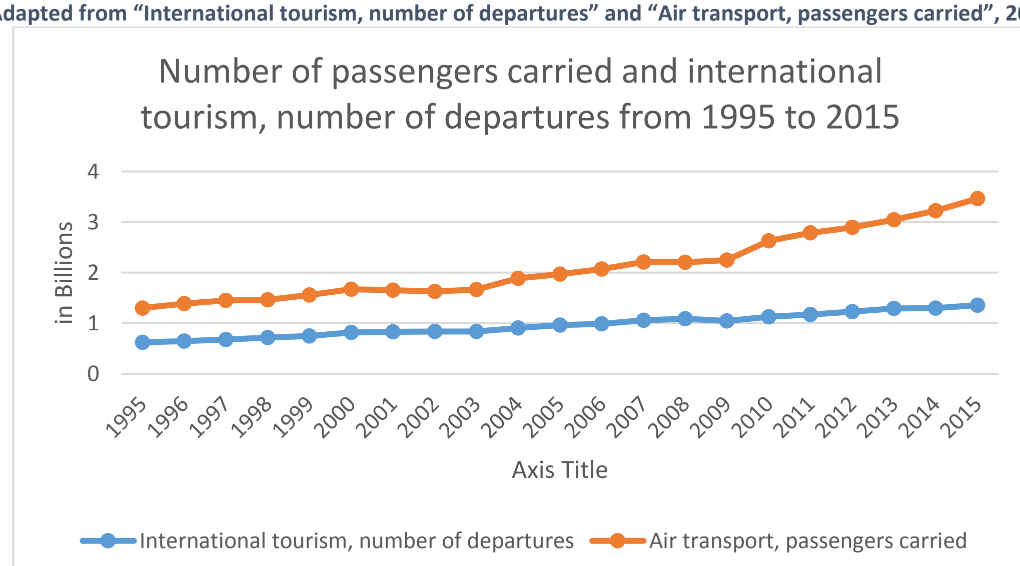
Figure 2. An Emirates Cargo Aircraft (Registration: A6-EFE) flies to 5 out of 6 Continents in a single week from August 16, 2017 to August 24, 2017 (flightradar24, 2017)

The concern is that this type of inter-continental flight patterns exposes or re-exposes disease-free regions to new diseases and vectors from flights that originate from areas that are endemic to these diseases and vectors (Beard, et al., 2016). The fear is that such rapid air transport allows global cities and their airport hubs to become an efficient means to "transporting pathogen between population centres… [and] constant movement of viruses, bacteria, and parasites among cities, countries, regions, and continents (Gubler, 1998)."

Second, air liberalization has made air travel more affordable, convenient, and expansive, but it has also put additional stress on the public health system to respond to the potential importation of disease. Unlike the restrictive bi-lateral air agreements prior to airline deregulations and open sky agreements, people now have access to secondary airports that fly to international destinations (Budd, Bell, & Warren, 2010). For example, in the United Kingdom, London-Heathrow was the primary international airport for England, but now there are international flights commencing out of all the secondary London-area airports like Gatwick, Luton, Stansted, and London City (Ennis, 2009). Public health resources that used to be concentrated on one or two major international airports are now spread thin with secondary airports competing for resources (Warren, Bell, & Budd, 2010).

Third, as the number of air passengers and international tourist continues to climb, the probability of exposure to foreign diseases is more likely than before. From the latest 2016 figures, air travel carried approximately 3.8 billion passengers (ICAO, 2017). In the latest release, International Air Transport Association (IATA) predicted that this number will rise to 7.2 billion passengers by 2035 (IATA, 2016). The number of international tourists is rising as well. In Figure 3 from 2015, 1.36 billion passengers travelled internationally for tourism ("International tourism, number of departures", 2017). With air transport being the primary vehicle of tourist departing for international destinations (Basnet, 2015), exposure to foreign diseases become more likely as tourists travel to exotic destinations for vacations.

Figure 3. Number of passengers carried and international tourism, number of departures from 1995 – 2015 (Adapted from "International tourism, number of departures" and "Air transport, passengers carried", 2015)



There are many ways that passengers can be exposed and infected due to air travel or traveling to destinations that have high risks. In Table 1, some of the diseases that have been transmitted on airplanes are listed.

Table 1. Types of diseases that have been transmitted on airplanes or airports (Adapted from Mangili & Gendreau, 2005)

Airborne/fomites	Food-borne diseases	Vector-borne diseases
Tuberculosis (TB)	Salmonellosis	Malaria
SARS	Staphylococcus	Dengue Fever
Common cold	Food poising	Yellow Fever
Influenza	Shigellosis	
Meningococcal disease	Cholera	
Measles	Viral Enteritis	

In one instance with airborne diseases, an unventilated flight of three hours infected 72% of the passengers by one passenger who had symptoms of influenza (Moser, et al., 1979). Although airplane ventilation reduces the exposure to airborne diseases, in another instance, 15 out of 75 passengers became ill from one passenger on a ventilated flight, where 9 passengers were seated within two rows of the infected passengers and the rest within five rows (Marsden, 2003). Another possibility is that air travel brings people together for large, international gatherings. For example, the Hajj – pilgrimage to Mecca – has caused great concerns in public health safety due to pilgrims flying in from all parts of the world each year. There are many instances where diseases like Polio were re-introduced into countries due to pilgrims infecting other pilgrims during the Hajj and returning home with the disease (Wilder-Smith, Leong, Lopez, Amaku, & Quam, 2015). Many vaccination and public health requirements are now implemented to reduce the risk of transmission between pilgrims (WHO EMRO, 2017).

Lastly, exotic vacations can bring infected tourists or vectors back into the home country. There are many incidents where tourists on vacations in developing countries get infected by disease and possibly spread it to others when they arrive home (Genderen, Thiel, Mulder, & Overbosch, 2012). For example, there are 10,000 cases of imported malaria reported in Europe each year from the 20 million people that visit areas endemic to Malaria (Gössling, 2002). Even Buzz Feed News (2017) posted an article called "5 Truly Gross Parasites That Have Ruined Real

People's Vacation." In this feature, the article focuses on how vacationers became infected and brought back – along with pictures – stowaways like the flesh-eating bacteria, brain-eating amoeba, sleeping sickness, hook worms, and nematodes. Airplanes flying to and from disease-endemic countries can also bring back vectors. In one report, 12 out of 67 airplanes arriving from tropical destinations at Gatwick airport carried mosquitos on-board the airplane (Curtis & White, 1984). In what is known as Airport Malaria, malaria-infected mosquitos arrived via airplanes and were able to transmit malaria to airport workers and nearby neighborhoods (Danis, et al., 1996). In another case, a girl was infected with Malaria during her travels in India, returned home to Italy, and was bit by a local specie of mosquito. The local mosquito obtained the malaria-infected blood from the girl and was able to transmit Malaria as it bit others (Baldari, et al., 1998).

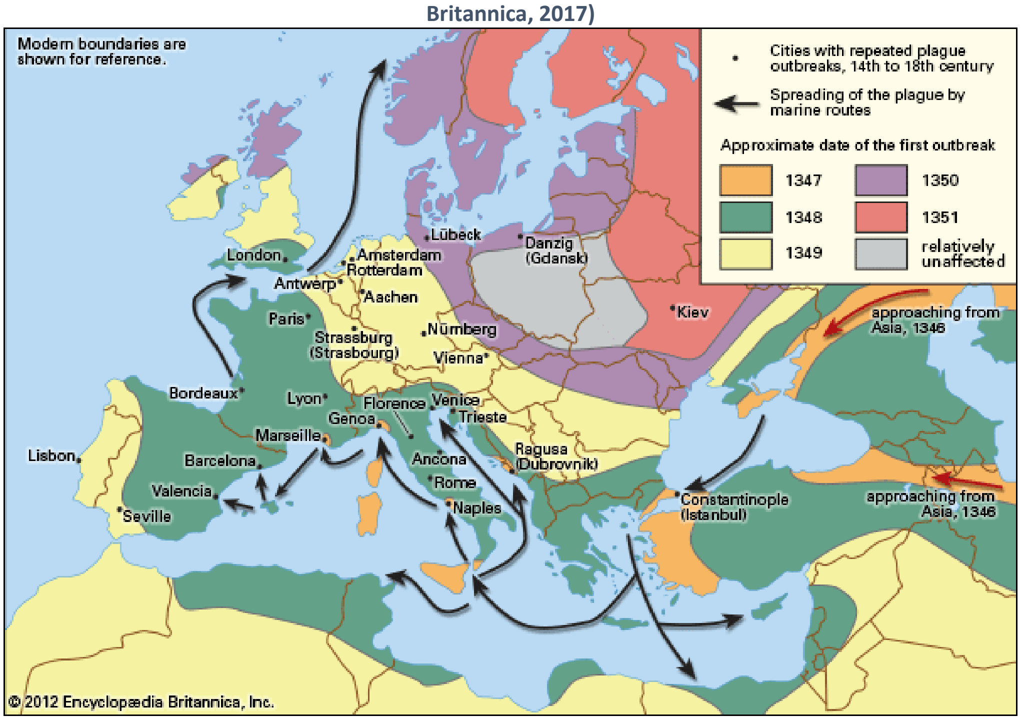
2.2 Disease outbreaks disrupt trade, economy, and livelihoods

In Section 2.1, we discussed how air transportation and global trade are a major cause of the global spread of disease. In Section 2.2, we want to focus on how the spread of diseases – and our inability to contain it – can cause outbreaks that can have severe negative consequences to global trade and supply chain, economy, and livelihoods of people. Diseases and vectors can have an "impact on demographics, quantity and quality of labor and capital inputs, etc. and if incidence reaches significant levels, can impact a variety of variables like human mobility, trade, investments, savings, and land use (WHO SEARO, 2014, p.13)." We illustrate this section with case studies from the Black Death, SARS, and Ebola.

2.2.1 Black Death

The Black Death or the Plague in the 14th century was a significant disease outbreak in history caused by international trade. In this pandemic, it was believed the Plague arrived from trading ships from Asia and through the Mediterranean, and later to the rest of Europe. Infected black rats and fleas on-board of trading ships were believed to be the main vector in the transmission of the *Yersinia pestis* bacteria (Ziegler P. , 2013). As shown in Figure 4, this outbreak first started mostly in port cities in Italy in 1347, France and southern England in 1348, Scandinavia by 1350, and began to slow as it reached the periphery of Russia by 1353 (Routt, 2017). The spread of the Plague was consistent with the trading routes of the time (Lenz & Hybel, 2016).

Figure 4. The route and transmission of the Black Death in the 14th Century Europe (The Editors of Encyclopædia Britannica, 2017)



In terms of livelihoods, the Black Death decimated the population in Europe. Although the figures vary, it was estimated that 30% to 60% of the European population died from the Plague (Alchon, 2003). Port cities like Pisa and Venice lost three-quarters of the populations, and many families were completely wiped out (PBS, 2017). Records in England showed that half the population died (Ziegler P., 2013). In another example, Paris also lost half of its population (Richard, 2017).

The greatly diminished population of Europe due to the Plague had an interesting – both positive and negative – impact on the development of the European economy. Some of the merchant houses went bankrupt due to the outbreak. A smaller population meant there was a contraction in demand for goods and merchandise, in which price dropped due to the glut of inventory (Routt, 2017). Lords and the feudal system can no longer have the same control over the peasant population (Council for Economic Education, 2011). It is also during this time that the system of quarantine began to be implemented, in which ships needed to be docked for forty days before it was declared disease-free and allowed to embark on its journey (Ali & Keil, 2006).

But, interestingly, the Black Death also fundamentally changed Europe for the better due the stress of overpopulation in Europe at that time. Severe population lost meant labor shortages that allowed peasants to demand higher wages and better working conditions. Higher wages also allowed manufacturing to flourish as people began to have disposable incomes to buy goods. Productivity rose as more efficient tool and techniques were used due to the labor shortage. Productions were altered away from labour-intensive agriculture to less laborious – such as raising sheep – occupations in the new economy. The Black Death reformed the European economic system at the time (Council for Economic Education, 2011).

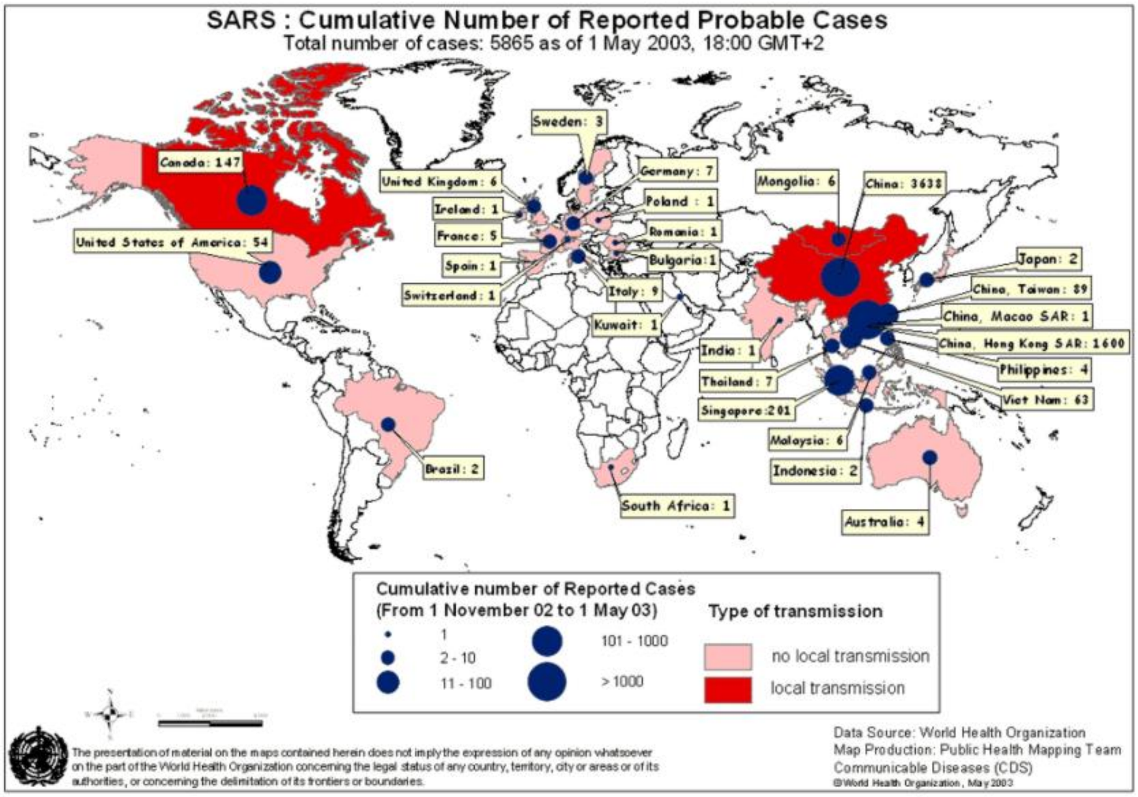
Currently, there are competing theories on the origin of the Black Death. New theories suggest that it was not the *Yersinia pestis* bacteria but a respiratory disease or an Ebola-like virus because modern Plague outbreak characteristics are inconsistent with what was reported in the 14th century (Bossak & Welford, 2009). However, whatever or whomever the culprit was, all the theories suggest that trade and trade routes were still the primary reason for the spread of Black Death throughout Europe.

2.2.2 SARS

Severe Acute Respiratory Syndrome (SARS) has been described as a perfect illustration of how the 21st century global airline network, through its inter-connectivity, can globally disseminate disease from East Asia to 29 countries rapidly (Bowen & Laroe, 2006). SARS is a highly contagious coronavirus that is primarily transmitted through person-to-person contact via infectious respiratory droplets that is produced when someone coughs or sneezes. SARS droplets can also contaminate surfaces (e.g. door knobs, elevator buttons) that it lands on, in which the virus can survive on the surface for 24-hours (CDC, 2012). In the outbreak between November 2002 and July 2003, SARS infected 8,096 people with 774 reported deaths (WHO, 2003). Although the mortality rate was only approximately 10%, the effect of SARS was compounded by the unknown fears of the virus, which further negatively impacted the affected regions politically, socially, and economically (Leung, 2008).

The spread of SARS was first reported when Canada's Global Public Health Intelligence Network (GPHIN) began to pick up reports of "flu outbreaks" in China in November 2002 (Mawudeku & Blench, 2005). By February 2003, SARS was being transmitted by several human carriers. In Hong Kong, a SARS-infected Doctor – who has been treating patients for "atypical pneumonia" in China – stayed in a hotel in Hong Kong, where he infected at least 10 hotel guests that stayed on the same hotel floor. Those hotel guests then departed for Vietnam, Singapore, and Toronto after their stay, which subsequently started the SARS outbreak in those countries (Siu & Wong, 2004). Figure 5 shows the global distribution of the SARS at its peak in April 2003.

Figure 5. The global dissemination of SARS by reported case at its in peak in May 2003 (WHO, 2003)



One of the infected hotel guest was a local man, and he became the index patient that infected over 100 people at the Prince of Wales hospital in Hong Kong. Other examples include Amoy Gardens, an apartment complex in Hong Kong, where 213 residents became ill with SARS (Siu & Wong, 2004). In Canada, SARS was introduced by a woman travelling back from Hong Kong in February 2003. She was traced to be responsible for the final count of 257 cases of SARS infection in the Toronto-area (CDC, 2003). In other instances, an American business man on-route to Singapore from China developed SARS symptoms during midflight, forcing the airplane to divert to Hanoi. His hospital stay in Hanoi also began to infect hospital staffs there as well (WHO, 2003). By March 2013, a global alert was issued by the WHO as reports of international and local transmission of SARS continued to appear globally (WHO, 2003).

As SARS swept through the world, affected regions began to feel the economic, social, and political effects of the outbreak. The hardest hit sectors were transportation and tourism

(Knobler, et al., 2004). Although all airlines suffered due the outbreak, airlines within the hardest hit regions suffered the greatest (Collins, 2005). In Table 2, losses incurred by airlines that were most affected by the SARS outbreak are displayed.

Table 2. Airlines losses during the SARS Outbreak (Adapted from Collins, 2005)

Airlines	Losses incurred
Cathay Pacific	• Daily load factor was down by 75%, from 30,000 passengers to 7000 passengers • Cuts scheduled passenger flights by 45% • Parked 22 wide-body aircrafts • Passenger revenue down by 29.5% • Overall profit fell by 67.3%
Dragonair	• Daily load factor was down by 96%, from 12,000 passengers to 750 passengers • Cut scheduled passenger by more than 50% • Deferred deliveries on 4 airplanes
Singapore Airlines	• Load factor dropped from 76.1% to 49.2% • Overall passenger number decreased by 50% during outbreak • Reduced capacity by 43.6%
Air Canada	• Pacific routes revenue fell by 44% during the outbreak period • With Air Canada’s biggest hub at Toronto Pearson: o Domestic routes revenue was down 19%, o US-Canada routes revenue was also down 19%
Air China	• 2100 flights were cancelled • Forced by Chinese regulators to fly routes even though the routes were unprofitable due to the outbreak

Airports also suffered greatly from the SARS outbreak as well. In Toronto, Pearson airport reported that 500,000 less passengers flew through its terminals compared to the year before (CBC News, 2003). At the Hong Kong airport, the overall passengers decreased by 68.9%. Fewer flight movements through the Hong Kong airport also decreased landing fees revenues by HK$3.5 million per day. It was reported that the overall flight capacity between Hong Kong and Canada decreased by 69% during the outbreak, and between Hong Kong and Europe, the number of flights decreased by 36%. The number of flights to China also went down by 45% (Collins, 2005).

Interestingly, export shipping volume from Hong Kong were not affected by the SARS outbreak (Siu & Wong, 2004).

Another indirect loss was incurred by the tourism industry. Hotels, bus tours, and conventions in Toronto were cancelled due to cancellation by visitors in fear of the outbreak (CBC News, 2003). The Canadian government pledged CA$150 million into a marketing and advertising campaign to promote Toronto as a safe place to visit (Ali & Keil, 2006). In Taiwan, it was reported that the decrease in tourist consumptions decreased employment in tourism by 0.5% to 1%, and overall GDP in Taiwan were affected by 0.429% to 0.774% due to the outbreak (Yang & Chen, 2009). In Hong Kong, tourism was down by 10.4% and overall tourist spending decreased by 14% (Siu & Wong, 2004). In Beijing, China, it was estimated that the damage to the transportation and tourism sector combined was approximately US$1.4 billion, which was more than 300 times the cost of treating SARS patients (Beutels, et al., 2009).

The biggest problem was not the SARS virus itself, but the fear and stigma that was attached to being in an afflicted area. There were numerous examples in which governments would hide or underplay the severity of an outbreak to ensure that its economies will not be disrupted or affected (Fidler & Gostin, 2006). For example, the Canadian government sent the largest delegation ever to WHO to lobby against placing Canada on the SARS travel advisory list to prevent further damage to the economy (Ali & Keil, 2006). In the case of SARS, one study showed that there was no long-term damage to the economy. Economies resumed to previous levels after the outbreak was declared over (Siu & Wong, 2004). In one article that studied the trends of airline stocks during the SARS, all airlines stocks rebounded after the outbreak was over (Keogh-Brown & Smith, 2008). However, in the next case with Ebola, the damages were longer and more severe.

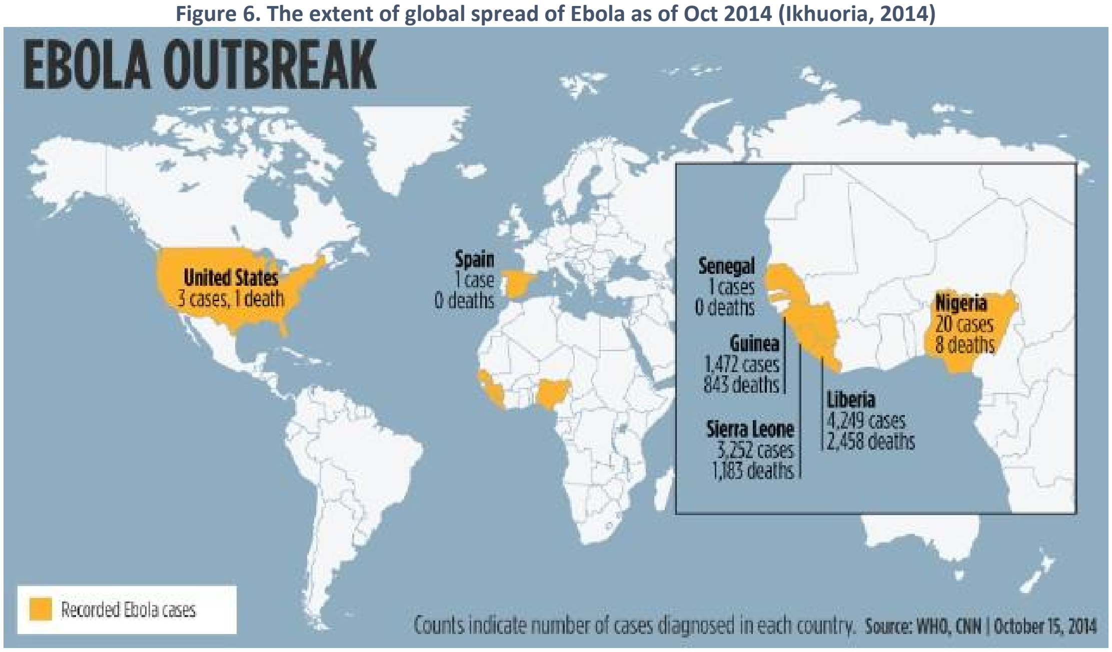
2.2.3 Ebola

In 2014, the biggest Ebola outbreak occurred in West Africa, with far-reaching effects into the economic and social fabrics of Guinea, Liberia, and Sierra Leone. Unlike SARS, where many of the countries had the financial resources to contain the outbreak, the Ebola outbreak occurred in the low and middle-income countries that lacked the health system and financial capacity to effectively combat the outbreak.

Ebola is a viral disease that causes hemorrhagic fever with 25% to 90% mortality rate depending on the demographics. Symptoms can range from fever, fatigue, muscle pain, and sore throat. As the disease advances, it can eventually cause external and internal bleeding as the kidney and liver functions starts to fail (WHO, 2017). Ebola is primarily spread through the blood and bodily fluid when the virus has direct contact with broken skin or through the mucous membranes in eyes, nose, and mouth. Other methods of transmission include sexual contact or through infected primates or fruit bats (CDC, 2015).

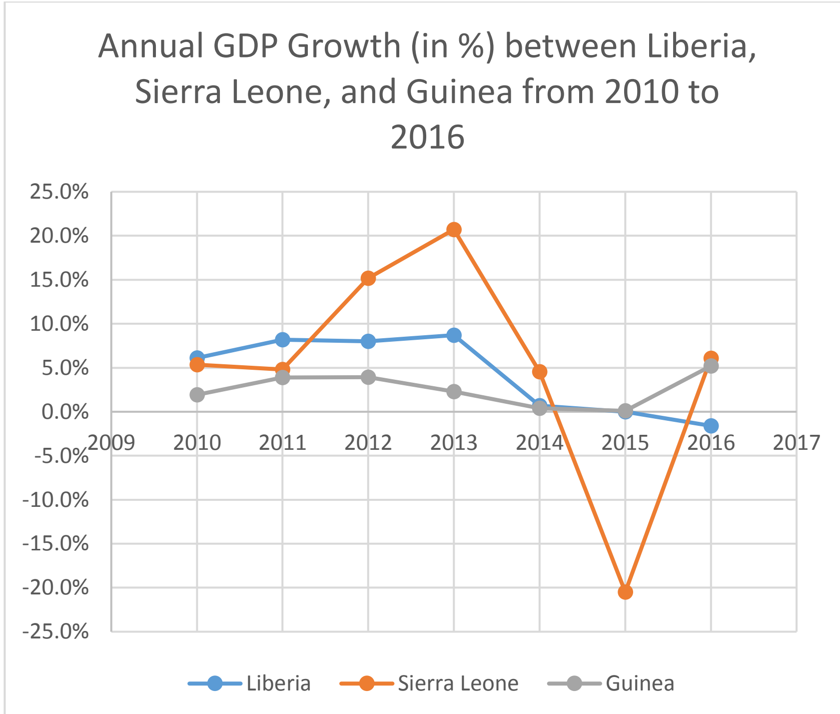
It was believed that the Ebola outbreak first began in Guinea in December 2013, when a young boy died from a disease that may have been transmitted by bats. Later, his sister and mother showed similar symptoms and passed away as well, and it was through these initial infections that nearby villages were transmitted the Ebola disease (Sack, Fink, Belluck, & Nossiter, 2014). The first case in Sierra Leone occurred by the Guinean border in May 2014, where a traditional healer was treating Ebola patients and when the healer died from Ebola, the burial ceremony may have infected others when they were washing the body (Fofana & Flynn, 2014). In Liberia, it was commonly believed that Liberian travellers returning from Guinea brought back Ebola with them (Williams, 2017). Similarly, in Mali, visitors arriving from Guinea were the first to show the symptoms of Ebola (Ebola situation assessment, 2014). The Ebola outbreak gain further notoriety when Ebola began to appear in the United States and Spain (Withnall, 2014). By the end of the Ebola outbreak in 2016, there were 28,616 cases of infected patients in 10 countries, resulting in 11,310 deaths (WHO, 2016). Figure 6 shows the affected countries and the distribution of mortality.

Figure 6. The extent of global spread of Ebola as of Oct 2014 (Ikhuoria, 2014)



The Ebola outbreak had an enormous impact on the three most affected countries of Guinea, Liberia, and Sierra Leone. Pre-Ebola GDP growth estimates for the year 2015 for Guinea, Liberia, and Sierra Leone, were estimated at 4.3%, 6.8%, and 8.9%, respectively (UN News Centre, 2017). However, the real GDP numbers were dire due to the Ebola outbreak. For 2015, the real GDP growth numbers came out to be 0.1%, 0%, and -20.5%, for Guinea, Liberia, and Sierra Leone, respectively (see Figure 7). For Sierra Leone, the 20.5% contraction came as its agriculture and mining industries grinded to a halt during the outbreak. The World Bank further predicted that the recovery will be slower due to the global commodities price slump (World Bank Group, 2016).

Figure 7. Annual GDP growth between Liberia, Sierra Leone, and Guinea from 2010 to 2016 (Adapted from World Bank Group, 2016)



The situation was further exacerbated by the disruption in the trading and supply chain in the country. Countries and airlines began to impose travel restrictions to the three most affected countries. Part of the fear was that since 60% of travellers leaving the three countries will travel to other low or medium-income countries, the spread of Ebola will be further accelerated within Africa due to poor health infrastructure in those destination countries (Bogoch, et al., 2015). With an overall 70% reduction in traffic to the Guinea, Liberia, and Sierra Leone, imported basic commodities became very expensive or unavailable (Hodge, Barraza, Measer, & Agrawal, 2014). Air traffic was reduced by 60%, and it became a bottleneck to bring in foreign aid workers and supplies. Border closures also affected the imported food supply chain, where anticipated food insecurity resulted in panic buying that caused a 150% increase in Cassava prices (John Wiley's and Sons, 2014). Self-imposed quarantines by the governments stopped industries from working and devastated the agricultural sector as crops destined for exports were not harvested and left to rot. People also began to riot and break the quarantine in order to find food and survive (Hodge et al., 2014).

Despite pleas from the African Union to end the travel restrictions, the advices were not heeded (France-Presse, 2014). The travel restriction, border closures, and quarantines further exacerbated an outbreak in countries that had a fragile, developing economy coupled with poor health system capacities and abject poverty. As a result, the Ebola was not just disruptive due to the seriousness of the outbreak, but its implications in closing and disrupting the access to the global economy, which made the situation even worse (Sy & Copley, 2014).

2.3 Vectors and vector-borne diseases

In the last two sections of the literature review, we focused on the variety of ways that diseases can cause outbreaks and transmit globally through the design of our aviation and international trade networks. In this section, we focus specifically on vectors and vector-borne diseases (VBD) that our risk tool is specifically built to assess and prevent. In the following section, we first focus on some of the most common vector types and their associated VBDs. After, we discuss the Chain of Infection as the fundamental basis of how vector threats can be eliminated or mitigated.

Vectors

The WHO (2017) defines vectors as:

> Living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are bloodsucking insects, which ingest disease producing micro-organisms during a blood meal from an infested host (human or animal) and later inject it into a new host during their subsequent blood meal. (p. 1)

Many vectors are in forms of arthropods, such as mosquitos, ticks (Fenech, 2010), bugs, mites, fleas, and freshwater snails (WHO SEARO, 2014). Other possibility includes animals like rodents and humans (Sutherst, 2004). The types of infectious disease or pathologic agents the vectors carry can be a virus, bacteria, helminths, or protozoa (Fenech, 2010).

As living organisms, vectors are dependent on the right environment to survive, but vectors are also becoming more versatile in adopting to new and changing ecological conditions (WHO SEARO, 2014). With increased climate change and increased human population density, more regions than before are becoming hospitable to vectors and allowing the vectors to reproduce quickly (Beard, et al., 2016). Furthermore, as vectors become resistant to chemical insecticides, past eradication solutions are no longer as effective. This makes vectors eradication and control difficult (IRAC, 2017). Vector spread into new regions are done in three stages: 1) initial dispersal, 2) establishment, and 3) spread (Tatem et al., 2006).

Vector-borne Diseases

Currently, VBDs account for over 17% of all infectious diseases globally with half the world's population vulnerable to VBDs. Every year, over a billion cases are attributed to VBDs which results in over a million deaths worldwide (WHO SEARO, 2014). From the 17th to the 20th century, VBDs caused more human diseases and deaths than every other causes combined (Gubler, 1998). Often, it is considered the "disease of the poor" as poverty and dismal living conditions are favorable for vectors to thrive (WHO SEARO, 2014).

The disease pathways for VBDs are quite complex. Different vectors transmit different diseases, but same species within vectors may or may not be able to transmit disease. For example, only certain species of mosquito like *Aedes Aegypti* and *Aedes Albopictus* mosquito are transmitting Zika, while other species mosquitos are not (Sifferlin, 2016). But disease pathways are also determined by environmental and social factors. Wars, displacement of people, and environmental degradation destroy infrastructures that curtails the spread of disease, and make regions vulnerable to new or re-introduction of VBDs (Budd, Bell, & Brown, 2009). And as we have already concluded in the last sections, globalization, travel, and trade also have a significant impact on the spread of VBDs, as new vectors begin to appear in new parts of the world. Table 3 shows some common types of VBDs.

Table 3. Some samples of VBDs that are clinically important (Adapted from Hunter, 2003)

Disease	Pathogen	Vector	Geographic distribution
Dengue	Flavivirus	Mosquito	Africa, Caribbean, Pacific, East Asia
Japanese Encephalitis	Flavivirus	Mosquito	Japan, Far East
West Nile	Flavivirus	Mosquito	Africa, India, Europe, North America
Yellow Fever	Flavivirus	Mosquito	Africa, South and Central America
Crimean-Congo Haemorrhagic fever	Nairovirus	Ixodic tick	Europe, Africa, Middle East, Central Asia
Murine typhus	Rickettsia typhi	Flea	Tropical regions
Rocky Mountain Spotted fever	R. rickettsii	Ticks	United States
Plague	Yersinia pestis	Flea	Africa, Asia, South America, United States
Lyme Disease	B. burgdorferi	Ticks	Europe, North America
Relapsing fever	B. duttoni	Lice	Ethiopia, Burundi, Peru, Bolivia, North Africa, India, Asia, China
Malaria	Plasmodium spp.	Mosquito	Tropical regions
Onchocerciasis	Onchocerca volvulus	Blackflies	Africa, Central and South America

In the remainder of this section, we discuss four of the most common vectors that the aviation risk assessment tool will target. They are mosquitos, ticks, fleas, and rodents. Although there are other vectors species that could be discussed, limiting the spread of these four vectors will curtail the spread of majority of the VBDs in this world. We further discuss the common VBDs associated with each vector.

2.3.1 Mosquitos

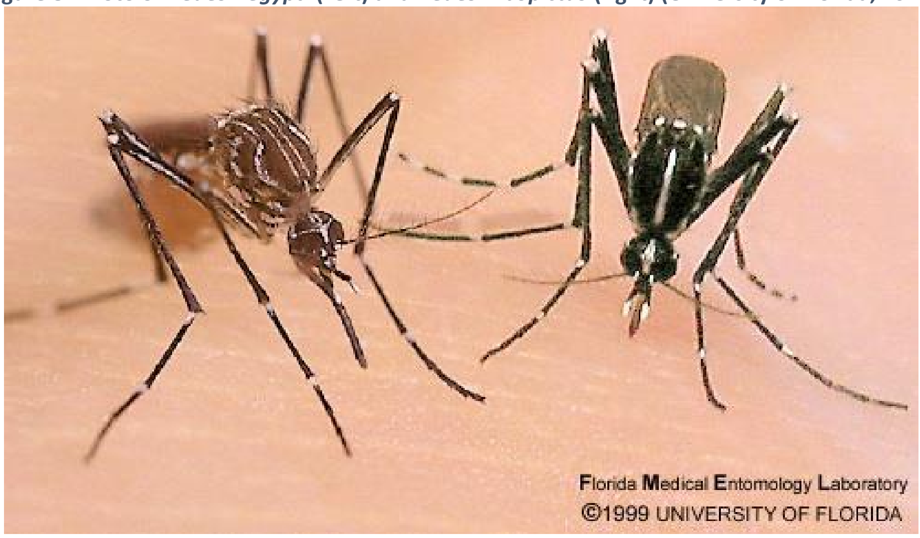
Mosquitos are considered one of the most prolific VBD carriers in the world (WHO, 2017). Mosquitos are a small, flying insect that bite animals and humans that causes itchiness and irritation but also very harmful diseases that cause serious injuries, incapacitation, and death to humans (Health Canada, 2016).

The infection of susceptible humans is through mosquito bites, in which female mosquitos need the blood meal to begin the reproduction cycle. Typically, a mosquito would bite an infected human, suck in the infected blood, and then transmit the disease to another human when the female mosquito takes a subsequent blood meal (American Mosquito Control Association, 2017). Zoonosis is also possible, when a mosquito takes a blood meal from an infected animal and later transmit the disease to a human when the mosquito bites again (LaMorte, 2016).

There are approximately 3,500 species of mosquitos identified throughout the world (CDC, 2015), and 95 species can be found in province of Quebec alone (Karnick & Cloutier, 2016). Although the majority of the mosquito species are not hosts to vector-borne diseases nor feed on humans, there are a few species that are human disease carriers (Hadley, 2017).

Aedes aegypti and *Aedes Albopictus* (see Figure 8) are two species that spread VBDs. They are responsible for spreading diseases, such as, Chikungunya, Dengue fever, Yellow fever, and Zika. Their ability to integrate and adapt into human environments makes them dangerous to bite and infect other humans (Kraemer, et al., 2015). Another deadly specie of VBD mosquito is the *Anopheles Gambiae*, the main vector for the dissemination of Malaria. In 2015, there was an estimated 212 million cases of Malaria worldwide, resulting in the deaths of 429,000 people (CDC, 2015). Overall, mosquitos are considered the biggest killers of humans in the world (Gates, 2014).

Figure 8. Photo of *Aedes Aegypti* (Left) and *Aedes Albopictus* (right) (University of Florida, 2016)

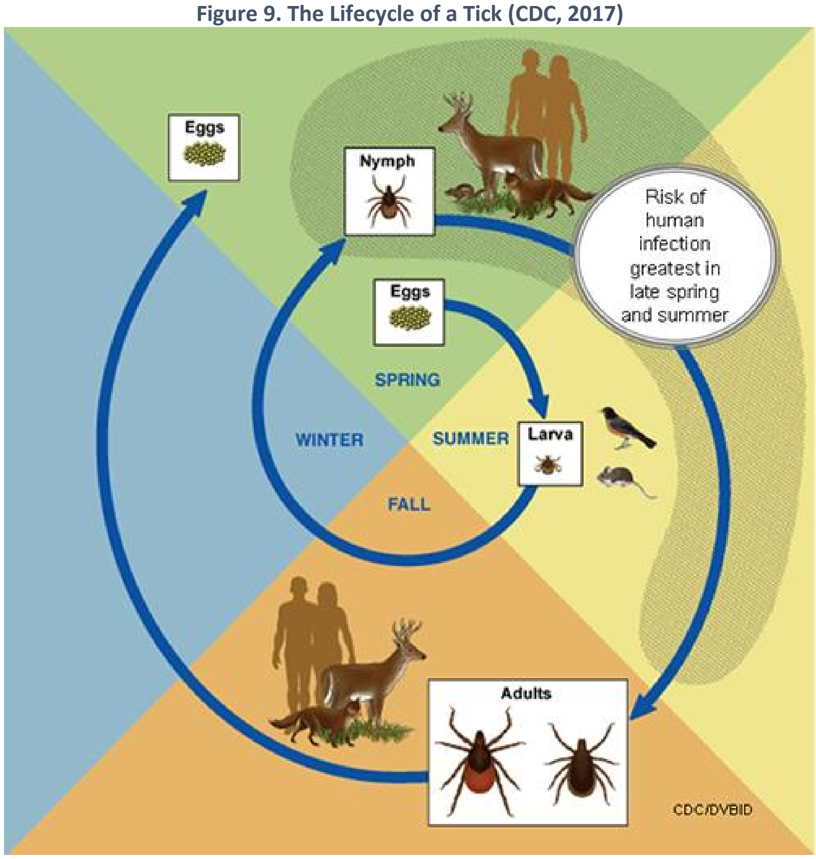


2.3.2 Ticks

In the 19th century, ticks were the first species that was discovered to be able to transmit VBDs to humans (Uilenberg & Jongejan, 2004). Today, ticks are only second to mosquito as the most prolific vector (de la Fuente, Estrada-Pena, Venzal, Kocan, & Sonenshine, 2008), but ticks transmit a greater variety of pathogen than any other vector (Uilenberg & Jongejan, 2004). Currently, there are 899 recognized species, distributed between three families of *Argasidae*, *Ixodidae*, and *Nuttalliellidae* (Hill & MacDonald, 2008).

Similar to mosquitos, the feeding characteristics can be very different between the different types of ticks. Many tick species do not seek human hosts but can become an accidental host when people began to enter forests and caves that are infested with ticks (Dantas-Torres et al., 2012). Figure 9 summarizes the lifecycle of a tick from egg to adult.

Figure 9. The Lifecycle of a Tick (CDC, 2017)



The tick has four stages in its lifecycle: egg, larva, nymph, and adult. Each lifecycle requires a blood meal before it can proceed to the next stage in life. Also, at each stage of the tick's life, different species of ticks feed on the different types of mammals until adulthood. From the figure above, a full life cycle can take up to two to three years. For example, as a larva, certain species of ticks will first feed on small animals like rodents or birds. As it becomes a nymph three seasons later, it can start to feed on larger mammals, including humans. As an adult, a tick will eat another blood meal in order to release eggs. It is during these blood meals that a tick can transmit VBDs into new hosts (Parola & Raoult, 2001).

Popular diseases associated with ticks include Lyme disease, which is a disease of great concern (Bradley, 2017). Rocky Mountain spotted fever, Crimean-Congo Haemorrhagic fever are other VBDs of particular concern with ticks (Dantas-Torres et al., 2012).

2.3.3 Fleas

Fleas (see Figure 10) are another important vector found around the world that are described as "small, laterally flattened, and highly specialized insects (Bitam et al., 2010, p.667)." As a vector, fleas have several distinctive attributes. Fleas are ectoparasites, meaning fleas are parasites that live on the skin or fur of animals (Bitam et al., 2010). Fleas can also jump up to 23 times their own height into new susceptible hosts (Burrows, 2009). Lastly, fleas have bridging vectors, such as dogs or cats, in which fleas are carried in the furs of the animals and passed along to new animal or human hosts when fleas come in close contact (Dobler & Pfeffer, 2011).

Figure 10. Oriental Rat Flea (X. chieopis), primary transmitter of the plague to humans (Pest and Diseases Image Library, Bugwood.org, 2017)

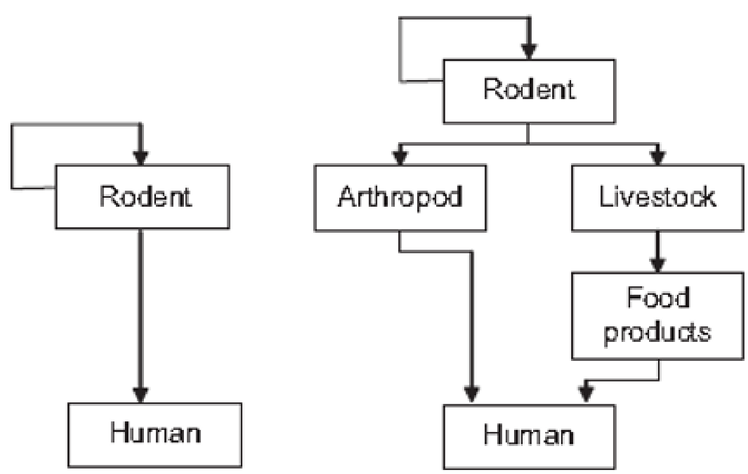
There are currently around 2,500 species of fleas, with each specie parasitizing different animals and birds (Dobler & Pfeffer, 2011). Like other vectors noted above, female fleas also require blood meals in order to reproduce. The flea lifecycle consists of four stages: Egg, Larvae, Pupae, and Adult. From Egg to Adult can take as little as 12 days to 30 days, depending on the conditions. After an adult female have its blood meal, it can lay up to 2,000 eggs within 24 hours. Larvae can also start eating blood as soon as it hatches. Again, it is through these blood feedings when the diseases are transmitted (Dechra Veterinary Products, 2017).

In terms of diseases, fleas only carry bacterial diseases and no viruses (Dobler & Pfeffer, 2011). The most common disease associated with the flea is the Plague, with its devastation explained in the Black Death section. Only 31 species of the fleas have been identified as vectors for the Plague, with the Oriental Rat Flea being the primary vector for humans from flea bites. Rodents are the bridging vector here, carrying the Plague-infected fleas to close contact with susceptible human hosts. Other diseases associated with ticks include murine typhus, tungiasis, flea-borne spotted fever, and tape worms (Bitam et al., 2010).

2.3.4 Rodents

Rodents are the most abundant mammals in the world, accounting for approximate 42% of the total living mammals (Allen, 2010). Rodents are also a comprehensive pest, capable of spreading disease and other types of destruction that can be harmful to humans. But what makes rodents so versatile is their ability to adapt and live in many environments. Many rodent species can easily adapt to living in the wild or close to human habitats, which further exposes humans to potential diseases (Meerburg et al., 2009). From a vector-borne disease perspective, rodents spread disease in many different ways. Figure 11 shows that the disease pathways are numerous.

Figure 11. Left, direct transmission route of rodents. Right, indirect transmission routes with rodents (Meerburg, Singleton, & Kijlstra, 2009)



On the direct route, rodent VBDs can be transmitted through bites or contamination of food sources or water by rodent feces. Rodents are also the natural carriers and reservoirs of many diseases, which keeps the cycle of transmission going. In the indirect route of transmitting diseases to humans, rodents are often the primary bridging vector. For example, infected ticks and fleas are carried by rodents to humans like the Plague. Lastly, livestock may have ingested infected rodents which may infect humans when humans eat the livestock as food products. Rodents also carry diseases that affect domesticated animals (Meerburg et al., 2009).

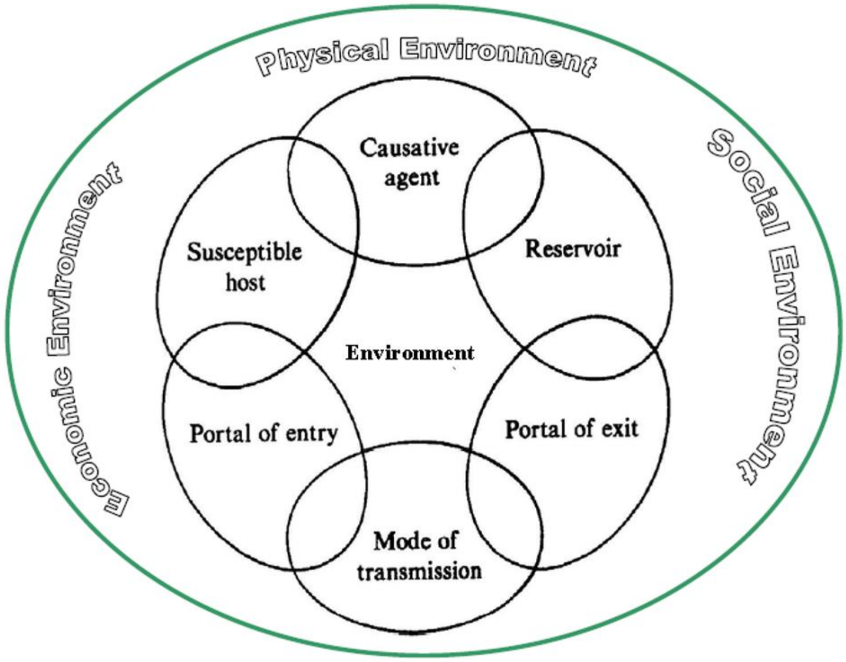
In terms of disease, some of the most harmful rodent VBDs are hantavirus, leptospirosis, and hepititus E. Indirectly, they are also carriers and reservoirs for diseases like the Crimean-Congo hemorrhagic fever, tick-borne encephalitis, Lassa fever, and Southern American arenaviruses (Gubler, et al., 2001). For animals, rodents are carriers for diseases like classical swine fever, foot and mouth disease, and other bacteria infections (Meerburg et al., 2009).

2.3.5 Chain of Infection

In this section, we want to explore the options of preventing or stopping vectors from entering an airplane and travelling to a new part of the world. Vector control is defined "as activities to reduce the populations of vectors or to reduce human contact with vectors (WHO, 2012)." There are many methods of vector control. Here, we discuss the Chain of Infection, which looks at vector control holistically.

The Chain of Infection is the basic principle of understanding how diseases are transmitted. Although a more comprehensive chain of infection will include factors like social, physical, and economic environment, we focus primarily on the six links of causative agent, reservoir, portal of exit, transmission, portal of entry, and susceptible/vulnerable hosts. The transmission of disease can be stopped by targeting any part of the chain (Saskatchewan Ministry of Health, 2010). In Figure 12, the chain of infection is shown.

Figure 12. The Chain of Infection (Saskatchewan Ministry of Health, 2010)



We examine each part of the infection chain from a vector point of view and discuss vector control solutions for each part of the chain. The killing of vectors by chemical means, such as aircraft disinsection, also disrupts this chain of infection in all stages. But other vector control methods can also disrupt the transmission of disease in different parts of the infection chain.

Causative Agent

At the top of the chain, we have the causative agent. Causative agents are the infectious organisms like viruses, bacteria, protozoa, or rickettsia. Vector control methods include disinsection, antibiotics, disinfectants, antimicrobials, and such that can be used to kill these agents (Ziegler M. , 2010).

Reservoir

In the second part of the chain is the reservoir. Reservoir is defined as the "sources which normally harbor disease-causing organisms and thus serve as potential sources of disease outbreaks (NCBI, 2017)." In our case, many of the vectors mentioned are natural reservoirs for various infectious diseases (Philip & Burgdorfer, 1961). Chemical methods, such as disinsection, are recommended to kill vectors as noted in our previous section. However, alternative vector control solutions here can be environmental or biological. In environmental control, vector habitats – stagnant water, unclean pipes, swamps - need to be eliminated so vectors cannot survive (WHO, 2012). With biological control, predators – such as mosquito larvae-eating fish – can be introduced (San Diego County, 2017) or in many cases, genetically modified vectors are introduced to halt the vector's mating lifecycle (Brunhuber, 2017).

Port of Exit

Port of exit pertains to how the causative agents leave the reservoir and transmit the disease (Ziegler M. , 2010). In the case of an insect vector, the port of exit is when vectors bite into a human or animal for a blood meal. For vector control, reduction of contact, such as mosquito nets, window screens, and closing entrances, will help reduce vector contact and vector bites (WHO, 2012).

Mode of Transmission

The fourth link is the mode of transmission. In our scenario, vectors – primarily through biting – is the main mode of transmitting the disease to a new host. In other scenarios, like humans to humans, it may be spread by droplets with SARS or through blood with Ebola (Ziegler M. , 2010). Similar to Port of Exit, reduction of contact with vectors will prevent infection and the spread of disease (WHO, 2012).

Port of Entry

The fifth link is the port of entry. In this part of the chain, it focuses on how the infectious agent enters the body of a human or animal host (Ziegler M. , 2010). In the vector scenario, the bites of the vectors usually pierce the blood vessel and from there, the infectious agents enter the body. Again, reduction of contact with vectors will reduce the probability of transmission (WHO, 2012).

Susceptible Host

The last link is the susceptible host. This pertains to the human or animals that can become infected with the disease (Ziegler M. , 2010). In terms of vector control, there are several options to reduce the rate of infection. First, through vaccines and medicine, people can be inoculated against some of the diseases (Gubler, 1998). However, there are many diseases (e.g. dengue fever, chikungunya, malaria) that do not have a vaccine (Weaver, 2014). Second, a robust public health system will ensure that surveillance is operational and have the capabilities to respond and mitigate potential diseases (Frenk & Gómez-Dantés, 2002). Third, reduction of contact with vectors will reduce the probability of transmission (WHO, 2012). Lastly, educating and communicating the vector disease and characteristics to the population will reinforce good prevention and behavior. Examples include wearing insect repellents, ensuring the home environment is vector free, and building awareness of the disease (Fenech, 2010).

2.4 Global Health, Aviation, and National Government Regulations

In the last three sections, the emphasis has been on the global transmission of diseases through air transportation, economic impact on disease pandemics, and the types of vectors that our risk model attempts to quantify. In this section, we want to focus on the international regulatory frameworks implemented to resolve the problems of global spread of disease through the international trade network as outlined in the first three sections of this literature review. As one paper puts it, the aim of the regulatory framework is "to regulate and control movements, flow and exchange, not stop in altogether (Bashford, 2003, p.124)." We first examine international regulatory regimes like WHO's International Health Regulations (IHR (2005)), ICAO's Standard and Recommended Practices (SARPs), and WTO's Sanitary and Phytosanitary Agreement (SPS). Then we discuss health regulations from a national perspective, using examples from Australia and New Zealand, Canada, and Hong Kong.

2.4.1 International Health Regulations

The main regulatory framework against the global spread of disease is World Health Organization's International Health Regulations of 2005 (IHR (2005)). The WHO is a specialized United Nations agency that was created as the global intergovernmental body with regards to international public health. Consisting of 193 sovereign member-states, the WHO has a wide range of power coordinating international public health (WHO, 2017). The World Health Assembly is the decision-making body within the WHO, and it has three specific powers: conventions, regulations, and recommendations (Constitution of the World Health Organization art.2, para. K.)

Table 4. The table of Contents of the International Health Regulations (IHR (2005))

Table

Structure and Content of the New IHR

Part	Articles	Substance Matter
Part I	1-3	Definitions, Purpose, and Scope, Principles and Responsible Authorities
Part II	5-14	Information and Public Health Response
Part III	15-18	Recommendations
Part IV	19-22	Points of Entry
Part V	23-34	Public Health Measures
Part VI	35-39	Health Documents
Part VII	40-41	Charges
Part VIII	42-46	General Provisions
Part IX	47-53	The IHR Roster of Experts, the Emergency Committee, and the Review Committee
Part X	54-66	Final Provisions
Annex 1		Core Capacity Requirements for Surveillance and Response and for Designated Airports, Ports, and Ground Crossings
Annex 2		Decision Instrument for the Assessment and Notification of Events that May Constitute a Public Health Emergency of International Concern
Annex 3		Model Ship Sanitation Control Exemption Certificate/Ship Sanitation Control Certificate
Annex 4		Technical Requirements Pertaining to Conveyances and Conveyance Operators
Annex 5		Specific Measures for Vector-Borne Diseases
Annex 6		Vaccination, Prophylaxis, and Related Certificates
Annex 7		Requirements Concerning Vaccination or Prophylaxis for Specific Diseases
Annex 8		Model Maritime Declaration of Health
Annex 9		Health Part of the Aircraft General Declaration

The IHR (2005) is one of two binding regulations that was adopted and approved by the World Health Assembly, and it was created to work towards mitigating and halting the spread of diseases across international borders. The 2005 revision also addresses several shortcomings of the previous edition of the IHR, especially when it comes to respect and dignity of human rights, expanding the definition of diseases under the scope of the IHR, and that public health data can come from non-governmental sources (Fidler & Gostin, 2006). In Table 4, the structure of the IHR (2005) is outlined. But most importantly, Article 2 of the IHR (2005) specifically addresses the balance of public health needs and the importance of trade and traffic, as it states:

> The purpose and scope of these Regulations are to prevent, protect against, control and provide a public health response to the international spread of disease in ways that are commensurate with and restricted to public risks, and which avoid unnecessary interference with traffic and trade. (p. 10)

Although legally-binding, the IHR (2005) relies on each of the member-states to respect and conduct itself to the spirit of international cooperation due to the lack of enforcement mechanisms. The framework of the articles in the IHR (2005) standardizes to how each member-state should respond and escalate potential public health risks to the WHO. The IHR (2005) does not supersede a member-states' sovereignty in dictating how public health ministries and agencies should operate internally, but requires that there is a national focal point contact to the WHO. However, the Director-General of WHO do have certain enumerated power in the IHR. One of such power is the ability to invoke whether a public health event is a Public Health Emergency of International Concern (PHEIC) outlined in Article 17. The Director-General does not need the consent of the afflicted member-state, and being listed as a country with a PHEIC would lead to swift damages in trade, movement of goods, reputation, and tourism (Aginam, 2006).

In the IHR (2005), there are a few specific articles and annexes that directly address conveyance operators, vector disinsection, and vector-borne diseases. Most notable provisions are delineated in *Chapter 2 – Special provisions for conveyances and conveyance operators* which includes Articles 24 to 29, *Article 43 – Additional Health Measures*, and *Annex 5 – Specific Measures for Vector-Borne Diseases*. To clarify, conveyance is defined as the vehicle, and in our case, the aircraft used in the operation.

Within Chapter 2 of IHR (2005), there are a few IHR Articles of special importance. In *Article 24 – Conveyance Operators*, section 1(c) requires member-states to enact regulations for conveyance operators to "permanently keep conveyances… free of sources of infection or contamination, including vectors and reservoirs. The application of measures to control sources of infection or contamination may be required if evidence is found. (p.21)"

In *Article 27 – Affect Conveyances*, this provision outlines the treatment of conveyances that may be affected. In the first section of Article 27, IHR (2005) grants competent authorities in a member-state to treat affected conveyances:

> 1. If clinical signs or symptoms and information based on fact or evidence of a public health risks, including sources of infection and contamination, are found on board a conveyance, the competent authority shall consider the conveyance as affected and may:
>
>   (a) Disinfect, decontaminate, disinsect or derat the conveyance, as appropriate, or cause these measures to be carried out under its supervision; and
>   (b) Decide in each case the technique employed to secure an adequate level of control of the public health risks as provided in these Regulations. Where there are methods or material advised by WHO for these procedures, these should be employed, unless the competent authority determines that other methods are as safe and reliable.
>
> The competent authority may implement additional health measures, including isolation of conveyances, as necessary, to prevent the spread of disease. Such additional measures should be reported to the National IHR Focal Point. (p. 22)

In *Article 28 – Ships and aircraft at Point of Entry*, IHR (2005) provides guidance to member-states to generally allow ships and aircrafts to operate despite public health concerns, however with exceptions subject to Article 43 which we will discuss after. Article 28 states:

> Subject to Article 43 or as provided in applicable international agreements, ships or aircraft shall not be refused *free pratique* by States Parties for public health reasons; in particular they shall not be prevented from embarking or disembarking, discharging or loading cargo or stores, or taking on fuel, water, food and supplies. States Parties may subject the granting of *free pratique* to inspection and, if a source of infection or contamination is found on board, the carrying out of necessary disinfection, decontamination, disinsection or derating,

> or other measures necessary to prevent the spread of the infection or contamination. (p. 22-23)

Next, in *Article 43 – Additional Health Measures*, the IHR (2005) provides guidance on balancing the member-states' need to implement health measures and potential disruption of international trade and traffic. This Article is of particular importance to ICAO in pushing for a common risk assessment tool. The tool can help guide member-states in evaluating the need to escalate health measures. It states that:

> 1. These Regulations shall not preclude State Parties from implementing health measures, in accordance with their relevant national law and obligations under international law, in response to specific public health risks or public health emergencies of international concern, which:
>   a) Achieve the same or greater level of health protection than WHO recommendations; or
>   b) Are otherwise prohibited under Article 25, Article 26, paragraphs 1 and 2 of Article 28, Article 30, paragraph 1(c) of Article 31 and Article 33
>
>   Provided such measures are otherwise consistent with these regulations.
>
>   Such measures shall not be more restrictive of international traffic and not more invasive or intrusive to persons than reasonably available alternatives that would achieve the appropriate level of health protection.
>
> 2. In determining whether to implement the health measures referred to in paragraph 1 of this Article or additional health measures under paragraph 2 of Article 23, paragraph 1 of Article 27, paragraph 2 of Article 28 and paragraph 2(c) of Article 31, States Parties shall base their determinations upon:
>
>   a) Scientific principles;
>   b) Available scientific evidence of a risk to human health, or where such evidence is insufficient, the available information including from WHO and other relevant intergovernmental organizations and international bodies; and
>   c) Any available specific guidance or advice from WHO.
>
> 3. A State Party implementing additional health measures referred to in paragraph 1 of this Article which significantly interfere with international traffic shall provide to WHO the public health rationale and relevant scientific information for it. WHO shall share this information with other States Parties and shall share information regarding the health measures implemented. For the purpose of this Article, significant interference generally means refusal of entry or departure of international travellers, baggage, cargo, containers, conveyances, goods, and the like, or their delay, for more than 24 hours.

4. After assessing information provided pursuant to paragraph 3 and 5 of this Article and other relevant information, WHO may request that the State Party concerned reconsider the application of the measures.

5. A State party implementing additional health measures referred to in paragraph 1 and 2 of this Article that significantly interfere with international traffic shall inform WHO within 48 hours of implementation, of such measures and their health rationale unless these are covered by a temporary or standing recommendation.

6. A State Party implementing a health measure pursuant to paragraph 1 or 2 of this Article shall within three months review such a measure taking into account the advice of WHO and the criteria in paragraph 2 of this Article.

7. Without prejudice to its rights under Article 56, any State Party impacted by a measure taken pursuant to paragraph 1 or 2 of this Article may request the State Party implementing such a measure to consult with it. The purpose of such consultations is to clarify the scientific information and public health rationale underlying the measure and to find a mutually acceptable solution.

8. The provisions of this Article may apply to implementation of measures concerning travellers taking part in mass congregations. (p. 28-29)

Lastly, we look at *Annex 5 – Specific Measures for Vector-Borne Diseases*. Annex 5 provides directions on when and where a chemical disinsection should take place to eradicate vectors on-board conveyances. The language of the Annex 5 is provided below:

1. WHO shall publish, on a regular basis, a list of areas where disinsection or other vector control measures are recommended for conveyances arriving from these areas. Determination of such areas shall be made pursuant to the procedures regarding temporary or standing recommendations, as appropriate.

2. Every conveyance leaving a point of entry situated in an area where vector control is recommended should be disinfected and kept free of vectors. When there are methods and materials advised by the Organization for these procedures, these should be employed. The presence of vectors on board conveyances and the control measures use to eradicate them shall be included:

    a) In the case of aircraft, in the Heath Part of the Aircraft Generation Declaration, unless this part of the Declaration is waived by the competent authority at the airport of arrival.

3. States Parties should accept disinsecting, deratting and other control measures for conveyances applied by other States if methods and materials advised by the Organization have been applied.

4. States Parties shall establish programmes to control vectors that may transport an infectious agent that constitutes a public health risk to a minimum distance of 400 metres from those areas of point of entry facilities that are used for operations involving travellers, conveyances, containers, cargo and postal parcels, with extension of the minimum distance if vectors with a greater range are present.

5. If a follow-up inspection is required to determine the success of the vector control measures applied, the competent authorities for the next known port or airport of call with a capacity to make such an inspection shall be informed of this requirement in advance by the competent authority advising such follow-up. In the case of ships, this shall be noted on the Ship Sanitation Control Certificate.

6. A conveyance may be regarded as suspect and should be inspected for vectors and reservoirs if:

   a) It has a possible case of vector-borne disease on board;
   b) A possible case of vector-borne disease has occurred on board during an international voyage; or
   c) It has left an affected area within a period of time where on-board vectors could still carry disease.

7. A State Party should not prohibit the landing of an aircraft or berthing of a ship in its territory if the control measures provided for in paragraph 3 of this Annex or otherwise recommended by the Organization are applied. However, aircraft or ships coming from an affected area may be required to land at airports or divert to another port specified by the State Party for that purpose.

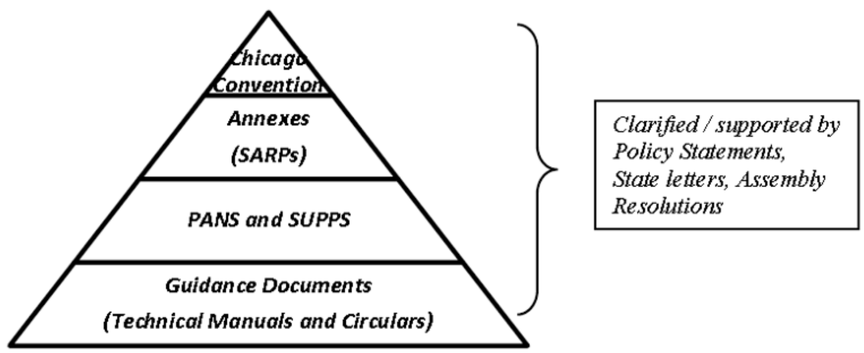
8. A State Party may apply vector control measures to a conveyance arriving from an area affected by a vector-borne disease if the vectors for the foregoing disease are present in its territory. (p. 50-51)

As stated earlier, the WHO recommendation thus far precludes any vector control methods outside of the chemical disinsection. However, the regulatory language does allow for other methods to be used as long as it also follows the WHO recommendations.

2.4.2 ICAO Chicago Convention and the Standard and Recommended Practices

For civil aviation, there are also regulations that target vectors and vector controls on airplanes. In the same umbrella as the WHO, the International Civil Aviation Organization (ICAO) is also a specialized UN agency tasked as the international regulatory body for all civil aviation related-matters (ICAO, 2017). In this section, we discuss the pertinent sections of ICAO's regulatory framework with regard to vector control and disinsection of aircrafts. The pyramid depicted in Figure 13 displays the levels of hierarchy of ICAO rules and recommendations.

Figure 13. Hierarchy of ICAO technical document (Source: Air Navigation Commission – ICAO, 2015)



At the top, the Chicago Convention of 1944 is the founding document and constitution of ICAO. This document not only authorizes the founding of ICAO, but it also establishes the principal civil aviation rules and regulations. Within this international legal framework, the Chicago Convention has a wide range of rules from sovereignty of airspace, rules of the air, entrance and clearance, cabotage, customs, search and rescue, investigation of accidents, and aircraft safety (Chicago Conventions, 1944). For the purpose of this thesis, the Chicago Conventions (1944) has *Article 14 – Prevention of Spread of Disease*, which is relevant to our risk assessment tool. In the Article, it is stated that:

> Each contracting State agrees to take effective measures to prevent the spread by means of air navigation of cholera, typhus (epidemic), smallpox, yellow fever, plague, and such other communicable diseases as the contracting States shall from time to time decide to designate, and to that end contracting States will keep in close consultations with the agencies concerned with international regulations relating to sanitary measures applicable to aircraft. Such consultation shall be without prejudice to the application of any existing international convention on this subject to which the contracting States may be parties.

Below the Chicago Convention is the International Standards and Recommended Practices (SARP). SARPs are considered annexes to the Chicago Convention and give further detailed specifications and practices that ICAO Member States should adopt. Although Member States are not obligated to adopt the SARPS, it is "recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interests of safety, regularity or efficiency of international air navigation (Air Navigation Commission - ICAO, 2015)."

Within the SARPs, there are specific provisions with regard to vector control and disinsection of aircrafts. In *Annex 9 Facilitations* (2015), this SARP deals specifically with the standardization of procedures to clear aircrafts, cargo, and travellers, and has specific language with regards to disinsection and vector control. Within Chapter 2 of SARP Annex 9, *Section D – Disinsection of Aircraft* and *Section E – Disinfection of Aircraft* provide guidance materials on vector control in aircrafts. *Section D – Disinsection of Aircraft* states:

> 2.23 Contracting States shall limit any routine requirement for the disinsection of aircraft cabins and flight decks with an aerosol while passengers and crews are on board, to same-aircraft operations originating in, or operating via, territories that they consider to pose a threat to their public health, agriculture or environment.
>
> 2.24 Contracting States that require disinsection of aircraft shall periodically review their requirements and modify them, as appropriate, in the light of all available evidence relating to the transmission of insects to their respective territories via aircraft.
>
> 2.25 When disinsection is required a Contracting State shall authorize or accept only those methods, whether chemical or non-chemical, and/or insecticides, which are recommended by the World Health Organization and are considered efficacious by the Contracting State.
>
> Note. — This provision does not preclude the trial and testing of other methods for ultimate approval by the World Health Organization.
>
> 2.26 Contracting States shall ensure that their procedures for disinsection are not injurious to the health of passengers and crew and cause the minimum of discomfort to them.

2.27 Contracting States shall, upon request, provide to aircraft operators appropriate information, in plain language, for air crew and passengers, explaining the pertinent national regulation, the reasons for the requirement, and the safety of properly performed aircraft disinsection.

2.28 When disinsection has been performed in accordance with procedures recommended by the World Health Organization, the Contracting State concerned shall accept a pertinent certification on the General Declaration as provided for in Appendix 1 or, in the case of residual disinsection, the Certificate of Residual Disinsection set forth in Appendix 4 (see Figure 14 as an example).

Figure 14. An example of a certificate of residual disinsection (Source: IHR (2005))

GOVERNMENT OF ……………………………………………………………………………

CERTIFICATE OF RESIDUAL DISINSECTION

Interior surfaces, including cargo space, of this aircraft . . . . were treated with an approved residual
(aircraft registration)
disinsection product on . . . . in accordance with the World Health Organization recommendations (WHO Weekly
(date)
Epidemiological Record No. 7, 1985, p. 47; No. 12, 1985, p. 90; No. 45, 1985, pp. 345-346; and No. 44, 1987, pp. 335-336) and any amendments thereto.

The treatment must be renewed if cleaning or other operations remove a significant amount of the residual disinsection product, and in any case within 8 weeks of the above date.

Expiry date: ……………………………………………………………………………

Signed: ……………………………………………………………………………

Designation: ……………………………………………………………………………

Date: ……………………………………………………………………………

2.29 When disinsection has been properly performed pursuant to 2.25 and a certificate as indicated in 2.28 is presented or made available to the public authorities in the country of arrival, the authorities shall normally accept that certificate and permit passengers and crew to disembark immediately from the aircraft.

2.30 Contracting States shall ensure that any insecticide or any other substance used for disinsection does not have a deleterious effect on the structure of the aircraft or its operating equipment. Flammable chemical compounds or solutions likely to damage aircraft structure, such as by corrosion, shall not be employed. (p. 2-3 – 2-4)

Section E – Disinfection of Aircraft is stated below:

> 2.31 Contracting States shall determine the conditions under which aircraft are disinfected. When aircraft disinfection is required, the following provisions shall apply:
>
> > a) The application shall be limited solely to the container or to the compartment of the aircraft in which the traffic was carried;
> >
> > b) The disinfection shall be undertaken by procedures that are in accordance with the aircraft manufacturer and any advice from WHO;
> >
> > c) The contaminated areas shall be disinfected with compounds possessing suitable germicidal properties appropriate to the suspected infectious agent;
> >
> > d) The disinfection shall be carried out expeditiously by cleaners wearing suitable personal protective equipment; and
> >
> > e) Flammable chemical compounds, solutions or their residues likely to damage aircraft structure, or its systems, such as by corrosion, or chemicals likely to damage the health of passengers or crew, shall not be employed.
>
> Note. — When aircraft disinfection is required for animal health reasons, only those methods and disinfectants recommended by the International Office of Epizootics should be used.
>
> 2.32 Contracting States shall ensure that where there is contamination of surfaces or equipment of the aircraft by any bodily fluids including excreta, the contaminated areas and used equipment or tools shall be disinfected. (p. 2-4)

In *Chapter 2 – Entry and Departure of Aircraft*, there are other relevant health provisions below:

> 2.4 Contracting States shall not prevent an aircraft from calling at any international airport for public health reasons unless such action is taken in accordance with the International Health Regulations (2005) of the World Health Organization.
>
> 2.4.1 Recommended Practice. — In cases where, in exceptional circumstances, air transport service suspensions on public health grounds are under consideration, Contracting States should first consult with the World Health Organization and the health authority of the State of occurrence of the disease before taking any decision as to the suspension of air transport services.
>
> 2.5 If, in response to a specific public health risk or a public health emergency of international concern, a Contracting State is considering introduction of health measures in addition to those recommended by WHO, it shall do so in accordance with the International Health Regulations (2005), including but not limited to Article 43, which states, in part, that when determining whether to implement

> the additional health measures States Parties shall base their determinations upon: (a) scientific principles; (b) available scientific evidence of a risk to human health, or where such evidence is insufficient, the available information including from WHO and other relevant intergovernmental organizations and international bodies; and (c) any available specific guidance or advice from WHO.
>
> Note 1. — Standard 2.5 applies only to those situations where there is an official IHR (2005) Temporary Recommendation (i.e. in the context of a declared public health emergency of international concern), or a Standing Recommendation in effect. These requirements in Article 43 can also apply to other contexts involving additional measures applied to international traffic (including aircraft), such as IHR Articles 23 2), 27 1) and 28.
>
> Note 2. — Article 43 of the IHR (2005) also requires that a State that implements additional measures thereunder that significantly interfere with international traffic is required to provide to WHO the public health and scientific rationale for such measures.
>
> 2.5.1 Recommended Practice — Any State impacted by a measure taken under Standard 2.4, or a suspension as described in Recommended Practice 2.4.1, should, where appropriate, request the State implementing such a measure to consult with it. The purpose of such consultations would be to clarify the scientific information and public health rationale underlying the measure and to find a mutually acceptable solution. (p. 2-5 – 2.6)

The language used in the ICAO SARP adopted similar language as the IHR, and as noted above, it defers back to WHO and IHR (2005) for further guidance on public health related issues.

2.4.3 The World Trade Organization Sanitary and Phytosanitary Agreement

Another international regulatory body that have provisions with regards to public health and international trade is the World Trade Organization (WTO). In WTO, the binding document safeguarding the public health interests to that of international trade is the Sanitary and Phytosanitary Measures Agreement (SPS Agreement, 1994). Similar to the IHR (2005), the SPS Agreement's (1994) goal is:

> The Agreement on the Application of Sanitary and Phytosanitary Measures seeks to strike the balance between the right of WTO members to protect health and the need to allow the smooth flow of goods across international borders. The Agreement recognizes the right of the WTO member to adopt legitimate measures to protect food safety and animal and plant health while ensuring these measures are not applied in an unnecessary manner for protectionist purposes. (p.3)

While the SPS Agreement covers subject areas beyond the scope of the master's thesis, there are several provisions within the SPS that are related to our topic at hand. First, the SPS Agreement harmonizes WTO members to adopt the same international standards to the extent possible to ensure that all stakeholders are not subjected to arbitrary laws and regulations. Second, the SPS recognizes that different geographic areas within an export country can have very different profiles with respect to diseases and invasive pests. Third, scientific evidence should be used to justify new trade restrictions for public health reasons. Fourth, the least trade-restrictive measures should be used to meet the public health requirements of the country. Lastly, the SPS Agreement is designed to deter member-states from using public health measures as a disguise for protective trade measures (WTO, 1998).

The SPS Agreement also has a dispute mechanism between States. The SPS committee was created for member states' to notify SPS committee on new public health laws and regulations that may impact the free flow of goods. This gives affected member-states time to review and comment of proposed changes, and time to negotiate before new rules and regulations come into effect. As of September 2017, there are over 22,000 notifications registered on the SPS committee website (WTO, 2017).

Within the SPS Agreement, there are several provisions within the Agreement that covers diseases and pests. In *Article 5 – Assessment of Risk and Determination of the appropriate Level of Sanitary or Phytosanitary Protection*, section 2 and 3 state:

> 2. In the assessment of risks, Members shall take into account available scientific evidence; relevant processes and production methods; relevant inspection, sampling and testing methods; prevalence of specific diseases or pests; existence of pest — or disease — free areas; relevant ecological and environmental conditions; and quarantine or other treatment.
>
> 3. In assessing the risk to animal or plant life or health and determining the measure to be applied for achieving the appropriate level of sanitary or phytosanitary protection from such risk, Members shall take into account as relevant economic factors: the potential damage in terms of loss of production

> or sales in the event of the entry, establishment or spread of a pest or disease; the costs of control or eradication in the territory of the importing Member; and the relative cost-effectiveness of alternative approaches to limiting risks. (p. 71-72)

Article 6 – Adaption to Regional Conditions, including pests – or disease – Free Areas and Areas of Low Pest or Disease Prevalence focuses on the regional and vector control policies in the country or region within that country, as it states:

> 1. Members shall ensure that their sanitary or phytosanitary measures are adapted to the sanitary or phytosanitary characteristics of the area — whether all of a country, part of a country, or all or parts of several countries — from which the product originated and to which the product is destined. In assessing the sanitary or phytosanitary characteristics of a region, Members shall take into account, inter alia, the level of prevalence of specific diseases or pests, the existence of eradication or control programmes, and appropriate criteria or guidelines which may be developed by the relevant international organizations.
>
> 2. Members shall, in particular, recognize the concepts of pest — or disease-free areas and areas of low pest or disease prevalence. Determination of such areas shall be based on factors such as geography, ecosystems, epidemiological surveillance, and the effectiveness of sanitary or phytosanitary controls.
>
> 3. Exporting Members claiming that areas within their territories are pest — or disease-free areas or areas of low pest or disease prevalence shall provide the necessary evidence thereof in order to objectively demonstrate to the importing Member that such areas are, and are likely to remain, pest— or disease—free areas or areas of low pest or disease prevalence, respectively. For this purpose, reasonable access shall be given, upon request, to the importing Member for inspection, testing and other relevant procedures. (p. 73)

The SPS Agreement has similarities to that of the IHR (2005) and the ICAO SARP Annex 9, but have higher emphasis on trade and geography.

2.4.4 National Laws and Regulations of Member States

The regulatory language of all three regulatory frameworks above have languages that defer to the sovereignty of member-states. In this context, this section examines countries that have adopted public health laws and regulations that exceeds the norm prescribed in the IHR (2005) and ICAO SARPs. We examine Australia and New Zealand's national law with regards to vectors and vector control, contrast that to Canada's lack of regulatory regime, and then focus on Hong Kong whom unilaterally escalated the health requirements as per IHR (2005) Article 43.

Australia and New Zealand

Australia and New Zealand have one of the most stringent and extensive laws with regards to quarantine and vector control of incoming ships and aircrafts. The main reason is due to Australia and New Zealand's unique ecosystem as an isolated continent and islands separated by the sea (Slepski, 2017). In the Australian Government's biosecurity website (2017), it clearly states:

> Biosecurity has played a critical role in reducing risk and shaping our nation to become one of the few countries in the world to remain free from the world's most severe pests and diseases.
>
> While our geographical isolation has played a key role in maintaining this status, our isolation as an island nation is rapidly changing as the barriers of time and distance become less relevant and international travel and trade increase.
>
> With more than 60 000 kilometres of coastline offering a variety of pathways for exotic pests and diseases, the Department of Agriculture and Water Resources screens, inspects and clears the millions of people, mail parcels, baggage, ships, animals, plants and cargo containers entering Australia every year using x–ray machines, surveillance, and, of course, the instantly recognisable detector dogs. (p. 1)

The underlying law in Australia is governed the Biosecurity Act of 2015. Under *Section 53*, "an incoming aircraft must take measures to control or destroy insect vectors of human disease that have a potential to cause, directly or indirectly, to List of Human Disease (LHD), and may exist in or on the aircraft or goods in or on the aircraft. (p. 65)" The Biosecurity Act also gives broad enforcement compliance and enforcement tools to enforce the law (The Australian Government, 2017).

In vector control and aircraft disinsection, the governments of Australia and New Zealand jointly regulate the disinsection and vector requirements. In Australia, the lead agency is the Department of Agriculture and Water Resources, and in New Zealand, the Ministry of Primary

Industries. Together, the two governments set the unified regulations on vector control of aircrafts called *Schedule of aircraft disinsection procedures for flights into Australia and New Zealand* (Schedule (2017)).

The Schedule (2017) is a comprehensive set of vector control instructions for airlines that fly into Australia and New Zealand. Within its content, the Schedule (2017) can be summarized into a few key sections:

1. Specific chemical products and ingredients to be used on aircraft disinsection.
2. Regulations on when and how aircrafts are to be disinsected.
3. Certification (Similar to Certificate of Residual Disinsection above) requirements specific to the Australian and New Zealand government.
4. It seeks Airlines to enter into voluntary agreement with the Governments to be pre-complaint before aircraft arrival. An online database of compliant and disinfected aircrafts are to be updated regularly, but no less than 1 hour before the aircraft reaches the airport.
5. Gives step-by-step process for each disinsection methods: Residual, pre-embarkation, pre-flight and top of descent, and on-arrival.
6. Specific spraying instructions for each aircraft type e.g. Boeing 787, Airbus A380
7. Step-by-step disinfection instructions for non-compliant, arrival aircraft (as shown in Table 5).

Table 5. A step-by-step guidance on pre-embarkation disinsection treatment for a Boeing 747 (The Australian Government, 2017)

Step	Action
1	A B747 requires four x 100g cans containing 2% permethrin as the active ingredient.
2	Carry out all procedures as outlined in Section 2.2.
3	Downstairs: two operators each with two cans starting at the rear of the aircraft and moving forward at a rate of not more than one step or one row of seats per second, with the spray being directed towards the open overhead lockers.
4	Upstairs: one operator using the remaining spray from all four cans with all lockers opened and moving at one step or one row of seats per second with two cans at a time.
5	A B747 Combi has the rear portion of the main cabin as a cargo area. This can be accessed via a door at the end of the main cabin and sprayed using one x 150g one-shot can that contains 2% d-phenothrin and 2% permethrin as the active ingredients. Refer to pre-flight hold disinsection procedures in Pre-flight hold disinsection.

Airlines that fail to adhere to Australia and New Zealand's guideline are subject to penalties and fines. This can include infringement notices, civil penalties, enforceable undertakings, injunctions, and criminal sanctions (The Australian Government, 2017).

Canada

Canada is in contrast to Australia and New Zealand in the government's response to vector control and disinsection. On the Transport Canada (2017) website, the disinsection policy is: "Transport Canada does not require the disinsection of aircraft arriving in or departing from Canada. However, Canadian registered aircraft must comply with the disinsection requirements of other countries. (p. 1)"

The foreign countries that requires Canadian-registered aircrafts to disinsect are Antigua, Australia, Argentina, Barbados, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Guadalupe, Honduras, India, Jamaica, Martinique, Mexico, Panama, Puerto Rico, St. Lucia, Trinidad and Tobago, and Venezuela (Transport Canada, 2017).

Hong Kong

In April 2017, the Special Administrative Region of Hong Kong issued a bulletin advising countries that are categorized as Category I or II under WHO's Zika watch are required to have disinsection and vector control performed. Article 43 allows member-states to escalate the health and entry requirements based on the scientific evidence. In the bulletin, it was suggested that due to scientific evidence, this new measured was implemented (Department of Health, 2017):

> In Hong Kong, upon the risk assessment by the Government, the Department of Health (DH) adopts a prudent approach on aircraft disinsection in reducing the risk of importation of Zika virus through infected mosquito, Aedes aegypti. After balancing the public health benefit against the potential impact on travellers, aircraft operators and airport, the declaration of aircraft disinsection will be implemented and aircraft disinsection be conducted in end-April 2017 (date to be announced) for all incoming aircraft from Zika affected areas (i.e. last port being a WHO Category 1 or Category 2 area). The current list of Zika affected areas can be found in WHO's latest Zika virus situation report: http://www.who.int/emergencies/zika-virus/situation-report/en/ (p.1)

To meet the standards of this new regulation, US-registered planes needed to be re-routed to a third country to be disinsected because the Environmental Protection Agency in the United States has not approved of any chemicals to be used. This caused a major disruption to the aircraft fleet management, and punished large countries with vast geographical and environmental differences (Slepski, 2017).

2.4.5 The WHO recommended Chemical disinsection standard

Right now, the only approved procedure for vector control in air transportation is chemical disinsection. Listed in Table 6 below, the WHO recommends four types of chemical disinsection methods: residual, pre-embarkation, pre-flight and top of descent, and on-arrival.

Table 6. The 4 types of recommended disinsection methods (WHO, 2012)

Types of Disinsection	Explanation
Residual	Is carried out while no passengers are onboard. The entire aircraft is sprayed with a residual insecticide and lasts eight weeks.
Pre-embarkation	Is carried out while no passengers are on board. Crew may be on board as this method is completed up to 40 minutes prior to passengers boarding the aircraft. The treatment lasts for the duration of the single flight.
Pre-flight and Top of Descent	Refers to a two-part process consisting of pre-flight and top of descent spraying. Pre-flight spraying is followed by a further in-flight spray of a non-residual insecticide, carried out at top of descent as the aircraft starts its descent into either Australia or New Zealand. The treatment lasts for the duration of the single flight.
On-Arrival	Is an in-flight spray of a non- residual insecticide, carried out once the aircraft lands in Australia or New Zealand. The treatment lasts for that one arrival.

The performance standard for chemical disinsection from the WHO requires that 80% of the vectors to be killed within a 24-hour period (personal communication, April 27, 2017). This standard drew many complaints from the various aviation stakeholders as the current standard does not include any means outside of chemical disinsection. Industry group also cited potential health concerns for flight crews that are exposed to the chemicals. They all agreed that other vector control mechanisms should be included in a holistic approach to curtailing the spread of vectors and VBDs to new regions (United States Delegation, 2016). One of the objectives of the risk assessment tool is to incorporate other vector control methods into the model, and help government and aviation stakeholders choose the correct vector control method depending on various factors.

2.5 Addressing current knowledge gap

There are other risk assessment tools that calculate the risk of vector importation into another country. In Huang, Das, Qiu, and Tatem (2012), a web-based vector transmission risk tool was developed by combining vector distribution, climate, and air traffic data. In Tatem et al. (2006), global shipping traffic data and climate data were used to assess vector suitability and accessibility. In Huang and Tatem (2013), malaria prevalence along with air traffic and passenger data were used to calculate the risk of vector importation. Lastly, the WHO Zika Technical report - Interim Risk Assessment (2016) for the European region used six factors to decide the likelihood of transmission. The six factors used there were vector base score, history of previous arboviral outbreak, shipping connectivity, air connectivity, population density, and urbanization.

Our proposed risk assessment tool addresses previous knowledge gaps by including departure and arrival airports, and aircrafts as part of the overall risk factors of importing vectors into a region. As the primary vehicle, and point of exit and entry for vectors, there has been no previous studies or research that looks at the efficacy of airport and aircraft vector control as part of an overall strategy to mitigate or stop the transmission of vectors. Furthermore, our risk tool does not rely on datasets to model risk probabilities, and the users of the risk tool can perform a rapid risk assessment by answering the series of indicators. Future iterations will include databases with data collected from airports and airlines for even more precise risk results. This risk assessment tool will be one of the first to address risk of vector importation from an overall, sequential perspective from the departure region, surveillance capabilities, departure airport, arrival airport, and conveyance (aircraft) operators.

Chapter 3 : Methodology

We presented the need to assess the risk and probability of introducing vectors and their vector-borne diseases into a new region through air transportation in the previous chapter. The literature review examined how increased global trade increased the risk of spreading disease, and the spreading of the disease globally is not only deadly but also disruptive to the supply chain of essential goods, trade, and livelihoods. We also reviewed what public health regulations are enacted and what vector control methods are used to mitigate and eliminate the probability of transporting vectors into a new area. In this chapter, our aim is to explain the successive steps taken to develop our vector risk assessment tool.

In reading through the notes and materials compiled by the vector working group prior to the 39th ICAO Assembly, there are many requirements on how a risk assessment tool should be developed. First, the risk assessment tool must include other preventative and pro-active vector control methods to control the spread of vectors outside of chemical aircraft disinsection. Second, there is a certain progressive, successive logic that the vector spread starts from the region of departure airport and surveillance, the departure airport itself, and then the aircraft or vehicle that carries the vectors to the arrival airport. Third, the risk assessment tool should be easy to use by aviation staff (e.g. pilots and flight operators) without too much technical knowledge of public health. Lastly, there is a particular emphasis on developing the weights for the risk assessment indicators to determine which indicators are more important or less important. Thus, a risk assessment tool should comprise of calculated risk weights, non-chemical vector control indicators, holistic from region to arrival airport, and should be friendly to use for different levels of users.

It is due to the particular emphasis on developing the weights that we choose Analytical Hierarchy Process (AHP) as the methodology used to build the risk assessment tool. In our discussion with the Chief of the Aviation Medicine section of ICAO, the aviation and public health stakeholders wanted a consistent, transparent, and measurable way to determine the weights of each of the risk indicators. They wanted to understand how the risk weights are calculated. Thus, AHP is chosen because of its particular emphasis of deriving weights through standardized comparison of one indicator to another.

AHP is a multi-criteria decision-making method invented by Saaty (2001) to “provide the objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision. (p. 1)” By using this method, we can stratify complex decision problems and its indicators into different levels and sub-levels, and quantify the risk with a transparent and a consistent scale. There are several advantages of using AHP to develop the tool. The first advantage is the utilization of pair-wise comparisons to derive the importance of each indicator. Saaty (2008) argued that direct comparison of one indicator to another by judgement is a way to derive risk priorities on what is important and what is less important. Second, the standardized Saaty scale used to make AHP comparisons allows qualitative and quantitative indicators to be directly compared by stakeholders and experts. This allows indicators that are traditionally measured differently to be directly compared (Saaty, 1990). Lastly, AHP creates a multi-level hierarchy tree that views the overall complexity of the problem. This allows the decision makers to stratify the problems from different aspects, and slot indicators into different levels depending on the magnitude of importance (Saaty, 1990).

The AHP method has also been used in other complex risk-related studies as well. Murtaza (2003) used the AHP to determine the risk of investing and doing business in foreign countries based on socio-political and economic factors. In Zeng, An, and Smith (2007), AHP was used to assess and analyze the risk severity and risk likelihood of complex construction projects. Tian and Yang (2013) utilized AHP to analyze the risk factors in the manufacturing of satellites and in which phase of the manufacturing process has higher risks in causing production problems. In Dey (2010), AHP was used in conjunction with the risk map to identify and prioritize the risks in building an oil pipeline in India. Gaudenzi and Borghesi (2006) used AHP to identify supply chain risks to improve customer value. Bachkar, Won, and Szmerekovsky (2013) used AHP to examine the risk factors involved in shipping container security. In Peng and Cui (2014), the AHP method was used to determine and prioritize the IT and network risk factors. These papers show that AHP is a method well suited to develop a risk assessment tool.

In the next four sections of the methodology chapter, we introduce the four steps necessary to build and develop the vector risk assessment aviation tool. The first two steps involve determining the correct and necessary indicators through the literature review and interviews. The third step involves expert and stakeholder inputs into the AHP questionnaire using the Saaty scale to judge pair-wise comparisons. The last step is to create the risk assessment tool and receive validation from aviation and public health stakeholders.

3.1 First step – Modifying and improving the original indicators

In this step, we first examine the indicators that were first developed by the ICAO working group that met prior to the 39th ICAO Assembly. In the three-day meeting, the group came up with a list of vector control indicators that the experts thought were important to stop or mitigate the spread of vectors in air transportation. In the first three categories, the indicators focused on the presence of vectors. The departure airport category and its indicators aimed at the effectiveness of the airport vector control program. Finally, the operator category has a series of indicators that targeted the operator's vector control processes. The original indicators list also used a different risk methodology in which the base score was established by the vector presence level (between confirmed, potential, and no vector presence), which then calculates the departure airport and operator indicator scores. The final aggregation of all three categories provides the final risk score.

It must be noted that this first iteration never became a functioning risk assessment tool, and our contribution is to use this first iteration as a foundation to further develop the indicators and risk assessment tool. One of the shortcomings of the original iteration is understanding how the risk score was calculated and the process of calculating it. The AHP methodology would address these limitations.

Table 7. List of the original indicators developed by the ICAO working group.

Category I: Confirmed vector presence
Is the period of the mosquito surveillance relevant to the season of their life cycle?
Are BG Sentinel traps used for surveillance purposes?
Is the surveillance conducted by designated personnel or contracted services?
Are the results of surveillance used to assess the need to implement mosquito control programs?
Are the results and associated risks of vectors communicated to the user of the installation?
Category II: Potential Vector presence
Category III: No Vector Presence
Absence of vector based on environmental condition
Absence of vector presence confirmed through surveillance program
Departure Airport
Do departing international operations include scheduled passenger operations?
Do departing international operations include cargo aircraft?
Do departing international operations include non-scheduled passenger operations?
Do departing international operations include military or state operations?
Does the airport provide disinsection services for aircraft?
Are jet ways or walkways/stairways for passenger loading closed?
Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?
Operator
Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operations?
Does the operator use self-closing screens for passenger entries?
Does the operator use self-closing screens for cargo entries?
Does the operator have personnel that monitor for the presence of insects around and within the aircraft?
Does the operator utilize residual disinsection?
Does the operator use maintenance facilities at the departure airport?
Does the maintenance facility utilize chemical or mechanical disinsection when servicing aircraft?

We then refer to the literature review conducted to see if there are additional indicators that should be incorporated into the indicator list. We also examine whether the indicators list in Table 7 can be better re-organized for the AHP method. This requires us to see if the current set of indicators is suitable for the multi-level stratification of the AHP hierarchy tree. Finally, since the risk tool needs to be approved by the WHO, we also ensure that the indicators added in this section are in compliance with the IHR (2005). Section 4.1 in the Results chapter of this master's thesis presents the modified set of indicators derived from this chapter.

3.2 Second step – Interviews and refining the final indicators list

In the second step, the objective is to validate the updated indicators list compiled from the first step, and ensure that the updated indicators list is appropriate and clearly defined. We validate the new indicators list by interviewing experts and stakeholders from aviation, government, and public health. There are three reasons to conduct the interviews. First, this is to ensure that the experts and stakeholders agree that the modified list of indicators is accurate and holistic to assess the risks of vector importation. Second, this gives the experts and stakeholders an avenue to express their thoughts and opinions on the list of indicators, and whether the indicators should remain unchanged, re-worded, modified, merged or deleted. Lastly, the interviews give the experts and stakeholders an opportunity to add any new, pertinent indicators that were omitted in prior iterations.

In this step, we have first created a structured interview guide from the modified indicator list developed in the first step. The structure interview guide lists each of the indicators compiled thus far, and asks the respondents to keep, delete, or merge each indicator. Furthermore, if the indicator wording is incorrect or needs to be revised, the respondent has an opportunity to suggest an update in the interview guide. Lastly, the respondents can further comment on each indicator, giving further background or rationale on why the indicator should or should not be adopted. A consent form is attached to the interview guide, which also contains a provision to audio record the interviews. The complete interview guide is available in Appendix A.

The panel of experts and stakeholders chosen is selected in collaboration with the Aviation Medicine section of ICAO. As the lead bureau in charge of this risk tool initiative, the chief of the Aviation Medicine identifies the key experts and stakeholders from different organizations that can provide meaningful feedbacks and expertise in the interview round. The inclusion criteria include individuals whom have more than three years experience in the civil aviation or public health field. Members that work within the public health or civil aviation organizations, such as ICAO, WHO, IATA, ACI, IFALPA, CDC, and ITA are also included. Exclusion factors include individuals who are not familiar with neither civil aviation nor public health or those who has less than three years of experience. Interview participants are sent confidential emails to participate and set an appointment time for either an in-person, phone, or Skype interview. The structured interview guide is sent before the interview, so each of the interview participant can review and study the document and indicators beforehand. Eight experts have been approached to participate in the interview, and the response rate was 100% due to prior knowledge that the risk tool was being developed. The interview process is scheduled to last approximately 90 minutes.

The eight expert interview participants were:

1. Andreas Meyer, Safety Management Officer, International Civil Aviation Organization (ICAO);
2. Daniel Chong, FAA Liaison - U.S. Mission to ICAO, Federal Aviation Administraton (FAA);
3. Lynn Slepski, Senior Public Health Advisor, U.S. Department of Transportation (DOT);
4. Jerome Hogsette, Lead Scientist – Research Entomologist, U.S. Department of Agriculture (USDA);
5. Jean-Sébastien Pard, Facilitation and IT Manager, Airport Council International (ACI);
6. Claude Thibeault, Medical Advisor, Consultants Aeromed Inc. on behalf of International Air Transport Association (IATA);
7. Jitendra Thaker, Technical Officer – Facilitations, International Civil Aviation Organization (ICAO);

8. Gordon Margison, Technical Officer, The International Federation of Air Line Pilot's Association (IFALPA).

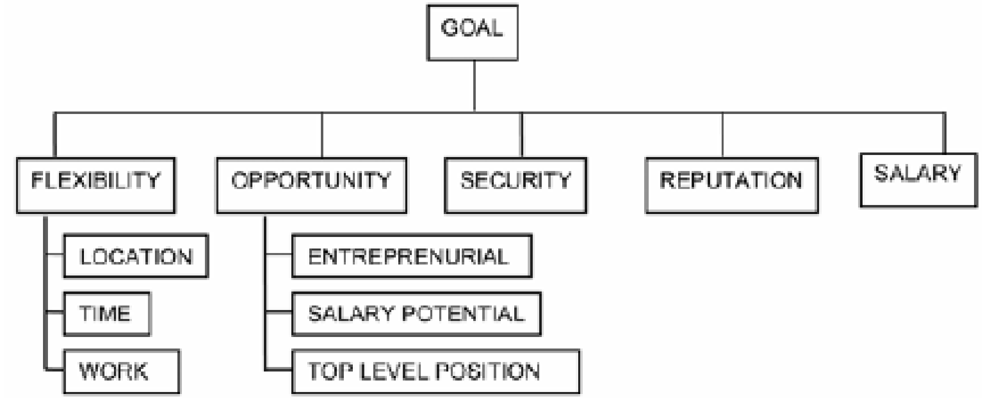
After the interview phase, we again aggregate the interview results in a matrix to see whether indicators are adopted, modified, merged, or deleted. Furthermore, we reformulate the next iteration of indicators list based on the feedback and suggestions from the interviews. After the new indicators list is compiled, we send an email to each of the interview participants for a final review period. In this 15-day final review period, we want to solicit any final comments on the newest version of the indicators list. We want to give a final opportunity for our experts and stakeholders to pitch for or against indicators that may have been retained, modified or deleted against their advice.

In Section 4.2, we present the findings from the interviews. That is, the interview results matrix that is created to assess and display which indicators should be changed, deleted, or modified. We show the newest and final iteration of the indicators list based on the feedbacks from the participants. The rationale and comments on each of the indicators are included to give further background on our decisions with each of the indicator.

3.3 Third step – Applying the Analytical Hierarchy Process (AHP)

The objective of the third step is to build the weights for the indicators using the AHP methodology. After concluding the final list of the indicators for the vector risk tool, we first create an AHP hierarchy tree to stratify our risk indicators and categories into different levels. This allows the risk tool to assess the risk from different perspectives, and different levels of risk based on importance and order. Using an example presented by Saaty (2008), Figure 15 is an AHP hierarchy tree with multiple levels. The top level (also known as level 0) is the goal and objective of finding the ideal job. Level 1 represents the different perspectives and criteria for the job search. Level 2 represents specific sub-criteria within a criterion such as such as the location, time, and work within the Flexibility category.

Figure 15. Saaty (2008) example of an AHP hierarchy tree on job selection decision for new graduates



Next, we conduct the AHP pair-wise comparisons between the different indicators based on the AHP hierarchy tree that is established similar to Figure 15. Here, the pair-wise comparisons establish which risk indicators pose higher or lower risks based on the judgements of experts and stakeholders.

For the AHP pair-wise comparison, we rely on an AHP online software called AHP Online System – BPMSG (https://bpmsg.com/academic/) which is also called AHP-OS. We choose this system for four reasons. First, it is the only free software made for AHP comparisons. Second, this is the only AHP software – free or commercial – that allows us to test and use the software whereas other software packages require us to contact a sales representative first. Third, the AHP Online System is online-based, so our participants can answer the questionnaire from anywhere in the world. Lastly, the AHP-OS allows group input, so an unlimited number of participants can be invited to answer the AHP questionnaire. The underpinning of the AHP Online System is also available at the website (Goepel, 2017).

Using this AHP-OS software, we input the risk indicators into the AHP hierarchy tree format, and the online system will then allow users to log-on the AHP-OS website to begin the online AHP comparison questionnaire. The AHP questionnaire is based on the pair-wise comparison using Saaty scale, which is shown in Figure 16. The Saaty scale ranges from 1 to 9, with 1 being the least intensity in importance to 9 being the extreme intensity in importance.

Figure 16. Saaty scale (Saaty, 2008)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

In Figure 17, the AHP software will let the participants start pair-wise comparisons from the top level of the AHP hierarchy tree and then work into the lower levels within the hierarchy tree. Using the Saaty scale and comparing one indicator to another, the participant then chooses the more important indicator and then decide by how much more important it is compared to a less important indicator. Once a participant completes the pair-wise comparison on all levels, the result of the final weights will be returned to the participant. Due to the graphical nature of the AHP method, the details and mathematical equations to convert pair-wise comparisons into the ratio scales and scores are further explained in Section 4.3.

Figure 17. Sample screenshot of the AHP Online System - BPMSG

AHP-OS Home Latest News

Pairwise Comparison AHP-OS

Pairwise Comparison V-Risks between XXX & YYY Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *V-Risks between XXX & YYY Airport*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *V-Risks between XXX & YYY Airport* - or B?		Equal	How much more?
1	1. Region	or 2. Surveillance	1	2 3 4 5 6 7 8 9
2	1. Region	or 3. Departure Airport	1	2 3 4 5 6 7 8 9
3	1. Region	or 4. Arrival Airport	1	2 3 4 5 6 7 8 9
4	1. Region	or 5. Conveyance Operators	1	2 3 4 5 6 7 8 9
5	2. Surveillance	or 3. Departure Airport	1	2 3 4 5 6 7 8 9
6	2. Surveillance	or 4. Arrival Airport	1	2 3 4 5 6 7 8 9
7	2. Surveillance	or 5. Conveyance Operators	1	2 3 4 5 6 7 8 9
8	3. Departure Airport	or 4. Arrival Airport	1	2 3 4 5 6 7 8 9
9	3. Departure Airport	or 5. Conveyance Operators	1	2 3 4 5 6 7 8 9
10	4. Arrival Airport	or 5. Conveyance Operators	1	2 3 4 5 6 7 8 9

CR = 0% Please start pairwise comparison

Check Consistency

Since multiple participants are invited to participate in the AHP questionnaire, the final AHP score of all the participants from the AHP questionnaire will be aggregated by the AHP software using geometric means. This global average will determine the actual weights of each of the risk indicators that we have developed in the first and second step. This will be incorporated into an Microsoft Excel spread sheet that will be the basis to calculate the risk in our vector assessment tool. Section 4.3, describes the results of this step in further detail.

In this step, five experts participated in the AHP questionnaire to formulate our risk assessment tool. Three experts participated in both the interview round and the AHP questionnaire. The other five experts from the interviews did not respond to the AHP questionnaire request. Two experts that met the inclusion criteria from outside the initial interview group were added to gain a more diverse opinion. Due to confidentiality reasons, the names of the participants and position are not revealed.

3.4 Fourth step – The risk assessment tool and validation from key stakeholders

In the last step, the AHP weights results are placed into an Microsoft Excel spreadsheet. This Excel spreadsheet is then organized into a format that provides users a platform to answer the series of indicators, which then calculates the risk score of vector importation. Since this is a pilot project and a first version of the risk assessment tool, we are interested in the feedback on the efficacy of this tool.

In this phase, we want to present to stakeholder organizations the risk assessment tool. From a top level, we would like to present and receive validations from ICAO, WHO, and government agencies like the CDC, Ministry of Health, and Civil Aviation Authorities. Moreover, partner organizations, such as the representatives from IATA, ACI, IFALPA, and ITA will be presented the risk assessment tool. We will also invite potential users to test the risk assessment tool and give us feedback. Table 8 provides a summary of all four steps of the methodology.

Table 8. Table summarizing the four-step methodology

Step	Description	Goal	Participants
1	Modifying and improving the original indicators	The first step aims to review the original indicators list and update the list according to the information gathered in the literature.	—
2	Interviews and refining the final indicator list	The second step aims to validate the updated indicator list through interviews with experts. The interview results are used to create the final indicators list.	8
3	Applying the Analytical Hierarchy Process (AHP)	The third step aims to implement the final indicators into the AHP-OS web application, and invite experts to participate in the AHP questionnaire. The aggregated result creates the weights for the risk assessment tool.	5
4	The risk assessment tool and validation from key stakeholders	The risk assessment tool is built using Microsoft Excel. Stakeholders are presented with the risk assessment tool, and asked to test it.	6 organizations, 7 countries

Chapter 4 : Results

In the last chapter, we explained the four steps methodology to develop the risk assessment tool. In this chapter, we present the corresponding results for each of the four steps outlined in the methodology chapter.

4.1 Results of the First Step – Modifying and improving the indicators

In the corresponding Section 3.1 of the Methodology chapter, we explained that our initial indicators list was derived from the ICAO working group in August 2016. After conducting a literature review on the risk of vector importation, we made three major revisions to the original indicators shown in Table 7. First, we added a new category that was absent in original iteration called Arrivals Airport. This addition was necessary because the IHR (2005) has specific sections with regards to Points of Entry (PoE) and incoming aircrafts that may be harboring communicable diseases. Second, we added new indicators that were relevant factors identified in our literature review and aligned our new risk indicators closely to the IHR (2005). Third, we merged the first three categories of Category I: Confirmed Vector Presence, Category II: Potential Vector Presence, and Category III: No Vector Presence into a single category. All the indicators within the three categories were merged as one category: Vector Presence. This combined category made more sense in organizing the indicators into the AHP methodology.

To align with the AHP methodology more closely, we organized all the indicators from the first ICAO working group and the literature review into categories. Tables 9 to 12 show the new categories and lists all the indicators within Vector Presence, Departure Airport, Arrival Airport, and Aircraft Operator, respectively. The tables present the main categories and list all the indicators within that category. New Indicators are indicated in *italics* and by an asterisks (*) next to the indicator number.

Table 9. Vector Presence category and its indicators A1 to A12

Indicator Number	Indicator Question
A1	Is the period of the mosquito surveillance relevant to the season of their life cycle?
A2	Are BG Sentinel used for surveillance purposes?
A3	Is the surveillance conducted by trained personnel or contracted services?
A4	Are the results of surveillance used to assess the need to implement mosquito control programs?
A5	Are the results and associated risks of vectors communicated to users of the airport?
*A6**	*Is the region and/or airport under any vector-borne disease advisory or a WHO published list of areas where disinsection or vector control are recommended?*
A7	Based on vector map (http://vectormap.nhm.ku.edu/vectormap)
*A8**	*Vector characteristics – What are the vector threats in the region?*
*A9**	*Has there been vector-borne disease outbreak or report consistent with WHO definition within the region in the last 6 months?*
A10	Absence of vector based on history and environmental conditions for specific period under consideration?
A11	Absence of vector presence confirmed through surveillance programs?
*A12**	*Is vector control program implemented and managed in accordance to identified need and recommendations?*

In Table 9, the first category of Vector Presence, we added four new indicators. In indicator A6, the vector-borne disease advisory is a part of IHR (2005) under Annex V, Section 1. Areas under advisory are recommended to perform disinsection or other vector control practices to mitigate the spread of VBDs. Indicator A8 was added to see if users (e.g. pilots) of the risk assessment tool can identify and understand the vector threats in the region. Indicator A9 was added because regions that have prior VBD outbreaks are typically prone to have similar outbreaks in the future (Phillips, 2017). Lastly, A12 was added to examine whether the vector control programs are implemented according to specific vector threats and presence.

Table 10. Departure Airport category and its indicators B1 to B10

Indicator Number	Indicator Question
B1	Do departing international operations included schedule passenger operations?
B2	Do departing international operations include cargo aircrafts?
B3	Do departing international operations include non-scheduled passenger operations?
B4	Do departing international operations include military or state operations?
B5	Does the airport provide details of approved disinsection services for aircraft?
B6	Are jetway or walkways/stairways for passenger loading closed?
B7	Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?
B8	Is mechanical disinsection equipment that can serve cargo aircrafts available?
*B9**	*Does the departure airport use any environmental vector controls?*
*B10**	*What category is the departure airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)*

In Table 10, the Departure Airport category, two new indicators were added to the category. The B9 indicator pertained to whether the airport have deployed environmental vector controls surrounding the airport to mitigate vector presence. This can include cleaning out stagnant water, pipes, and swamps to make the area around the airport inhospitable to vectors (WHO, 2012). Indicator B10 used the IHR (2005) Monitoring Framework Checklist to assess the "disinfection, decontamination and vector control" capabilities of the departure airport to deter vectors from leaving the area on airplanes. The checklist scores from this framework are <1, 1, 2, and 3. For <1, the score meant the vector control capabilities are foundational. The score of 1 indicated that the capabilities have inputs and process in vector control. The score of 2 indicated the vector control programs have achieved outputs and outcomes. The score of 3 indicated additional achievement beyond the score of 2 (WHO, IHR Core Capacity Monitoring Framework: Checklist and Indicators for Monitoring Progress in the Development of IHR Core Capacities in States Parties, 2011).

Table 11. Arrival Airport category

Indicator Number	Indicator Question
C1*	*Is the arrival airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position if arriving aircraft may be carrying possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?*
C2*	*Does the arrival airport use any environmental vector controls?*
C3*	*Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?*
C4*	*What category is the arrival airport's PoE vector program in reference to WHO's IHR (2005) Monitoring Framework Checklist? (Categories are <1, 1, 2, 3)*
C5*	*What category is the arrival airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)*
C6*	*Is the arrival airport familiar with ICAO PANS-ATM, Doc 4444 procedures on "notification of suspected communicable diseases on board an aircraft, or other public health risk?"*

The Arrival Airport category was omitted in the original indicator list. The reason was due to the ICAO working group focusing only on ensuring that the vectors do not leave the departure airport, and if the vectors did make it on-board the aircraft, the vector control methods in the aircraft would destroy or halt the vectors from exiting the aircraft (Meyers, 2017). However, this omission undermined the importance of the arrival airport as an international PoE that protects the region from the spread of vectors and vector-borne diseases as per IHR (2005).

In Table 11, six indicators were added to the Arrival Airport category. First, indicator C1 asked whether the airport has an isolated parking area that is at least 400 meters from the nearest Point of Entry (PoE). This ensures that even if the vector leaves the aircraft, it is isolated from the rest of the airport or the surrounding region. Indicator C2 served the same purpose as indicator B9, to ensure that the environment around the airport is inhospitable to vector survival. Indicator C3 asked whether diversion airports are nearby if arrival airport does not have the vector control capabilities to handle flights with vector threats. Indicator C4 was similar to indicator B10, in which the IHR framework checklist assesses the PoE capabilities. Indicator C5 questioned the arrival airport's ability to disinfect, decontaminate based on the IHR (2005) framework checklist. Finally, indicator C6 asked whether air traffic controller at the arrival airport is familiar in communicating with pilots in aircrafts that are suspected to have a communicable disease on-board.

Table 12. Aircraft Operator category

Indicator Number	Indicator Question
*D1**	*Is the Operator's vector program consistent with IATA and WHO guidelines?*
*D2**	*Is the Operator in compliance in standards and practices per WHO IHR (2005) Annex IV?*
*D3**	*Does the operator have a guideline or policy for cargo and luggage vector control practices?*
D4	Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operations?
D5	Does the operator use self-closing screens for passenger entries?
D6	Does the operator use self-closing screens for cargo entries?
D7	Does the operator have personnel that monitor for the presence of insects around and within the aircraft?
D8	Does the operator utilize residual disinsection consistent with WHO or government regulations?
D9	Does the operator use maintenance facilities at the departure airport?
D10	Does the maintenance facility utilize chemical or mechanical disinsection when servicing aircraft?
D11	Does the maintenance facility conduct repair in a closed hangar?

In the Aircraft Operator category, we added three new indicators as shown in Table 12. In indicator D1, it asked whether the aircraft operators are complying to WHO or IATA guidelines as noted in our rules and regulations of the literature review. Indicator D2 asked whether the aircraft operator is following the Annex IV of the IHR (2005), which lists the "technical requirements pertaining to conveyances and conveyance operators." Lastly, indicator D3 targeted whether the aircraft operator have guidelines to mitigate or disinfect cargo and luggage from vector threats in accordance to Section B, Annex IV of IHR (2005).

Using new and existing indicators, the new indicators list will serve as the basis of the interview in the next section. The next step will help us affirm whether the risk indicators developed in this step were accurate in assessing the risks of vector importation.

4.2 Results of the Second Step – Interviews and refining the final indicators list

We used the results obtained in the last section to conduct the interview phase of the methodology. In this section, we show the results of the interview section in a phase-by-phase process that includes creating the interview guide, interview participant selection, interview results matrix, final selection of indicators, and the AHP hierarchy tree.

4.2.1 Creating the interview guide

In the first phase of this process, we used the results from Section 4.1 to create a structured interview guide. To reiterate the purpose of the interview, we wanted to introduce to experts and stakeholders the new revisions and additions to the indicators list, and ask for their input and opinion on whether the revision is accurate in assessing vector importation. In this interview guide, each indicator was listed as a question that asks the following three points:

1) Is the indicator relevant (Circle or Highlight Answer)? Keep / Delete / Merge
2) If the indicator is kept, is the wording correct? If not, enter the new wording below.
3) Any further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.)?

In this format, we wanted to ascertain whether our experts and stakeholders believe that the indicators within the risk model are relevant. We asked whether the indicators should be kept, deleted or merged with others to evaluate the usefulness of the indicators. Further, we asked the participants if the wording of the indicator is correct, understanding that clarity in the indicator language can reduce ambiguity, confusion, and ensure the language is diplomatically correct. Lastly, a comment section was included so that we can gain further understanding from the experts and stakeholders on their opinion of this indicator. The interview guide is available under Appendix A.

4.2.2 Recruit the interview participants

In the recruitment phase, we consulted with the chief of the Aviation Medicine section of ICAO to discuss the experts and stakeholders that should participate in the interview process. We drew the participants from two groups. First, pertinent members of the ICAO working group from August 2016 were invited to participate. Not only does this group represents a diverse view from civil aviation, public health, government, and entomology, but the selected members can also give further background of the first meeting that was held in August 2016. The selected participants from this group were:

- Andreas Meyer, Safety Management Officer, International Civil Aviation Organization (ICAO);
- Daniel Chong, FAA Liaison - U.S. Mission to ICAO, Federal Aviation Administraton (FAA);
- Lynn Slepski, Senior Public Health Advisor, U.S. Department of Transportation (DOT);
- Jerome Hogsette, Lead Scientist – Research Entomologist, U.S. Department of Agriculture (USDA).

Next, we recruited participants from ICAO's Aviation Medical Forum. The Forum is a bi-weekly phone conference that discusses major public health issues in civil aviation. Members represent key aviation industry trade groups. Our selection included members that represents airlines, airports, pilots, and ICAO. From this group, the selected participants were:

- Jean-Sébastien Pard, Facilitation and IT Manager, Airport Council International (ACI);
- Claude Thibeault, Medical Advisor, Consultants Aeromed Inc. on behalf of International Air Transport Association (IATA);
- Jitendra Thaker, Technical Officer – Facilitations, International Civil Aviation Organization (ICAO);
- Gordon Margison, Technical Officer, The International Federation of Air Line Pilot's Association (IFALPA);

Each of the participants were contacted individually via email to set-up a time and place for an interview. For participants in the Montreal-area, the interviews were held in the place of work for the interview participants. For the participants outside the immediate region, a Skype or phone call was planned.

4.2.3 Compiling the interview notes

After the interview phase concluded, we compiled the notes from all the interview participants and began to examine all the changes that were proposed. We first looked at all the proposed addition, deletion, and merger of the indicators. We also examined all the proposed language changes to the indicators. We put all the proposed changes into a matrix to see if there were any patterns and consensus proposed by the group. Table 13 shows the interview results matrix.

For the interview results matrix, several letters are used as legend in Table 13. "A" denotes that this indicator should also be added in another section. "D" denotes the indicator should be deleted. "C" denotes conflict, in which participants are conflicted to the validity of the indicator but not enough for it to be deleted. "M" denotes that the indicator's language needs substantial re-wording to achieve clarity. "Mg" denotes that the indicator should be merged with another indicator. "W" denotes that the indicator needed minor re-wording. Blank indicators mean that no changes are required. "JEE" means that indicator is superseded by a newer WHO Joint External Evaluation (JEE) reporting standard.

Table 13. Interview results matrix

	Vector Presence												Departure Airport									
Interviewees	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**A12**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
Meyer, Andreas		m			w		c			w												
Pard, Jean-Sebastien		w			w		c			w					m		c	c		c		
Chong, Daniel	mg		w			*	mg	mg	c	mg	w	w	m,d	m,d	m,d	m,d	m	w			mg	
Thibeault, Claude		m			c		c, mg	mg	m	d			mg	mg	mg	mg	c		c	c		
Thaker, Jitendra		m	w		w		c			d			mg	mg	mg	mg	c					
Margison, Gordon																						
Slepski, Lynn		w	w	w					m		m	m, c	m	m	m	m			c	c	c	JEE
Hogsette, Jerry	w	w	w	w	w		mg	mg		mg	mg	w	mg	mg	mg	mg	c,w	w		d	w	w

	Arrival Airport						Conveyance Operator										
Interviewees	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**
Meyer, Andreas	a					w	d	d	d	mg			c				
Pard, Jean-Sebastien						w							c				
Chong, Daniel	c	mg		mg	mg	d	d	d	mg	mg	d		mg	mg	m		
Thibeault, Claude						d	m, mg	d	mg		mg	mg	m, c	w	d	w	
Thaker, Jitendra						w	w, m	d								w	c
Margison, Gordon			c			c											
Slepski, Lynn	a	c	d	JEE	JEE	c	d	d				w	d		d		
Hogsette, Jerry	a	w	d			d				d	d				mg	mg	mg

4.2.4 Review and decision on the risk indicators

The interview results matrix gave us an overview perspective of the opinions and suggestions that the experts and stakeholders had on the indicators list. For example, indicator C6 had a strong response from all participants on the usefulness of this indicator. Three participants suggested to delete it, two participants were conflicted to whether indicator C6 should be included, and the rest wanted this indicator to be re-worded. In this phase, we used the compiled information and interview notes from all the participants, and created a final indicators list based on their suggestions.

In this section, we breakdown each indicator into four sections: original indicator, notes, decision, and new indicator. The original indicator is the indicator that we asked about in the indicator interview guide. Notes are important and influential comments from participants on each of the indicators during the interview. Decision is what we propose to do with the indicator based on the suggestions. New indicator is the final wording of the indicator based on the feedback from everyone.

There were three other notable changes made in this interview phase. First, during our interview, we asked each participant if we should split the Vector Presence category into two distinct categories of Region (of the departure airport) and Surveillance. All participants agreed unanimously to separate Vector Presence into two categories. Second, due to the multiple levels of the AHP hierarchy, we changed indicator heading from A1, B1, C1, D1, E1 to 1.1, 2.1, 3.1, 4.1, 5.1, respectively. The new numerical indicator heading is simply more scalable. Third, we changed the category from aircraft operator to conveyance operator to adopt the same terminology as IHR (2005).

After all the suggestions and inputs were updated, we sent the final indicators list out to the same group of participants. We opened the newest edition of the indicators list to a 15-day open comment period to elicit any final comments and suggestions on the list that we had developed. After closing, the indicators list was finalized. The following tables narrate all the comments from the interview phase and the final 15-day comment period. The tables will be organized based on the five categories. After each category heading, decisions and revisions to each of the indicators within the category are explained. Again, the four sections are: original indicators, notes, decision, and new indicator.

Results of Table 9. Vector Presence category (Later separated into Region and Surveillance categories)

In the Vector Presence category, as shown previously in Table 9, the greatest number of changes occurred due to splitting Vector Presence category into Region category and Surveillance category. Out of the 13 indicators originally developed, five indicators were moved into the Region category, while four indicators became part of the Surveillance category. Additionally, one indicator was moved to the Departure Airport category, while the last three indicators either merged or was deleted.

Original Indicator	(A1) Is the period of the mosquito surveillance relevant to the season of their life cycle?
Notes	- One respondent pointed out the wording should not say “mosquito surveillance”, but rather if the “vector” is in season.
Decision	1) Modified the indicator sentence 2) Added this indicator to “region” category
New Indicator	(1.2) Is it the relevant season and climate of the targeted vector in the region where the airport is located?

Original Indicator	(A2) Are BG Sentinel used for surveillance purposes?
Notes	- Majority agreed to change BG Sentinel to a generic term to reflect the use of other types vector traps.
Decision	1) Modified the indicator sentence 2) Added this indicator to “surveillance” category
New Indicator	(2.1) Does the airport vector surveillance program use vector collection devices/traps that are approved by the scientific community as being appropriate for the targeted vector?

Original Indicator	(A3) Is the airport vector surveillance conducted by trained personnel or contracted services?
Notes	- Most respondents either votes for no changes or wants the language to be more specific.
Decision	1) Modified the sentence to be more specific 2) Added this indicator to "surveillance" category
New Indicator	(2.2) Is the vector surveillance conducted by trained airport/government personnel or approved contracted services?

Original Indicator	(A4) Are the results of surveillance used to assess the need to implement mosquito control programs?
Notes	- Replace word "mosquito" with "vector". - Many respondents believe the language should be stronger.
Decision	1) Modified the sentence change mosquito to vector 2) Deleted "used to assess" to make the language stronger 3) Added indicator to "surveillance" category
New Indicator	(2.3) Are the results of the vector surveillance used to develop and implement airport vector control programs?

Original Indicator	(A5) Are the results and associated risks of vectors communicated to users of the airport?
Notes	- Many respondents are confused as to who the users are. Passengers? Management? - There are many literatures that support the use of education and communication to educate passenger of communicable diseases and prevention. - Added management to the sentence. - *Are vector control and public health program data publicly available for access?*
Decision	1) Modified sentence to include management 2) Small grammar changes 3) Added the "surveillance" category
New Indicator	(2.4) Are the results and associated risks from vector surveillance communicated to users *and management* of the airport?

Original Indicator	(NEW) Does the departing airport or region have a vector surveillance program to assess the presence and/or absence of targeted vectors?
Notes	- This will be the new top tier indicator that several respondents have asked for. - If the answer is "no" then risk tool automatically puts no in all other sub-indicators.
Decision	1) Added to the "surveillance" category 2) Not currently in-use, it is just "surveillance" for now
New Indicator	Deleted.

Original Indicator	(A6) Is the region and/or airport under any vector-borne disease advisory or a WHO published list of areas where disinsection or vector control are recommended?
Notes	- Everyone agrees this is important.
Decision	1) Added to "region" category of indicators 2) Minor language changes
New Indicator	(1.3) Is the region where the airport is located under any vector-borne disease advisory and/or the WHO published list where disinsection or vector control are recommended?

Original Indicator	(A7) Based on vector map (http://vectormap.nhm.ku.edu/vectormap)
Notes	- Merged with A8 because vector threats in the region are shown with the vector map.
Decision	1) Created a new indicator built between A7 and A8 2) Added to the "region" category
New Indicator	(1.1) Is the region where the airport is located known to have targeted vectors based on vector map (http://vectormap.nhm.ku.edu/vectormap)

Original Indicator	(A8) Vector characteristics – What are the vector threats in the region?
Notes	- Use a more definitive source e.g. vector map to identify actual vector threats.
Decision	1) Merged with A7
New Indicator	See above.

Original Indicator	(A9) Has there been a vector-borne disease outbreak or report consistent with WHO definition with the region in the last 6 months?
Notes	- Still the process of clarifying the appropriate timeframe. - Residual risks from previous outbreaks.
Decision	1) Added to "region" category 2) Changed wording
New Indicator	(1.4) Has there been a vector-borne disease outbreak in this region in the past?

Old Indicator	(A10) Absence of vector based on history and environmental conditions for specific period under consideration?
Notes	- Many respondents believe that history should not be included due to changing weather pattern.
Decision	1) Merge with A11
New Indicator	See below.

Old Indicator	(A11) Absence of vector presence confirmed through surveillance programs
Notes	- Surveillance is the only method of really knowing what vector threats are out there or not.
Decision	1) Merge with A11 to form single indicator 2) Filed under "region"
New Indicator	(1.6) Is the absence of targeted vectors in the region confirmed through the vector surveillance program?

Old Indicator	(A12) Is vector control program implemented and managed in accordance to identified need and recommendations?
Notes	- Many respondents believe the wording is too broad and generic? By whom? Whose recommendations? - Possible merger with A4.
Decision	1) Moved to "departure airport"
New Indicator	(3.6) Is the airport vector control program implemented and managed in accordance to ongoing presence of target vectors and environmental change?

Old Indicator	(NEW) What is the volume of flights in the region where the airport is located based on the *Air Connectivity Index*?
Notes	- Several respondents asked that the volume of flights should be added into the risk analysis. - Literature reviews support that larger volume of flight equals higher risks. - WHO used this *Air Connectivity Index* as part of their risk analysis for Zika spread in Europe. - Added to region rather than departure airport because the index is scored by countries not by airports.
Decision	1) Added to "Region" category
New Indicator	(1.5) Same as original indicator.

Results of Table 10. Departure Airport category

In the Departure Airport category, Table 10 outlined the ten indicators for this category. After the interview and decision, the biggest change was the merger of indicators B1 to B4 into one indicator with four sub-indicators. Other changes included the deletion of B8 and B10, and the merger of B9 into A12.

Old Indicator	(B1) Do departing international operations included schedule passenger operations?
Notes	- Majority of respondents believe that B1 to B4 should be merged or have the indicator deleted. - The word "international" does not adequately address the fact that domestic flights in large countries can also just be as risky e.g. Boston to Montreal is probably less risky than Miami to Hawaii flight.
Decision	1) Merged B1 to B4 into one indicator with 4 sub-indicators. 2) Changed wording to include flights to non-endemic regions. 3) Added to "departure airport" category.
New Indicator	(3.1) Does the departure airport have routes to non-endemic regions of targeted vectors or international operations that include: - (3.1.1) Scheduled passenger operations - (3.1.2) Non-scheduled passenger operations - (3.1.3) Cargo operations - (3.1.4) Military or state operations

Original Indicator	(B2) Does departing international operations include cargo aircrafts?
Notes	
Decision	1) Merged with B1
New Indicator	See above.

Original Indicator	(B3) Departing international operations include non-scheduled operations?
Notes	
Decision	2) Merged with B1
New Indicator	See above.

Original Indicator	(B4) Departing international operations include military or state operations?
Notes	
Decision	3) Merged with B1
New Indicator	See above.

Original Indicator	(B5) Does the airport provide details of approved disinsection services for aircrafts?
Notes	- Majority of respondents do not understand the indicator as-is. What does it mean by "provide details?"
Decision	1) Minor word change – deleted "details" from indicator 2) Added to the "Departure Airport" category
New Indicator	(3.2) Does the airport provide approved chemical or mechanical disinsection services for aircrafts?

Original Indicator	(B6) Are jetway or walkway/stairways for passenger loading closed?
Notes	- The initial indicator does not address smaller airports that does not have passenger loading jetway/stairway, etc. - When indicator asked "closed" does it mean when the jetway is not in service? Yes.
Decision	1) Changed sentence to reflect other openings 2) Added to "departure airport" category
New Indicator	(3.3) Are the jetways/walkways/stairways/doors for passenger loading closed when it is not in service?

Original Indicator	(B7) Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?
Notes	- Currently there are no commercially available nor WHO-approved mechanical disinsection devices available on the market. - However, in this risk tool, the assumption is that the mechanical disinsection devices **are available commercially, however it is not approved by WHO**. It can be used as part of a multi-level, integrated vector control defense.
Decision	1) Added to "departure airport" category
New Indicator	(3.4) Same as original indicator.

Original Indicator	(B8) Is mechanical disinsection equipment that can serve cargo aircrafts available?
Notes	- Currently there are no mechanical disinsection product for cargo openings. Further, no companies have even attempted to test and create this product at this time. - We can possibly omit this.
Decision	1) Should we delete? Yes.
New Indicator	Deleted.

Original Indicator	(B9) Does the departure airport use any environmental vector controls?
Notes	- Mechanical vs environmental control. What is a better term? - Respondents asked what are the standards to achieve satisfactory vector control? What if some are environmental control are done but others are not?
Decision	1) Merger with A12
New Indicator	See A12.

Original Indicator	(B10) What category is the departure airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)
Notes	- This indicator has been superseded by new JEE framework in Feb 2016. - No indicator or similar equivalent exists in the new JEE.
Decision	**1) Delete.**
New Indicator	Deleted.

Original Indicator	(B11) Is the departure airport able to provide minimum distance of 400m from the nearest PoE or designated parking position that can isolate aircrafts from vector threats?
Notes	- Originally only in the arrival airports category. Respondents asked it to be added to departure as well? - Airport should be able to provide vector-free zones parking to minimize vector transmission. - PAHO/WHO pamphlet stated that max flying range or Aedes aegypti is 400 meters.
Decision	1) Added to "departure airport" category
New Indicator	(3.5) Same as original indicator.

Results of Table 11. Arrival Airport category

In this category, as previously outlined in Table 11, the Arrival Airport was unique as it was only added after the literature review. After the interview process, indicators C5 and C6 were deleted, and C4 adopted the new IHR (2005) Joint External Evaluation (JEE) language. From the six indicators originally, the final number of indicators for this category is four.

Original Indicator	(C1) Is the arrival airport able to provide minimum distance of 400m from the nearest PoE or designated if arriving aircraft may be carry possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?
Notes	- Do arriving airports have the capacity to park aircrafts from high risk areas to minimize spread of vectors?
Decision	1) Added to "Arrival airport" category
New Indicator	(4.1) Same as original indicator.

Original Indicator	(C2) Does the arrival airport use any environmental vector controls?
Notes	- Mechanical vs environmental control. Which term to use? - Respondents asked what are the standards to achieve satisfactory vector control? What if some environmental control are done but others are not? - New indicator wording encompasses biological, chemical, environmental, and mechanical as recommended by their regional traits and environment.
Decision	1) Adopt wording from A12 2) Added to "arrival airport" category
New Indicator	(4.2) Is the arrival airport's vector control program implemented and managed in accordance to possible targeted vectors threats and environmental change?

Original Indicator	(C3) Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?
Notes	Annex 5.7 *"A State Party should not prohibit the landing of an aircraft or berthing of a ship in its territory if the control measures provided for in paragraph 3 of this Annex or otherwise recommended by the Organization are applied. However, aircraft or ships coming from an affected area may be required to land at airports or divert to another port specified by the State Party for that purpose."*
Decision	1) Added to "arrival airport" category
New Indicator	(4.3) Same as original indicator.

Original Indicator	(C4) What category is the arrival airport's PoE vector program in reference to WHO's IHR (2005) Monitoring Framework Checklist? (Categories are <1, 1, 2, 3)
Notes	- This indicator has been replaced by the JEE standards since Feb 2016.
Decision	1) Added to "arrival airport" category 2) Use new JEE language for indicator
New Indicator	(4.4) What score did the region of the arrival airport receive for "PoE.1 Routine capacities are established at PoE" in reference to WHO's IHR (2005) Joint External Evaluation? (Score 1 to 5)

Original Indicator	(C5) What category is the arrival airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)
Notes	- This indicator has been superseded by new JEE framework in Feb 2016. - No indicator or similar equivalent exists in the new JEE.
Decision	1) Delete.
New Indicator	Deleted.

Original Indicator	(C6) Is the arrival airport familiar with ICAO PANS-ATM, Doc 4444 procedures on "notification suspected communicable diseases on board an aircraft, or other public health risk?"
Notes	- Majority of respondents believe that the utilization of the PANS ATM Doc 4444 is associated with passengers showing symptoms of a communicable disease on board the aircraft. It is highly unlikely that a pilot would ask for a diversion due to possible insect vectors on board the aircraft.
Decision	1) Delete.
New Indicator	Deleted.

Results of Table 12. Conveyance Operator category

In this category, as previously outlined in Table 12, the Conveyance Operator category started with 11 indicators. After the interview process, four indicators were deleted due to the indicators being incorrect, impractical, or the technology was unavailable. Furthermore, indicator D9 merged with indicator D10 and indicator D11, creating a principal indicator with two sub-indicators. The final indicators list dwindled from 11 indicators to seven indicators which included the two sub-indicators.

Original Indicator	(D1) Is the Operator's vector program consistent with IATA and WHO guidelines?
Notes	- The indicator is incorrect. Operators follow government regulations that is recommended by WHO guidelines.
Decision	1) Delete.
New Indicator	Deleted.

Original Indicator	(D2) Is the Operator in compliance in standards and practices per WHO IHR (2005) Annex IV?
Notes	- The indicator is incorrect, there is no compliance measure in Annex IV.
Decision	1) Delete.
New Indicator	Deleted.

Original Indicator	(D3) Does the operator have a guideline or policy for cargo and luggage vector control practices?
Notes	- No comment.
Decision	1) Added to "Conveyance Operator"
New Indicator	(5.2) Same as original.

Original Indicator	(D4) Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operations?
Notes	- No comment.
Decision	1) Added to "Conveyance Operator"
New Indicator	(5.3) Same as original.

Original Indicator	(D5) Does the operator use self-closing screens for passenger entries?
Notes	- This product is currently commercially unavailable and is not WHO-approved. - There is a company that can manufacturer this product right away if the demand exists.

	- In our risk tool, we assume that the product is commercially available, but not WHO-approved. Product can be added as another level of defense in vector control.
Decision	1) Added to "Conveyance Operator"
New Indicator	(5.4) Same as original.

Original Indicator	(D6) Does the operator use self-closing screens for cargo entries?
Notes	- Again, this product is currently commercially unavailable and is not WHO-approved. - Unlike passenger entries, there are currently no companies and organization that have any products for cargo entries in the foreseeable future.
Decision	1) Should this be deleted? Yes. 2) We ask all the participants again. Decide to delete.
New Indicator	Deleted.

Original Indicator	(D7) Does the operator have personnel that monitor for the presence of insects around and within the aircraft?
Notes	- Majority of the respondents believed that this indicator is either impractical, should be seriously revised, or deleted.
Decision	1) Deleted.
New Indicator	Deleted.

Original Indicator	(D8) Does the operator utilize residual disinsection consistent with WHO or government regulations?
Notes	- Some respondents thought this would be a standard based on a country or destination's laws and regulations. If the operator is not consistent, then it is banned from flying to those destinations.
Decision	1) Added to "conveyance operator" category.
New Indicator	(5.1) Same as original indicator.

Original Indicator	(D9) Does the operator use maintenance facilities at the departure airport? If yes: a) Does the maintenance facility utilize chemical or mechanical disinsection when servicing aircraft? b) Does the maintenance facility conduct repair in a closed hangar
Notes	- No comments.
Decision	1) Added to "conveyance operator" category. 2) Created a sub-category within this indicator with D10 and D11.
New Indicator	(5.5) Does the operator use maintenance facilities at the departure airport? If yes: - (5.5.1) Does the maintenance facility utilize chemical or mechanical disinsection when servicing aircraft? - (5.5.2) Does the maintenance facility conduct repair in a closed hangar

Original Indicator	(D10) Does the operator use maintenance facilities at the departure airport?
Notes	- No comment.
Decision	1) Merge with D7.
New Indicator	See D7.

Original Indicator	(D11) Does the maintenance facility conduct repair in a closed hangar?
Notes	- No comment.
Decision	1) Merge with D7.
New Indicator	See D7.

4.2.5 The final indicators list

After reviewing all the inputs and suggestions from the interview participants in the last section, our indicators list was refreshed with all the changes. The final indicators list is displayed from Tables 14 to 18. The final indicator list is now divided into five major categories: Region, Surveillance, Departure Airport, Arrival Airport, and Conveyance Operator.

Table 14. Region category and its indicators

Indicator Number	Indicator Question
1.1	Is the region where the airport is located known to have targeted vectors based on vector map? (http://vectormap.nhm.ku.edu/vectormap)
1.2	Is it the relevant season and climate of the targeted vector in the region where the airport is located?
1.3	Is the region where the airport is located under any vector-borne disease advisory and/or the WHO published list where disinsection or vector control are recommended?
1.4	Has there been a vector-borne disease outbreak in this region in the past?
1.5	What is the volume of flights in the region where the airport is located based on the Air Connectivity Index?
1.6	Is the absence of targeted vectors confirmed through the vector surveillance programs?

Table 15. Surveillance category and its indicators

Indicator Number	Indicator Question
2.1	Does the airport vector surveillance program use vector collection devices/traps that are approved by the scientific community as being appropriate for the targeted vector?
2.2	Is the vector surveillance conducted by trained airport/government personnel or approved contracted services?
2.3	Are the results of the vector surveillance used to develop and implement airport vector control programs?
2.4	Are the results and associated risks from vector surveillance communicated to users and management of the airport?

Table 16. Departure Airport and its indicators

Indicator Number	Indicator Question
3.1	Does the departure airport have routes to non-endemic regions of targeted vectors or international operations that include:
3.1.1	Scheduled passenger operations?
3.1.2	Cargo operations?
3.1.3	Non-Scheduled passenger operations?
3.1.4	Military or state operations?
3.2	Does the airport provide approved chemical or mechanical disinsection services for aircrafts?
3.3	Are the jetway/walkway/stairway/door to the aircraft closed when it is not in service?
3.4	Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?
3.5	Is the departure airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position that can isolate aircrafts from vector threats?
3.6	Is the airport vector control program implemented and managed in accordance to ongoing presence of target vectors and environmental change?

Table 17. Arrival airport and its indicators

Indicator Number	Indicator Question
4.1	Is the arrival airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position if arriving aircraft may be carrying possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?
4.2	Is the arrival airport's vector control program implemented and managed in accordance to possible targeted vectors threats and environmental change?
4.3	Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?
4.4	What score did the region of the arrival airport receive for â€œPoE.1 Routine capacities are established at PoE in reference to WHO's IHR (2005) Joint External Evaluation?

Table 18. Conveyance Operator and its indicators

Indicator Number	Indicator Question
5.1	Does the operator utilize residual disinsection consistent with WHO or government regulations?
5.2	Does the operator have a guideline or policy for cargo and luggage vector control practices?
5.3	Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operation?
5.4	Does the operator use self-closing screens for passenger entries?
5.5	Does the operator use maintenance facilities at the departure airport? IF yes:
5.5.1	Does the maintenance facility utilize chemical or mechanical disinsection when servicing the aircraft?
5.5.2	Does the maintenance facility conduct repair in a closed hangar?

4.3 Results of the Third Step – Applying the Analytical Hierarchy Process

In the last section, we finalized the indicators list for the risk assessment tool based on the literature review and interviews. In this section, we used these indicators to build the risk assessment tool based on the Analytical Hierarchy Process (AHP). We first converted the five categories and the indicators into the AHP Hierarchy tree format. Second, we invited participants to fill-in an online AHP pair-wise comparison questionnaire to build the weights between the indicators. Third, we examined the step-by-step mathematical process of AHP and demonstrated how we derived at our final weights score using the pair-wise comparisons between the five categories. Fourth, we showed the average, aggregated weight score based on the questionnaire inputs from all the participants. Fifth, we again examined the new AHP hierarchy tree with the weights assigned, and explained how users and stakeholders can use the tool. Sixth, we discussed the importance of the five main categories. Finally, we reveal the vector assessment tool.

4.3.1 Converting the indicators into the AHP hierarchy tree

One of the main advantages of the AHP framework is the ability to organize and break-down indicators into separate categories and create a multi-level questionnaire that stratifies each of the indicators based on the level of importance. In the first phase of the results, we first re-organized our risk indicators into the AHP hierarchy tree which is integral to the AHP process.

For our risk assessment tool, the AHP hierarchy has four distinct levels. Level 0 is the main objective of the AHP risk tool. In our risk model, the main objective was to calculate the risk of vector importation between two airport origin-destination pairs. In level 1, we organized the AHP hierarchy into five main categories that evaluated the risk of vector importation. The five categories were Region, Surveillance, Departure Airport, Arrival Airport, and Conveyance Operator. In level 2, we placed the risk indicators into their respective categories based on the final indicators list. Lastly, level 3 represented the sub-indicators within the level 2 indicators, which were indicator 3.1 and indicator 5.5.

Since the AHP questionnaire is online-based, the AHP-OS required us to complete the AHP hierarchy tree first before any participants can answer the online questionnaire. Figure 18 shows the complete AHP hierarchy tree based on the risk indicators list.

Figure 18. The complete AHP Hierarchy tree

Decision Hierarchy			
Level 0	Level 1	Level 2	Level 3
V-Risks between XXX & YYY Airport	1. Region	1.1 Vector map indicate vectors?	
		1.2 Vector in-season?	
		1.3 Under Vector advisory?	
		1.4 Previous outbreak?	
		1.5 Volume of flights?	
		1.6 Sur confirms no vector?	
	2. Surveillance	2.1 Approved Sur traps used?	
		2.2 Sur done by pros?	
		2.3 Sur results used for v-ctrl?	
		2.4 S Sur results communicated?	
	3. Departure Airport	3.2 Provide diss. service?	
		3.3 Jetway etc. closed?	
		3.4 Jetway etc. with mechanical diss.?	
		3.5 400m v-free zone?	
		3.6 V-ctrl implemented?	
		3.1 Have intl/non-endemic ops?	3.1.1 Scheduled
			3.1.2 Cargo
			3.1.3 Non-scheduled
			3.1.4 Govt Mil
	4. Arrival Airport	4.1 >400M distance from PoE?	
		4.2 V-ctrl implemented?	
		4.3 Diversion airport avail?	
		4.4 JEE PoE score?	
	5. Conveyance Operators	5.1 Use residual diss.?	
		5.2 Cargo/luggage vector ctrl?	
		5.3 Door closed when not-in-use?	
		5.4 Screens for passenger door?	
		5.5 Use MX at dep. airport?	5.5.1 Dissection during MX?
			5.5.2 Repair A/C in closed hangar?

4.3.2 The online AHP questionnaire

After creating the AHP hierarchy tree, the AHP-OS system allowed participants to log into the online system and answer the questionnaire. In this section, we elaborate on how the questionnaire was conducted, and how the pair-wise comparison worked. Further, we discuss the Saaty scale used for the comparisons, and the number and levels of comparisons needed to complete the questionnaire.

First, participants that were invited to participate were given the web link and unique username for the AHP-OS system. Once logged in, the participant was shown the complete AHP hierarchy tree. The AHP hierarchy tree has a clickable menu that allowed the participant to start pair-wise comparisons at each level. For our tree, we had three levels of pair-wise comparisons to make:

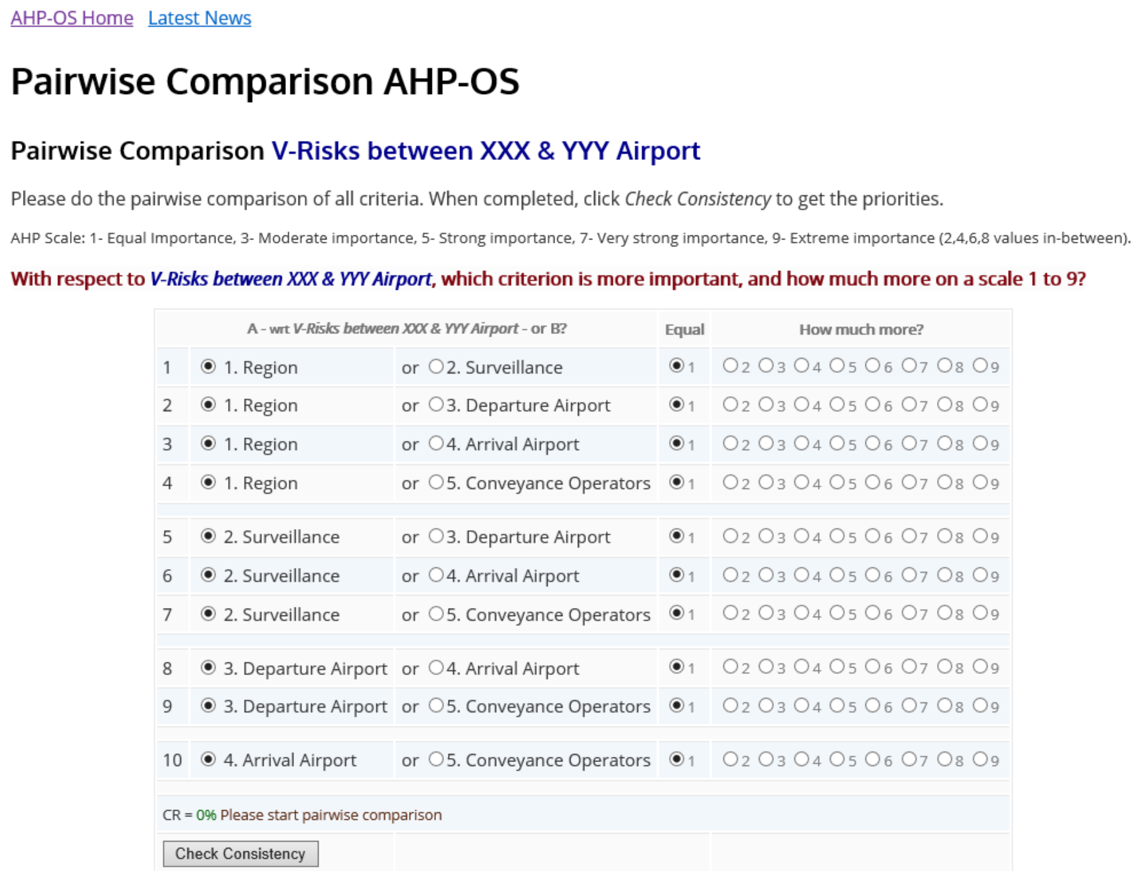
1) One comparison at Level 1 – This pair-wise comparisons compare between the five categories of Region, Surveillance, Departure Airport, Arrival Airport, and Conveyance Operator.

2) Five comparisons at Level 2 – For Region, there are pair-wise comparisons between indicators 1.1 to 1.6. For surveillance, there are comparisons between indicators 2.1 to 2.4. For Departure Airport, the pair-wise comparisons are between indicators 3.1 to 3.6. For Arrival Airport, the pair-wise comparisons are between indicators 4.1 to 4.4. Lastly, the Conveyance Operator compares indicators 5.1 to 5.5.

3) Two comparisons at Level 3. This is where the sub-indicators of 3.1 has another level of pair-wise comparison between sub-indicators 3.1.1 to 3.1.4. For indicator 5.5, the comparison is between sub-indicator 5.5.1 and 5.5.2

To better illustrate, Figure 19 shows the pair-wise comparison at level 1. Here, we establish the weights between the five categories by direct pair-wise comparisons. With five categories in this level, 10 direct pair-wise comparisons are needed to establish which categories has higher risk weight and which has lower risk weights. As displayed below, Region is compared to Surveillance, Departure Airport, Arrival, and Conveyance Operator. Surveillance is compared to Departure Airport, Arrival Airport, and Conveyance Operator. Departure Airport is compared Arrival Airport, and Conveyance Operator. Finally, Arrival Airport compares Conveyance Operator. This represents every possible pairing at level 1.

Figure 19. The AHP-OS online questionnaire for level 1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Pairwise Comparison AHP-OS

Pairwise Comparison V-Risks between XXX & YYY Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *V-Risks between XXX & YYY Airport*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *V-Risks between XXX & YYY Airport* - or B?		Equal	How much more?
1	◉ 1. Region	or ○2. Surveillance	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 1. Region	or ○3. Departure Airport	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 1. Region	or ○4. Arrival Airport	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 1. Region	or ○5. Conveyance Operators	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 2. Surveillance	or ○3. Departure Airport	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 2. Surveillance	or ○4. Arrival Airport	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ 2. Surveillance	or ○5. Conveyance Operators	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ 3. Departure Airport	or ○4. Arrival Airport	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ 3. Departure Airport	or ○5. Conveyance Operators	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ 4. Arrival Airport	or ○5. Conveyance Operators	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Using another example to demonstrate the AHP hierarchy questionnaire process, Figure 20 is the AHP questionnaire screenshot for the level 2 Departure Airport. Here, we have 15 pair-wise comparisons that comprise of all the risk indicators that are listed under the Departure Airport category. Again, all the indicators within Departure Airport category between indicators 3.1 and 3.6 are compared against each other to calculate the weights for the risk assessment tool. The other four categories of Region, Surveillance, Arrival Airport, and Conveyance Operator have the same setup in which risk indicators within each category are directly compared to each other. Lastly, we have two level 3 pair-wise comparisons for indicators 3.1 and 5.5. At that level, it uses the same questionnaire that performs pair-wise comparison between sub-indicators 3.1.1 to 3.1.4

and sub-indicators 5.5.1 to 5.5.2, respectively. The participant must complete all eight comparison questionnaires in all three levels in order to submit the AHP questionnaire. The rest of the pair-wise comparison questionnaires for level 2 and 3 are available under Appendix B.

Figure 20. The AHP-OS online questionnaire for level 2 – Departure Airport

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Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 3. Departure Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *3. Departure Airport*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *3. Departure Airport* - or B?		Equal	How much more?
1	◉ 3.2 Provide diss. service?	or ○ 3.3 Jetway etc. closed?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 3.2 Provide diss. service?	or ○ 3.4 Jetway etc. with mechanical diss.?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 3.2 Provide diss. service?	or ○ 3.5 400m v-free zone?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 3.2 Provide diss. service?	or ○ 3.6 V-ctrl implemented?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 3.2 Provide diss. service?	or ○ 3.1 Have intl/non-endemic ops?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 3.3 Jetway etc. closed?	or ○ 3.4 Jetway etc. with mechanical diss.?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ 3.3 Jetway etc. closed?	or ○ 3.5 400m v-free zone?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ 3.3 Jetway etc. closed?	or ○ 3.6 V-ctrl implemented?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ 3.3 Jetway etc. closed?	or ○ 3.1 Have intl/non-endemic ops?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ 3.4 Jetway etc. with mechanical diss.?	or ○ 3.5 400m v-free zone?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
11	◉ 3.4 Jetway etc. with mechanical diss.?	or ○ 3.6 V-ctrl implemented?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
12	◉ 3.4 Jetway etc. with mechanical diss.?	or ○ 3.1 Have intl/non-endemic ops?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
13	◉ 3.5 400m v-free zone?	or ○ 3.6 V-ctrl implemented?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
14	◉ 3.5 400m v-free zone?	or ○ 3.1 Have intl/non-endemic ops?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
15	◉ 3.6 V-ctrl implemented?	or ○ 3.1 Have intl/non-endemic ops?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Filling out the questionnaire was straight forward. Participants needed to answer two elements per question: 1) Comparing one indicator to another, which one of the two is more important, and 2) After choosing the more important indicator, how much more important is it using the 1 to 9 Saaty scale. The participant filled-out all the pair-wise comparisons on the screen until all the comparisons in all the levels were completed.

4.3.3 Ranking and Saaty scale

To fill-out the online questionnaire, two documents were sent with the invitation email to help respondents navigate the AHP-OS online system, rank the pair-wise comparisons, and provide guidance on the Saaty scale. First, since AHP relied on the participant's expert opinions and judgements to derive the weights, the participants were given a ranking sheet. We asked the participants to first rank the most to least important indicators. Based on the ranking, the participants could easily input which indicators were more important in the pair-wise comparisons.

Next, we used the Saaty scale as the standard scale to distinguish between the level of importance between two indicators. The participant's answer using the Saaty scale will derive the weights calculations. Figure 21 shows the Saaty scale with the explanations for each intensity from 1 to 9.

Figure 21. The Saaty scale (Saaty, 2008)

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

It was up to the participants to answer the intensity of importance based on their expertise, experience, and judgement. The risks weights will be calculated based on the answers given by the participants. In the next section, we discuss the results based on the underlying mathematical principles of AHP.

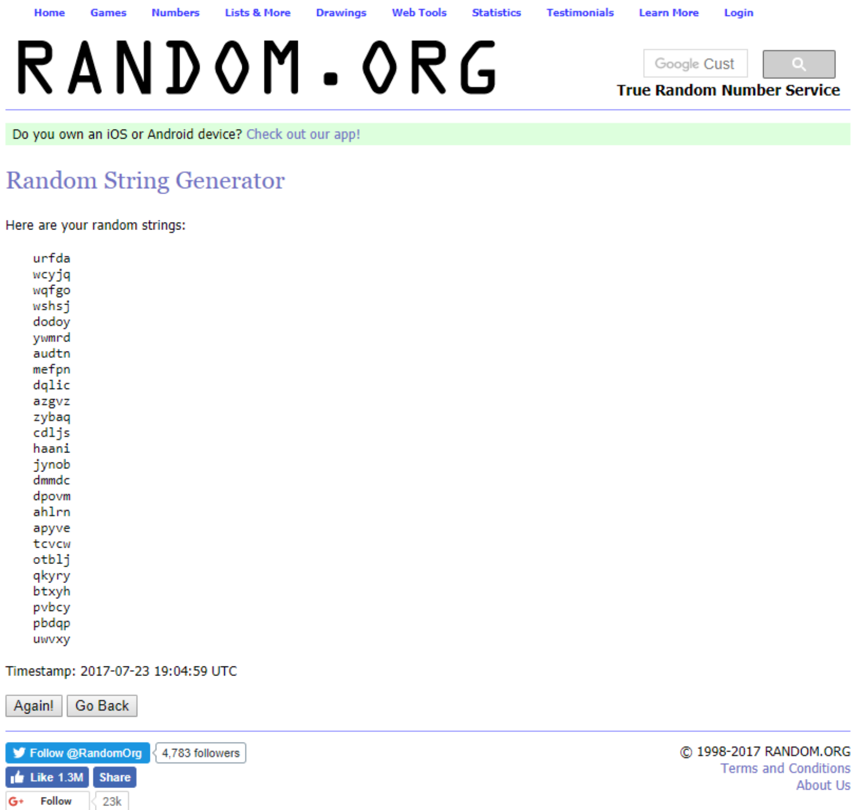
4.3.4 The weights and results

In this phase, we show how the weights for the vector risk assessment tool were derived. After the questionnaire was filled out by the participants, AHP organized the answers into a pair-wise comparison matrix that was essential to the calculation of the weights. Since AHP is visual, we will first dissect the level 1 comparisons between the five categories into the matrix, and show the underlying step-by-step mathematics needed to develop the weights. We will then further discuss the weights calculated in the level 2 and level 3 indicators, and discuss the group input and its effect on the final weights.

Transforming participant answers to the pair-wise comparison matrix

In this section, we dissect the answers from one of the participants. We first look at the answers provided, and then transformed the answers into a pair-wise comparison matrix. Again, we used the Level 1 comparisons between the five categories to understand how the AHP framework calculates its weights. In this phase, we had five participants who filled out the online AHP questionnaire. Each participant was given an unique, confidential username to access the online AHP-OS system, and we will only use the confidential name to discuss the results in this section. Figure 22 shows all the random usernames generated by random.org, which was generated on July 23, 2017.

Figure 22. Random usernames generated for the AHP participants



To understand the mathematical concept behind the AHP methodology, we will first take a sample from one of the participants. Using the answers provided from this participant, we will use it as an example to explain the step-by-step AHP process, and then extrapolate this answer for other participant's responses.

The AHP, step-by-step

We explain the math behind AHP using the answer provided by participant *wcyjq.* Using the answers provided by *wcyjq*, we can explain how we derive the weights mathematically that is necessary to develop the risk assessment tool. Answers provided by other participants will use the same process, and as a group, the answers will be calculated based on geometric means. Although the online AHP-OS automatically computes and generates the final weights, we demonstrate the process by using Microsoft Excel. There are five steps in developing the weights.

The first is converting the pair-wise comparison questionnaire into the pair-wise matrix. Second, normalize the matrix. Third, perform a consistency ratio analysis. Fourth, we look at the answers from other participants, and the aggregated results based on the geometric average of all the answers. Fifth, the new, final AHP hierarchy tree with the global averaged weights is shown.

Step 1 – Pair-wise comparison

First, we examine the answer provided by *wcyjq.* Instead of the AHP-OS' interface of choosing between two elements then choosing the Saaty scale intensity, Figure 23 shows the two pair-wise comparison in opposite ends, and the respondent choose the intensity towards to the more important indicator. The frame in bold was the chosen answer by the user. Figure 23 shows the level 1 response between the five categories for user *wcyjq* (REG stands for Region; SUR stands for Surveillance; DA stands for Departure Airport; AA standards for Arrival Airport; CO stands for Conveyance Operator).

Figure 23. AHP questionnaire answer from user *wcyjq*

Factor	Factor weighting score																	Factor
	More important than...								E	Less important than...								
1. REG	9	8	7	6	5	4	3	2	1	2	**3**	4	5	6	7	8	9	2. SUR
1. REG	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	**9**	3. DA
1. REG	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	4. AA
1. REG	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	5. CO
2. SUR	9	8	7	6	5	4	3	2	1	2	3	4	**5**	6	7	8	9	3. DA
2. SUR	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	4. AA
2. SUR	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	5. CO
3. DA	**9**	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	4. AA
3. DA	9	**8**	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	5. CO
4. AA	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	5. CO

Next, we convert the answer into the AHP pair-wise comparison matrix. Mathematically, the matrix contains the pair-wise comparisons of all possibilities within the five compared categories, which looks like Figure 24:

Figure 24. The pair-wise elements in a pair-wise comparison matrix

$$\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$$

Figure 25. Filled-in upper triangular of the matrix

	1. REG	2. SUR	3. DA	4. AA	5. CO
1. REG	**1**	1/3	1/9	2	3
2. SUR		**1**	1/5	8	3
3. DA			**1**	9	8
4. AA				**1**	1/2
5. CO					**1**

In Figure 25, we fill out the upper triangular part of the matrix (the lower portion is greyed out). The bold 1's diagonally across the matrix represents pair-wise comparison to itself, defaulting to 1 which is the same importance in the Saaty scale. We then fill out the matrix, in which we are comparing the left column to the top row. For instance, we compare REG (left column) to SUR (top row). The answer we received from *wcyjq* was that SUR was three times more important than REG. But because we are always comparing left column to top row and the top row is more important, we fill it out as a reciprocal of 3, which is 1/3. When we compare SUR (left column) to REG (top row), then it will receive a 3. Any judgement rendered left side of 1 in Figure 25 is the actual judgement value. Judgements on the right side of 1 in Figure 25 is the reciprocal value (Bunruamkaew, 2012). We do the same for REG (left column) and DA (top row) where it is 1/9 but entered as a 9 when it is compared from DA (left column) to REG (top row) perspective. We fill-out the rest of the upper triangular part of the matrix using the same method until it is complete.

Figure 26. The completed pair-wise comparison for user wcyjq

	1. REG	2. SUR	3. DA	4. AA	5. CO
1. REG	**1**	1/3	1/9	2	3
2. SUR	3	**1**	1/5	8	3
3. DA	9	5	**1**	9	8
4. AA	1/2	1/8	1/9	**1**	1/2
5. CO	1/3	1/3	1/8	2	**1**

In Figure 26, we have the complete pair-wise comparison filled-out with both the judgement value and reciprocal value completed. The lower triangular portion of the matrix is the reverse of the upper triangular portion of the matrix. For example, instead of REG (left column) compared to DA (top row), it is now DA (left column) compared to REG (top row). The actual judgement value and reciprocal value are switched.

Next, we add the value of each column within the pair-wise comparison matrix using the formula in Equation 1. Summation of Columns in the pair-wise comparison matrix:

$$C_{ij} = \sum_{i=1}^{n} C_{ij}$$

As a result, we have the numbers presented in Figure 27. As an example, in column REG, we sum up 1 + 3 + 9 + 0.50 + 0.33 for 13.83. It is the same for the rest of the columns.

Figure 27. Summation of column values in the pair-wise comparison matrix

	1. REG	2. SUR	3. DA	4. AA	5. CO
1. REG	**1**	0.33	0.11	2	3
2. SUR	3	**1**	0.20	8	3
3. DA	9	5	**1**	9	8
4. AA	0.50	0.13	0.11	**1**	1
5. CO	0.33	0.33	0.13	2	**1**
SUM	13.83	6.79	1.55	22	15.5

Step 2 – Normalizing the matrix

In this step, we normalize the matrix so that the summation column equals to 1. We achieve this by dividing each element in the matrix to the column total. Equation 2. Normalization formula outlines the formula:

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}$$

In Figure 28, we normalize each element by dividing it by the column total. Using column REG as an example again, we divide 1 to 13.83 (our sum from Figure 27). The result is 0.072307. For column REG, the rest of the normalized elements are 0.21692, 0.650759, 0.036153, and 0.023861. When all the columns are added, the column total sum now adds up to one. The same principle applies to all the other columns, and their normalized sum also equals to 1.

Figure 28. Normalized matrix

	1. REG	2. SUR	3. DA	4. AA	5. CO	Total	Average
1. REG	0.072307	0.048601	0.070968	0.090909	0.193548	0.476333	0.095
2. SUR	0.21692	0.147275	0.129032	0.363636	0.193548	1.050412	0.210
3. DA	0.650759	0.736377	0.645161	0.409091	0.516129	2.957517	0.592
4. AA	0.036153	0.019146	0.070968	0.045455	0.032258	0.203979	0.041
5. CO	0.023861	0.048601	0.083871	0.090909	0.064516	0.311758	0.062
SUM	1	1	1	1	1		1

Finally, we generate the weight. In Figure 28, the average column is the weight. This is done by the summing the entire row, then dividing it by the number of indicators to derive the average. For example, for row REG, we added 0.072307, 0.048601, 0.070968, 0.090909, and 0.193548. The summation is 0.476333, which is then divided by the number (*n*) of indicators compared. Notice how when we add up all the average column from the five rows, the sum is also 1. Equation 3. Weights Generated shows the mathematical formula in how we generate the final weight:

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix}$$

Note that the final average (or weights) computed by the AHP-OS is slightly different from our Excel-based calculations. This is because the Excel calculations approximates the Eigen value and

Eigen vectors, and Eigen value and vectors are what Saaty used to derive weights (Teknomo, 2017). The weights we derive from the AHP-OS program are based on Eigen values and vectors.

Step 3 – Consistency Ratio (CR) analysis

In the final step, we perform the Consistency Ratio (CR) analysis. The purpose of the CR analysis is to determine whether the indicators compared are consistent. For example, if A > B, B > C, then A should be > C. The CR analysis does allow for some inconsistency, but the ratio should be 10% and under (Teknomo, 2017). Equation 4. Consistency Ratio shows the basic mathematical equation to measure the CR:

$$CR = \frac{CI}{RI}$$

The two components to calculate CR are Consistency Index (CI) and Random Consistency Index (RI).

Table 19. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

We first begin with RI, which is provided by Saaty (1990) in Table 19, in which *n* stands for the number of indicators being compared. In our case, we compare the five categories at level 1 so the RI is 1.12. In another example, for Departure Airport, we compare six indicators, in which the RI is 1.24. Next, we look at the mathematical concept behind CI. The CI reflects the consistency in the judgement (Bunruamkaew, 2012). The CI equation is shown in Equation 5. CI Equation:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

In this equation, λ_{max} can be calculated approximately in Excel by the product of average (or weights) of each row and the reciprocal of the normalized matrix where the matrix compares to itself (Teknomo, 2017). For example, in Figure 29, we multiply the reciprocal of 0.072307 to the average 0.095 on the first REG row. The two elements to be multiplied are highlighted in bold. The calculation is (1/.072307) * 0.95, and the answer is 1.318.

Figure 29. Calculating the λ max by multiplying the reciprocal of the matrix in each row to the weight

	1. REG	2. SUR	3. DA	4. AA	5. CO	Total	Average
1. REG	**0.072307**	0.048601	0.070968	0.090909	0.193548	0.476333	**0.095**
2. SUR	0.21692	**0.147275**	0.129032	0.363636	0.193548	1.050412	**0.210**
3. DA	0.650759	0.736377	**0.645161**	0.409091	0.516129	2.957517	**0.592**
4. AA	0.036153	0.019146	0.070968	**0.045455**	0.032258	0.203979	**0.041**
5. CO	0.023861	0.048601	0.083871	0.090909	**0.064516**	0.311758	**0.062**

We do the same for the all the rows, and then add it together to obtain the $\lambda_{max.}$ This is then plugged into the CI equation with the *n* being the number of categories compared. In turn, it is divided by RI to obtain the CR score. Here, the AHP-OS score for user *wcyjq* is 7.1%, which is under the 10% CR limitation set by Saaty (1990).

Step 4 – Group inputs

Since we have five participants who answered the AHP questionnaire, the answers they provided to the AHP questionnaire will be averaged by geometric means. Since all the participants answer the same indicators using the same Saaty scale, the final weights used in the vector assessment tool will be a global average that balances the perspectives from all the participants. In this section, we show the averaged group weights for the level 1 categories, the level 2 risk indicators within the five categories, and finally the sub-indicators for indicators 3.1 and 5.5. The average shown here is the calculated average by the AHP-OS software. Tables 20 to 27 show the final weights. Each table will list the weights generated by each user, the CR analysis, and the final group average. The columns represent the indicators, the rows represent the participant's answers, and the final group average will be listed at the top. AHP-OS also automatically generates the higher and lower importance by color shades. The greener the shade, the higher the importance. Low importance is represented by shades of light pink.

Table 20. Average group weights between level 1 comparisons of the 5 categories

Participants	1. Region	2. Surveillance	3. Departure Airport	4. Arrival Airport	5. Conveyance Operators	CR_{max}
Group result	**27.3%**	**29.2%**	**21.9%**	**8.3%**	**13.3%**	**1.0%**
zybaq	16.5%	44.4%	16.5%	16.5%	6.3%	0.9%
urfda	40.5%	8.2%	14.3%	8.8%	28.2%	7.5%
dodoy	25.0%	54.1%	4.0%	3.5%	13.4%	9.1%
dqlic	34.3%	18.9%	31.1%	6.3%	9.5%	6.6%
wcyjq	9.0%	20.3%	61.1%	3.9%	5.8%	7.1%

Table 21. Average group weights between the indicators within the Region category

Participants	1.1 Vector map indicate vectors?	1.2 Vector in-season?	1.3 Under Vector advisory ?	1.4 Previous outbreak?	1.5 Volume of flights?	1.6 Sur confirms no vector?	CR_{max}
Group result	**8.7%**	**20.1%**	**25.9%**	**17.0%**	**8.4%**	**19.9%**	**1.8%**
zybaq	6.2%	12.7%	25.6%	17.7%	4.9%	32.9%	3.9%
urfda	10.2%	8.3%	40.8%	7.1%	7.6%	26.1%	6.3%
dodoy	3.5%	28.3%	17.3%	36.0%	9.6%	5.3%	3.8%
dqlic	29.6%	26.9%	14.2%	7.9%	4.9%	16.5%	4.3%
wcyjq	3.9%	19.9%	22.0%	18.5%	13.3%	22.3%	15.5%

Table 22. Average group weights between the indicators within the Surveillance category

Participants	2.1 Approved Sur traps used?	2.2 Sur done by pros?	2.3 Sur results used for v-ctrl?	2.4 S Sur results communicated?	CR_{max}
Group result	**16.2%**	**26.0%**	**40.5%**	**17.4%**	**0.1%**
zybaq	7.8%	20.9%	46.2%	25.1%	7.7%
urfda	20.3%	10.0%	52.0%	17.6%	7.1%
dodoy	5.3%	46.0%	38.0%	10.7%	0.8%
dqlic	33.3%	33.3%	16.7%	16.7%	0.0%
wcyjq	22.7%	22.7%	42.4%	12.2%	0.4%

Table 23. Average group weights between the indicators within the Departure Airport category

Participants	3.2 Provide diss. service?	3.3 Jetway etc. closed?	3.4 Jetway etc. with mechanical diss.?	3.5 400m v-free zone?	3.6 V-ctrl implemented?	3.1 Have intl/non-endemic ops?	CR_{max}
Group result	**25.6%**	**15.8%**	**16.6%**	**13.2%**	**18.2%**	**10.5%**	**1.8%**
zybaq	24.4%	9.1%	15.6%	6.6%	38.7%	5.6%	5.7%
urfda	16.1%	20.1%	12.3%	20.2%	18.2%	13.0%	3.2%
dodoy	46.0%	9.5%	13.8%	3.3%	4.5%	23.0%	4.4%
dqlic	22.5%	16.2%	15.3%	30.3%	11.2%	4.4%	6.7%
wcyjq	12.8%	19.8%	15.5%	15.5%	28.1%	8.2%	5.3%

Table 24. Average group weights between the indicators within the Arrival Airport category

Participants	4.1 >400M distance from PoE?	4.2 V-ctrl implemented?	4.3 Diversion airport avail?	4.4 JEE PoE score?	CR_{max}
Group result	**25.0%**	**47.2%**	**11.4%**	**16.4%**	**0.6%**
zybaq	12.2%	63.9%	12.2%	11.7%	0.2%
urfda	17.2%	35.7%	23.5%	23.5%	9.1%
dodoy	21.0%	61.8%	4.9%	12.3%	2.7%
dqlic	43.9%	31.1%	10.4%	14.6%	4.4%
wcyjq	35.5%	39.5%	8.9%	16.1%	0.8%

Table 25. Average group weights between the indicators within the Conveyance Operator category

Participants	5.1 Use residual diss.?	5.2 Cargo/luggage vector ctrl?	5.3 Door closed when not-in-use?	5.4 Screens for passenger door?	5.5 Use MX at dep. airport?	CR_{max}
Group result	**24.7%**	**23.1%**	**26.2%**	**16.2%**	**9.8%**	**0.7%**
zybaq	6.7%	27.3%	28.7%	28.7%	8.7%	0.6%
urfda	49.6%	7.1%	22.8%	11.8%	8.7%	5.1%
dodoy	35.9%	42.0%	12.5%	3.5%	6.1%	4.2%
dqlic	9.9%	37.8%	21.6%	21.6%	9.1%	1.2%
wcyjq	33.1%	9.6%	29.8%	18.2%	9.3%	7.4%

Table 26. Average group weights between the sub-indicators within question 3.1

Participants	3.1.1 Scheduled	3.1.2 Cargo	3.1.3 Non-scheduled	3.1.4 Govt Mil	CR_{max}
Group result	**38.4%**	**23.3%**	**20.1%**	**18.3%**	**0.3%**
zybaq	25.0%	25.0%	25.0%	25.0%	0.0%
urfda	15.8%	54.4%	14.0%	15.8%	1.2%
dodoy	66.2%	20.6%	6.8%	6.4%	1.1%
dqlic	35.6%	12.4%	32.6%	19.4%	1.7%
wcyjq	46.1%	10.3%	21.8%	21.8%	0.2%

Table 27. Average group weights between the sub-indicators within question 5.5

Participants	5.5.1 Dissection during MX?	5.5.2 Repair A/C in closed hangar?	CR_{max}
Group result	**51.1%**	**48.9%**	**0.0%**
zybaq	75.0%	25.0%	0.0%
urfda	83.3%	16.7%	0.0%
dodoy	14.3%	85.7%	0.0%
dqlic	33.3%	66.7%	0.0%
wcyjq	50.0%	50.0%	0.0%

Step 5 – Final, weighted AHP hierarchy tree

Finally, Figure 30 shows the new AHP Hierarchy tree with the final weights provided by the average of the group inputs from the participants. Global Priorities (shown as Glb Prio.) score on the right column is the final weight score and will be discussed in the next section.

Figure 30. Final AHP Hierarchy Tree with the final weights in green

Decision Hierarchy

Level 0	Level 1	Level 2	Level 3	Glb Prio.
V-Risks between XXX & YYY Airport	1. Region 0.281	1.1 Vector map indicate vectors? 0.113		3.2%
		1.2 Vector in-season? 0.217		6.1%
		1.3 Under Vector advisory? 0.252		7.1%
		1.4 Previous outbreak? 0.161		4.5%
		1.5 Volume of flights? 0.090		2.5%
		1.6 Sur confirms no vector? 0.167		4.7%
	2. Surveillance 0.260	2.1 Approved Sur traps used? 0.208		5.4%
		2.2 Sur done by pros? 0.268		7.0%
		2.3 Sur results used for v-ctrl? 0.367		9.5%
		2.4 S Sur results communicated? 0.157		4.1%
	3. Departure Airport 0.223	3.2 Provide diss. service? 0.274		6.1%
		3.3 Jetway etc. closed? 0.172		3.8%
		3.4 Jetway etc. with mechanical diss.? 0.162		3.6%
		3.5 400m v-free zone? 0.135		3.0%
		3.6 V-ctrl implemented? 0.162		3.6%
		3.1 Have intl/non-endemic ops? 0.096	3.1.1 Scheduled 0.401	0.9%
			3.1.2 Cargo 0.241	0.5%
			3.1.3 Non-scheduled 0.194	0.4%
			3.1.4 Govt Mil 0.164	0.3%
	4. Arrival Airport 0.084	4.1 >400M distance from PoE? 0.286		2.4%
		4.2 V-ctrl implemented? 0.436		3.7%
		4.3 Diversion airport avail? 0.126		1.1%
		4.4 JEE PoE score? 0.153		1.3%
	5. Conveyance Operators 0.152	5.1 Use residual diss.? 0.271		4.1%
		5.2 Cargo/luggage vector ctrl? 0.234		3.6%
		5.3 Door closed when not-in-use? 0.249		3.8%
		5.4 Screens for passenger door? 0.152		2.3%
		5.5 Use MX at dep. airport? 0.093	5.5.1 Dissection during MX? 0.576	0.8%
			5.5.2 Repair A/C in closed hangar? 0.424	0.6%

4.3.5 The five main categories of the risk assessment tool

The five major categories in the risk assessment tool form the level 1 comparisons in the AHP hierarchy tree. As the first level of comparison for the participants, the level 1 results have a considerable impact on the weights of level 2 risk indicators since the global priorities are derived as product of level 1 categories and level 2 indicators. Furthermore, the five categories are sequential, and each category represents a part in a holistic approach in which each category is linked to each other as a series of events to prevent the vector importation into another region. Table 28 shows the five categories and their respective weights based on our participant's answer. The combined weights of the five categories equal to 1. The five categories are: Region, Surveillance, Departure Airport, Arrival Airport, and Conveyance Operators.

Table 28. The five categories and final weights

Category	Weights
Region	0.281
Surveillance	0.260
Departure Airport	0.223
Arrival Airport	0.084
Conveyance Operator	0.152

Region (of the Departure Airport)

For our participants, the Region where the departure airport is located represents the most important factor and it accounts for 28.1% of our overall weight when compared to the other four categories. In the increased global trade and transportation section of the literature review, the region establishes whether the infectious vectors inhabit that region as a home environment or foreign invasive species (Gubler, 1998). Seasonality also affects when the vectors are in abundance and transmission is most likely (Beard, et al., 2016). Other factors, such as poor land-use and sanitation in the regional environment can also contribute to higher probability of high vector population and increased chance of re-occurring outbreaks (Phillips, 2017). By understanding and answering the risk indicators within the Region category, we can establish an overall determination of whether there are infectious vectors that could be exported. The geographical extent of the region (e.g. state, province, city) can be determined by the user of the risk tool.

Surveillance

Surveillance is defined as “the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice (WHO, Public health surveillance, 2017).” For our participants, their aggregated result determined that this is the second most important category, worth 26% of the overall risk weight. Surveillance monitors the region to confirm whether the targeted vectors exist in the region or not. The risk indicators within this category evaluates the robustness and presence of the regional surveillance capabilities. A region with a good surveillance system can monitor and communicate the activities of vector and vector-borne diseases, and prevent disease outbreaks (Morse, et al., 2012). Early detection of disease emergence can also create strategies to prevent the full outbreaks that was experienced in the Black Death, Ebola, and SARS case studies. As it was noted, it is better to have good surveillance in a high risk region than no surveillance in a low risk region (Meyer, 2017).

Departure and Arrival Airport

Airports are the transit points within the air transport network, which makes airport the point of export as well as the final Point-of-Entry (PoE) against vectors that are transported there (World Health Organization Writing Group, 2006). Although Departure Airport and Arrival Airport are separate categories within the risk tool, we will combine the two because the two categories share many similarities. The Departure Airport is worth 22.3% of the overall risk weight, and the Arrival Airport is scored at 8.4% of the weight.

For our interview and questionnaire respondents, the Departure Airport has a special place of importance because vectors can be stopped at the departure airport. A high risk region will have a high risk airport. But if the departure airport can stop vectors from entering aircrafts, then preventions at the Arrival Airport and on the Conveyance Operator would not be necessary (Meyer, 2017). Further, many literatures suggest that outbound screening is preferred due to the better local knowledge of vectors, being less expensive, and more practical (World Health Organization Writing Group, 2006). Lastly, many risk indicators in this category is aligned to the Chain of Infection, in which barriers (e.g. keeping jetways closed), isolation, and prevention methods at airports will help curtail the spread of vectors.

Arrival Airport, surprisingly, received a much lower score than expected. Although it shared similar indicators, the respondents did place a lot more importance on the departure airport to stop vector export than having the arrival airport stop the vector import. This runs counter to the IHR (2005) and the Joint External Evaluation (JEE) audit, in which both the IHR and JEE placed emphasis on the capabilities of the PoE to respond to disease outbreaks and medical emergencies, but have nothing on the role and responsibilities of the departure airport. The overall role and impact of the Arrival Airport category in this vector assessment tool is quite limited compared to the Departure Airport category.

Conveyance Operators

Conveyance operators refer to the airline and cargo operators that operates the aircrafts. For our participants, the conveyance operator accounts for 15.2% importance of the overall weight. Since aircrafts are the essential vehicle that fly to and from destinations, aircrafts are also the essential vehicle to spread vectors into new regions. But from our Rules and Regulation section, aircrafts and airlines are already heavily regulated to prevent the spread of disease. With rules of chemical disinsection firmly in place, there are not many variations for major airlines unless the airlines would choose to be fined or punished by governments for abrogating existing rules. The low importance of conveyance operator in this risk assessment tool could be attributed to predictability of risks and variations.

4.4 Results of the Fourth step – The risk assessment tool and validation from key stakeholders

In the final step, we created the vector risk assessment tool derived from the weights that we developed in the Section 4.3.4. In the conclusion of Section 4.3.4, we mentioned the global priorities listed on the right column of the AHP hierarchy in Figure 30. These global priorities percentage scores are the final risk weights that are the product of level 1 categories weights and the weights of a risk indicator within that category. For example, based on the AHP comparison, the final weight of the Region category is worth 28.1%. Within the Region category, indicator 1.1 is weighted at 11.3%. The global priority of 3.2% is derived from multiplication of 0.281 * 0.113. Thus, out of the total of 29 risk indicators and sub-indicators in our risk assessment tool, indicator 1.1 is worth 3.2% of the total risk.

The risk assessment tool is organized as a series of 29 indicators. Users of the tool will have to answer all the indicators posed in the risk tool, and the result will generate a percentage score from 0% to 100%. The higher the score, the higher the risk. There are two other factors to consider. First, the indicator type. There are two types of indicators posed in the risk tool. The first type is yes or no indicators, where the user will either respond in the negative or affirmative to the indicator. The second type is numerical score indicator in which the user will answer the numerical score of the indicator.

Second factor is risk rating. For example, in *indicator 1.4 - Has there been a vector-borne disease outbreak in this region in the past,* answering yes will result in the increase of risk by 4.64% whereas answering negative will result in 0%. In other cases, like indicator 2.1, answering yes will result in zero increase in risk, while answering no increases the risk by 4.73%. For numerical indicators, the risk rating is factored by score levels. For example, with indicator 4.4 on the JEE score, having the highest JEE score of 5 will result in zero increase in risk, 4 will increase the risk by 25%, 3 will increase the risk by 50%, 2 will increase the risk by 75%, and a score of 1 will increase the risk by 100% of the global priority score. The final risk assessment tool is displayed from Figures 31 to 35.

In terms of validation with key stakeholders, we were able to present the tool to many organizations. The risk assessment tool has been presented to the Aviation Medical Forum, where representatives from IATA, ACI, IFALPA, and ITA saw a preview of the risk tool. A group conference call involving the CDC and WHO was briefed on the existence of the risk tool. Furthermore, the risk tool has also been presented to delegates from 11 different countries in a regional ICAO conference. Delegates from Thailand has had a personal demonstration of the tool. However, formal validation has not been achieved yet. The response has been enthusiastic so far, but a formal consultation process is needed to study the AHP methodology and the results derived from it. The risk tool will be presented to the WHO in 2018.

A beta, web-version of the tool is now available for testing, but it is not ready for public use.

Figure 31. Region (of departure airport) portion of the risk assessment tool

			Level 0 weight	0.281			
	1. Region Indicators	**Question Type**	**Risks involved**	**Weight**	**Global Priority Score**	**User Response**	**Score**
1.1	Is the region where the airport is located known to have targeted vectors based on vector map (http://vectormap.nhm.ku.edu/vectormap)	Yes/No based on Map	Yes = higher risk	0.113	3.175%	N	0
1.2	Is it the relevant season and climate of the targeted vector in the region where the airport is located?	Yes/No	Yes = higher risk	0.217	6.098%	Y	0.060977
1.3	Is the region where the airport is located under any vector-borne disease advisory and/or the WHO published list where disinsection or vector control are recommended?	Yes/No	Yes = higher risk	0.252	7.081%	N	0
1.4	Has there been a vector-borne disease outbreak in this region in the past?	Yes/No	Yes = higher risk	0.161	4.524%	N	0
1.5	What is the volume of flights in the region where the airport is located based on the Air Connectivity Index[1]?	Use Air Connectiviy Index ranking	Higher ranking = higher risk	0.09	2.529%	39	0.020669712
1.6	Is the absence of targeted vectors confirmed through the vector surveillance programs?	Yes/No	Yes = lower risk	0.167	4.693%	Y	0

Figure 32. Surveillance portion of the risk assessment tool

			Level 0 Weight	0.26			
	2. Surveillance Indicators	**Question Type**	**Risks involved**	**AHP Score**	**Global Priority Score**	**User Response**	Score
2.1	Does the airport vector surveillance program use vector collection devices/traps that are approved by the scientific community as being appropriate for the targeted vector?	Yes/No	Yes = lower risk	0.208	5.408%	N	0.05408
2.2	Is the vector surveillance conducted by trained airport/government personnel or approved contracted services?	Yes/No	Yes = lower risk	0.268	6.968%	N	0.06968
2.3	Are the results of the vector surveillance used to develop and implement airport vector control programs?	Yes/No	Yes = lower risk	0.367	9.542%	N	0.09542
2.4	Are the results and associated risks from vector surveillance communicated to users *and management* of the airport?	Yes/No	Yes = lower risk	0.157	4.082%	N	0.04082

Figure 33. Departure Airport portion of the risk assessment tool

	3. Departure Airport Indicators	Question Type	Risks involved	AHP Score	Global Priority Score	User Response	Score
			Level 0 Weight	0.223			
3.1	Does the departure airport have routes to non-endemic regions of targeted vectors or international operations that include:			0.096	2.141%		
3.1.1	Scheduled passenger operations?	Yes/No	Yes = higher risk	*0.401*	0.858%	Y	0.008584608
3.1.2	Cargo operations?	Yes/No	Yes = higher risk	*0.241*	0.516%	Y	0.005159328
3.1.3	Non-Scheduled passenger operations?	Yes/No	Yes = higher risk	*0.194*	0.415%	Y	0.004153152
3.1.4	Military or state operations?	Yes/No	Yes = higher risk	*0.164*	0.351%	Y	0.003510912
3.2	Does the airport provide approved chemical or mechanical disinsection services for aircrafts?	Yes/No	Yes = lower risk	0.274	6.110%	N	0.061102
3.3	Are the jetway/walkway/stairway/door to the aircraft closed when it is not in service?	Yes/No	Yes = lower risk	0.172	3.836%	Y	0
3.4	Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?	Yes/No	Yes = lower risk	0.162	3.613%	N	0.036126
3.5	Is the departure airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position that can isolate aircrafts from vector threats?	Yes/No	Yes = lower risk	0.135	3.011%	N	0.030105
3.6	Is the airport vector control program implemented and managed in accordance to ongoing presence of target vectors and environmental change?	Yes/No	Yes = lower risk	0.162	3.613%	N	0.036126

Figure 34. Arrival Airport portion of the risk assessment tool

			Level 0 Weight	0.084			
	4. Arrival Airport Indicators	**Question Type**	**Risks involved**	**AHP Score**	**Global Priority Score**	**User Response**	Score
4.1	Is the arrival airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position if arriving aircraft may be carrying possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?	Yes/No	Yes = lower risk	0.286	2.402%	Y	0
4.2	Is the arrival airport's vector control program implemented and managed in accordance to possible targeted vectors threats and environmental change?	Yes/No	Yes = lower risk	0.436	3.662%	Y	0
4.3	Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?	Yes/No	Yes = lower risk	0.126	1.058%	N	0.010584
4.4	What score did the region of the arrival airport receive for "PoE.1 Routine capacities are established at PoE" in reference to WHO's IHR (2005) Joint External Evaluation?	JEE Score	Scale: 1 - 5 (higher score = lower risk)	0.153	1.285%	3	0.006426

Figure 35. Conveyance Operator portion of the risk assessment tool

			Level 0 Weight	0.152			
	5. Conveyance Operator Indicators	**Question Type**	**Risks involved**	**AHP Score**	**Global Priority Score**	**User Response**	Score
5.1	Does the operator utilize residual disinsection consistent with WHO or government regulations?	Yes/No	Yes = lower risk	0.271	4.119%	Y	0
5.2	Does the operator have a guideline or policy for cargo and luggage vector-control practices?	Yes/No	Yes = lower risk	0.234	3.557%	Y	0
5.3	Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operation?	Yes/No	Yes = higher risk	0.249	3.785%	N	0
5.4	Does the operator use self-closing screens for passenger entries?	Yes/No	Yes = lower risk	0.152	2.310%	N	0.023104
5.5	Does the operator use maintenance facilities at the departure airport? IF yes:	Yes/No	Yes = higher risk	0.093	1.414%	N	0
5.5.1	Does the maintenance facility utilize chemical or mechanical disinsection when servicing the aircraft?	Yes/No	Yes = lower risk	*0.576*	*0.814%*	Y	0
5.5.2	Does the maintenance facility conduct repair in a closed hangar?	Yes/No	Yes = lower risk	*0.424*	*0.599%*	Y	0

Chapter 5 : Discussion

In this chapter, we discuss the aviation risk assessment tool from different perspectives. First, we discuss this tool as a pilot project for ICAO and civil aviation. Second, we want to demonstrate the usability of the risk tool by comparing origin-destination airports and discuss the results from these pairings. Third, we present how we can incorporate this risk tool as a supply chain risk management strategy. Fourth, we want to discuss the various stakeholders and users of the tool. Fifth, we discuss creating a database that pre-populates data for origin-destination pairs in future iterations. Finally, we will discuss limitation and outlook of the AHP methodology.

5.1 The pilot project

The development of the vector assessment tool is a response to the ICAO resolution A39-28 to develop a global-standard risk assessment tool that provides a consistent approach to analyzing risk of vectors and vector importation. The objective is to dissuade countries from unilaterally imposing new vector control regulations and standards that are unscientific and disruptive to the air transportation, passengers, and supply chain of cargos. With the initial groundwork laid out by the ICAO working group and their meeting in August 2016, we have access to the notes and direction of what the risk tool requirements are. The requirements put a heavy emphasis on examining the vector importation risk holistically rather than be reliant on the current strategy of chemical disinsection of aircrafts. The goal is to first create a working pilot project, present the tools to key stakeholders, and with the stakeholder's acceptance, evolve this risk tool to maturity.

At the pilot project phase, we have created the risk assessment tool through the literature review, interviews, and the AHP questionnaire process. The result is a 29 indicators risk assessment tool that is organized into the five categories that we discussed in Section 4.4. By answering the 29 risk indicators, users of the risk tool will receive a score between 0% to 100%. The higher the score equates to a higher risk of possible vector importation. But more importantly, one of the key considerations of the risk tool is simplicity, and that aviation stakeholders from all levels and sectors (e.g. international organizations, government, airport, airlines, pilots, flight operators) can utilize this tool to quickly assess the vector importation situation from a civil aviation perspective. The risk tool should also be adaptable into paper forms for rapid assessment in low resource settings, as well as having this risk tool available in a web platform for all to access. The indicators within the risk tools are also comprehensive enough for country-to-country discussion, but easy enough for pilots and flight operators to quickly answer these indicators in real-time situations. But the validation and adoption by government and international agencies is still critical here.

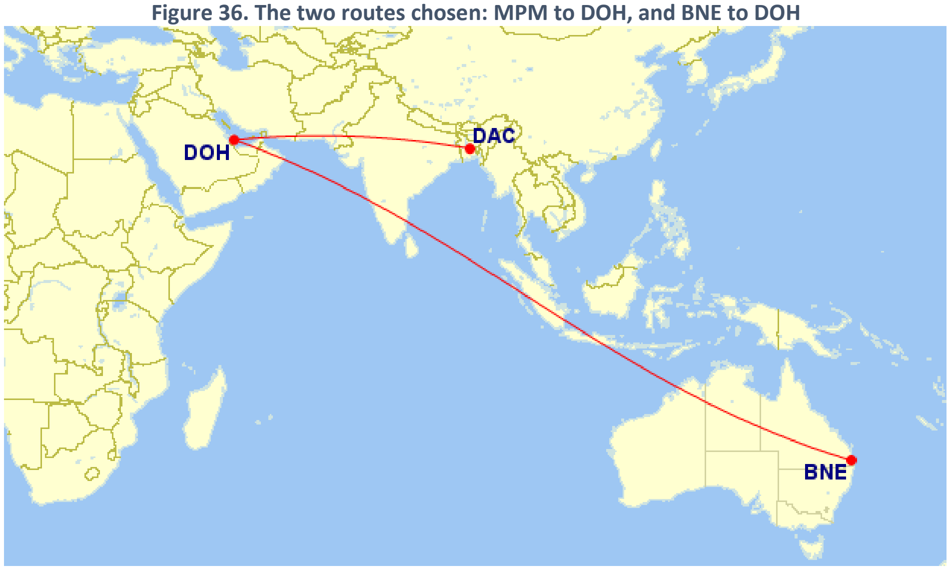
5.2 Demonstrating the vector risk assessment tool

In this section, we want to demonstrate the usability of the risk assessment tool by conducting trials on two origin-destination routes. We want to find routes that are perceived to be either low or high risk, and pick routes from different regions of the world. For our carrier and arrival airport, we decide to choose Qatar Airways and Doha Hamad International Airport. Since the Arrival Airport and Conveyance Operator categories only combined to be worth 23.6% of the risk weights, we decided that it was easier to compare the risk of vector importation by looking at how the Region, Surveillance, and Departure Airport can impact the overall result. In Figure 36, the two origin-destination we chose are Brisbane, Australia (BNE) to Doha, Qatar (DOH), and Dhaka, Bangladesh (DAC) to Doha, Qatar (DOH). After the two comparisons, we examine the interpretation of the risk scores. It should be noted that the answers provided in this demonstration are for illustrative purposes only, any errors in answering the indicators are not intentional.

First, we set some basic parameters on the flight information:

1) **Vectors targeted for this assessment:** Aedes Aegypti
2) **Month of Departure:** June
3) **Region:** To be determined.
4) **Departure Airport:** To be determined.
5) **Arrival Airport:** Doha Hamad International Airport (DOH)
6) **Conveyance Operator:** Qatar Airways

Figure 36. The two routes chosen: MPM to DOH, and BNE to DOH



5.2.1 Picking the Arrival Airport and Conveyance Operator

We choose Doha Airport and Qatar Airways as the Arrival Airport and Conveyance Operator for two reasons. First, we want to find an airline and airport that serve global destinations to different continents. We chose Qatar Airways and Doha airport because it is one of the few airlines that serve destinations in all continents except Antarctica, and it has service to countries with various income levels. Second, we want to pick an arrival airport in a country that has completed a WHO Joint External Evaluation (JEE) assessment to fulfill indicator 4.4. Qatar Airways and Doha Airport fulfill both qualifications. Next, we start answering the indicators for the Arrival Airport and Conveyance Operator categories.

Table 29. Arrival Airports Results for Doha Hamad International Airport (DOH)

	4. Arrival Airport Indicators	Global Priority Score	User Response	
4.1	Is the arrival airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position if arriving aircraft may be carrying possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?	2.402%	Y	0
4.2	Is the arrival airport's vector control program implemented and managed in accordance to possible targeted vectors threats and environmental change?	3.662%	Y	0
4.3	Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?	1.058%	N	1.058%
4.4	What score did the region of the arrival airport receive for "PoE.1 Routine capacities are established at PoE" in reference to WHO's IHR (2005) Joint External Evaluation?	1.285%	3	0.643%
				1.701%

In Table 29, we look at the arrival airport risk score for the Doha Hamad International Airport. First, we examine indicator 4.1. Through our Google search for airport charts, blueprints and satellite imagery, we identify that the airport provides an isolation area that is 400 meters from the nearest PoE. This type of airport charts are also available for pilots who are flying to those destinations. The score here is zero increase in risks. Next, we look at the vector control program at the airport. Although we are unable to ascertain the robustness of the vector control program, we are able to ascertain that Doha airport does manage its vector control program. Again, since Doha meets this criterion, the increase risk is zero. Next, in indicator 4.3, Doha airport is the only commercial, international airport in Qatar, therefore it is impossible to divert to another airport in Qatar. This raises the risk by 1.058% percent. Lastly, for indicator 4.4, Qatar received a JEE score of 3 from the WHO, which means the risk level is 50% of the risk score (5 – 0%, 4 – 25%, 3 – 50%, 4 – 75%, 5 – 100%). An additional 0.643% is added to the risk.

The total risk of the Arrival airport is only 1.701% of the global score. Like we stated earlier in the Section 4.3.5, the overall importance of arrival airports is the least within the five categories. Again, the emphasis of the risk tool relies heavily on the departure airport but not the arrival airport.

Table 30. Conveyance Operator Results for Qatar Airways

	5. Conveyance Indicators	Global Priority Score	User Response	
5.1	Does the operator utilize residual disinsection consistent with WHO or government regulations?	4.119%	Y	0
5.2	Does the operator have a guideline or policy for cargo and luggage vector-control practices?	3.557%	Y	0
5.3	Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operation?	3.785%	N	0
5.4	Does the operator use self-closing screens for passenger entries?	2.310%	N	2.310%
5.5	Does the operator use maintenance facilities at the departure airport? IF yes:	1.414%	N	0
5.5.1	Does the maintenance facility utilize chemical or mechanical disinsection when servicing the aircraft?	*0.814%*	N/A	0
5.5.2	Does the maintenance facility conduct repair in a closed hangar?	*0.599%*	N/A	0
				2.310%

Next, we look at Qatar Airways as the conveyance operator of this flight in Table 30. For indicator 5.1, we know that Qatar Airways flies daily to four destinations in Australia, and it follows the strict rules and regulations that the government set for chemical disinsection. Therefore, the risk for not following the rules is absent, in turn, there is no increase in risk. The same follows for indicator 5.2, where cargo and luggage have strict guidelines that Qatar Airways must meet. For indicator 5.3, due to the hot weather in Qatar, doors are closed when the aircrafts are parked. For indicator 5.4, since the self-closing screen is not commercially available at the time of writing, there is automatic addition to the risk score of 2.310%. Lastly, since we are only using Doha as the arrival airport in this scenario, this indicator is not applicable. The final risk tally in this category is only 2.310%.

This section exemplifies the fact that big, global airlines will typically run low risk scores due to their international airline destination network. Their ability to comply with different government obligations makes big carriers relatively low risk in transporting vectors on aircrafts. Small airlines, airlines in low-income countries and charter flights may not have the same ability to meet the requirements set forth in this category, and this is where pilots and flight operators can use our tool to ensure their operation runs in compliance to the law. However, this also does not account for the fact that the chemical disinsection may not be effective due to vector resistance to chemical disinsection. Actual efficacy of current chemical disinsection regime may not be killing vectors at the intended rate.

In the next comparison section, we will automatically add the combined Arrival Airport and Conveyance Operator risk score of 4.011% to each of origin-destination pairings. We will only examine the Region, Surveillance, and Departure Airport categories in the upcoming routings.

5.2.2 Brisbane (BNE) to Doha (DOH)

In our first origin-destination pair, we look at the risk of vector importation from Brisbane (BNE) to Doha (DOH). We choose this routing because of the stringent rules of Australian flights, and due to its location being northeastern state of Queensland that has the tropical climate conducive to mosquitos. We first start by examining the region of Queensland and Brisbane.

Table 31. Region category for Brisbane region

	1. Region Indicators	Global Priority Score	User Response	
1.1	Is the region where the airport is located known to have targeted vectors based on vector map (http://vectormap.nhm.ku.edu/vectormap)	3.175%	Y	3.175%
1.2	Is it the relevant season and climate of the targeted vector in the region where the airport is located?	6.098%	N	0
1.3	Is the region where the airport is located under any vector-borne disease advisory and/or the WHO published list where disinsection or vector control are recommended?	7.081%	Y	7.081%
1.4	Has there been a vector-borne disease outbreak in this region in the past?	4.524%	Y	4.524%
1.5	What is the volume of flights in the region where the airport is located based on the Air Connectivity Index[1]?	2.529%	44	2.006%
1.6	Is the absence of targeted vectors confirmed through the vector surveillance programs?	4.693%	N	4.693%
				21.479%

In the Region category seen in Table 31, Queensland and Brisbane have been identified as a region with Aedes Aegypti mosquito as per indicator 1.1. This raises the risk level by 3.175%. For mosquito season in indicator 1.2, the mosquito season is generally from November to April – the Summer months in Australia – so the mosquito is not in season at the time of departure. For indicator 1.3, the WHO advisory has not been implemented at time of writing, but our assumption here is that if the area suffered from a recent vector-borne outbreak, we would assume the risk to be there. For indicator 1.4, recent Ross River Fever outbreaks caused by mosquito vectors affirms additional risk in this category. In indicator 1.5, the Air Connectivity Index ranks Australia 44 out of 208 countries, so it receives 79% of the full score at 2.006%. Lastly, surveillance confirms the presence of vectors, therefore BNE region receives another 4.693% increase in risks. The overall risk of vectors in the Brisbane, Queensland area is very high as it receives a score of 21.479%.

Table 32. Surveillance category for Brisbane region

	2. Surveillance Indicators	Global Priority Score	User Response	
2.1	Does the airport vector surveillance program use vector collection devices/traps that are approved by the scientific community as being appropriate for the targeted vector?	5.408%	Y	0
2.2	Is the vector surveillance conducted by trained airport/government personnel or approved contracted services?	6.968%	Y	0
2.3	Are the results of the vector surveillance used to develop and implement airport vector control programs?	9.542%	Y	0
2.4	Are the results and associated risks from vector surveillance communicated to users *and management* of the airport?	4.082%	Y	0
				0

In the surveillance category seen in Table 32, the surveillance system in and around the Brisbane area is terrific. With all four indicators in the affirmative, no additional risk is added here. For indicators 2.1 and 2.2, the airport has active surveillance traps conducted by professional staff. It was able to identify the presence of Aedes Aegypti mosquitos at the airport site. For indicators 2.3 and 2.4, vector control program is active, and the users of the airport and citizens of Brisbane are constantly notified of the risk of vectors in the region.

Table 33. Departure Airport category for Brisbane Airport

	3. Departure Airport Indicators	Global Priority Score	User Response	
3.1	Does the departure airport have routes to non-endemic regions of targeted vectors or international operations that include:	2.141%		
3.1.1	Scheduled passenger operations?	0.858%	Y	0.858%
3.1.2	Cargo operations?	0.516%	Y	0.516%
3.1.3	Non-Scheduled passenger operations?	0.415%	Y	0.415%
3.1.4	Military or state operations?	0.351%	N	0
3.2	Does the airport provide approved chemical or mechanical disinsection services for aircrafts?	6.110%	Y	0
3.3	Are the jetway/walkway/stairway/door to the aircraft closed when it is not in service?	3.836%	Y	0
3.4	Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?	3.613%	N	3.613%
3.5	Is the departure airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position that can isolate aircrafts from vector threats?	3.011%	N	3.011%
3.6	Is the airport vector control program implemented and managed in accordance to ongoing presence of target vectors and environmental change?	3.613%	Y	0
				8.413%

Lastly, we look at the Departure Airport risk indicators at the Brisbane Airport which is shown in Table 33. First, we added risks because BNE has flights that are scheduled, non-schedule, and cargo. The airport does not have any military operations. These three sub-indicators add 1.789% to the overall risk. For indicator 3.2, the Australian government provides a list of approved vendors for disinsection services in Australia, so the risk is not added. For indicator 3.3, we did a Google image search and find all the empty jetways and entrances to be closed. For indicator 3.4, mechanical disinsection is not commercially available yet, so the risk of 3.613% is added. For indicator 3.5, after reviewing a detailed chart of the BNE airport, no 400 meters isolation area is found, which adds an additional 3.011% risk. Lastly, indicator 3.6 is an affirmative as their vector program is active and effective. The tally for the Departure Airport category is 8.413%.

The final score of the risk of importing a vector between BNE and DOH is 33.904%. Most of the risk is derived from the high risk region in which the airport is located, but active surveillance and vector control programs has dramatically cut down the potential risk of vector importation. In the next pairing, we look at a high risk departure region of Dhaka, and examine the differences in the score.

5.2.3 Dhaka (DAC) to Doha (DOH)

In this demonstration, we chose a high risk area that does not have the same stringent standard as Australia. We also chose Dhaka, Bangladesh as the other pairing because the country has also undergone a JEE visit, which gives invaluable insight to the capabilities of vector control in the region.

Table 34. Region category for Bangladesh region

	1. Region Indicators	Global Priority Score	User Response	
1.1	Is the region where the airport is located known to have targeted vectors based on vector map (http://vectormap.nhm.ku.edu/vectormap)	3.175%	Y	2.375%
1.2	Is it the relevant season and climate of the targeted vector in the region where the airport is located?	6.098%	Y	5.487%
1.3	Is the region where the airport is located under any vector-borne disease advisory and/or the WHO published list where disinsection or vector control are recommended?	7.081%	Y	7.071%
1.4	Has there been a vector-borne disease outbreak in this region in the past?	4.524%	Y	4.641%
1.5	What is the volume of flights in the region where the airport is located based on the Air Connectivity Index[1]?	2.529%	121	1.070%
1.6	Is the absence of targeted vectors confirmed through the vector surveillance programs?	4.693%	N	5.433%
				26.077%

The Bangladesh region almost received a full score for the Region category as seen in Table 34. The only reason why it did not receive a full score was its low Air Connectivity Index score with a rank of 121, which is only 42% of the total risk percentage for indicator 1.5. For indicator 1.1, Bangladesh region is confirmed to be an Aedes Aegypti zone by vector map. For indicator 1.2, mosquitos are found in all seasons in Bangladesh. Due to the monsoon season, there is increased incidences of vector-borne diseases and outbreaks which affirms the risk for both indicators 1.3 and 1.4. Lastly, the presence of vectors negates the surveillance indicator here. The final risk tabulated for the Region category is 26.077%.

Table 35. Surveillance category for Bangladesh region

	2. Surveillance Indicators	Global Priority Score	User Response	
2.1	Does the airport vector surveillance program use vector collection devices/traps that are approved by the scientific community as being appropriate for the targeted vector?	5.408%	Y	
2.2	Is the vector surveillance conducted by trained airport/government personnel or approved contracted services?	6.968%	Y	
2.3	Are the results of the vector surveillance used to develop and implement airport vector control programs?	9.542%	N	9.542%
2.4	Are the results and associated risks from vector surveillance communicated to users *and management* of the airport?	4.082%	N	4.082%
				13.624%

For the Surveillance category in Table 35, the JEE identified that Bangladesh does have good surveillance capabilities. Therefore, it is determined that there are no additional risks in indicators 2.1 and 2.2. However, for indicators 2.3 and 2.4, there are reports that the coordination and communication for vector control between agencies have severe deficiencies. For this reason, we decided to add additional risk score for the latter two indicators. The final risk score for the Surveillance category is 13.624%.

Table 36. Departure Airport category for Dhaka Shahjalal International Airport

	3. Departure Airport Indicators	Global Priority Score	User Response	
3.1	Does the departure airport have routes to non-endemic regions of targeted vectors or international operations that include:	2.141%		
3.1.1	Scheduled passenger operations?	0.858%	Y	0.858%
3.1.2	Cargo operations?	0.516%	Y	0.516%
3.1.3	Non-Scheduled passenger operations?	0.415%	Y	0.415%
3.1.4	Military or state operations?	0.351%	Y	0.351%
3.2	Does the airport provide approved chemical or mechanical disinsection services for aircrafts?	6.110%	N	6.110%
3.3	Are the jetway/walkway/stairway/door to the aircraft closed when it is not in service?	3.836%	Y	0
3.4	Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?	3.613%	N	3.613%
3.5	Is the departure airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position that can isolate aircrafts from vector threats?	3.011%	N	3.011%
3.6	Is the airport vector control program implemented and managed in accordance to ongoing presence of target vectors and environmental change?	3.613%	N	3.613%
				18.487%

Lastly, we look the Departure Airport category at the Dhaka airport in Table 36. For indicator 3.1, the Dhaka airport has operations for all four sub-types. For indicator 3.2, it does not appear that the Dhaka airport offers residual disinsection services for aircrafts. For indicator 3.3, Google and

YouTube videos reveal that jetways and entrances are closed when not in use. However, like the other pairings, mechanical disinsection capabilities in indicator 3.4 do not commercially exist, therefore the additional risk is added. Also, from our observation for the Dhaka airport charts, it does not have a 400 meters isolation area for aircrafts. Lastly, for indicator 3.6, the JEE report for Bangladesh specifically pointed out the lack of vector control and disinsection procedures for airports, which adds more risk to the category. The final risk score here is 18.487%.

For the Dhaka airport, the final risk score is 65.317%, which is almost twice as high as the BNE-DOH route. The biggest contributing factor here is the Surveillance and Departure Airport score, which added significant risk to possible vector importation.

5.2.4 Interpreting the risk score

In this section, we want to discuss the interpretation of the risk scores. Based on our demonstration, Brisbane scored 33.904% and Dakar scored 65.317%. But more importantly, what do these scores mean? For the pilot project, we want to keep it simple by using three possible outcome levels: low risk, medium risk, and high risk. In AHP terminology, possible outcomes, such as our three levels, are called alternatives. We discuss how we establish thresholds for the three risk levels.

Here, we want to develop the three risk level thresholds in three ways. First is to assume that the risks can be identified in equal one-thirds. Here, low risk represents 0% to 33%, medium risk from 34% to 66%, and high risk represents from 67% to 100%. The second method is to use the Level 1 category weights to determine the risk level. In this method, 0% to 28% will represent low risk per the overall risk weights of the Region category, medium risk will be 29% to 55% to represent the second most important category of Surveillance, and high risk will be anything above 56%. Lastly, we can use the AHP questionnaire to do a pair-wise comparison between three risk levels to determine the thresholds. We did a comparison between the three alternatives based on the author's judgement, and the score came out to be 0% to 16% for low risk, 17% to 53% for medium risk, and 54% and above is high risk. Figure 37 tabulates the difference of scoring between the three methods.

Figure 37. The different range of low, medium, high risks from three different interpretations

	Low Risk		Medium Risk		High Risk	
Even 1/3	0%	33%	34%	66%	67%	100%
Category weights	0%	28%	29%	55%	56%	100%
AHP pairwise	0%	16%	17%	53%	54%	100%

Based on the three different methods of computing the risk levels, our two origin-destination pairs would fit in different risk levels depending on the methods that we choose to adopt. Interestingly, both our BNE and DAC flights straddle in the low-medium risk level and medium-high risk levels, respectfully, when we use the even one-thirds method. But with category weights and AHP pair-wise comparison, both routes would have firmly been in the medium and high risk levels, respectfully. If we choose to use the AHP methods to determine the risk level thresholds, we can conduct another round of AHP questionnaires with stakeholders to establish the risk levels in future iterations.

What is the difference between low risk, medium risk, and high risk? At this juncture, we decided that low risk means that no further action is necessary and that any unilateral initiatives to impose further restrictions or regulations is unfounded. At the medium level, precautions should be taken, and all stakeholders within that origin-destination pair should assess the shortcomings and implement an action plan. The goal should be to reduce the risk from medium to low. Further restrictions and regulations can be recommended if certain high value risk indicators from the risk assessment tool fail. Lastly, if the origin-destination pair is high risk, all stakeholders should agree that necessary vector control plans should be implemented immediately to mitigate the potential spread of vectors and VBDs. Stakeholders in the area should also begin immediate assessment and implement an action plan to reduce the long-term risks of vector importation/exportation.

Lastly, we believe what skews the number is the Conveyance Operator category, which still commands approximately 13% of the overall risk score. With major airlines being mostly compliant with the rules and regulation, the score will always skew lower because it is hard to lose all 13%. For this reason, we believe that it makes sense for the high risk ranges to start lower, like the 54% and 56% that we have witnessed. But this threshold between the different risk ranges could be contentious for the different stakeholders.

In the next iteration, stakeholder's inputs are further needed to identify the thresholds between the risk levels. At the present phase, we want the stakeholders to extensively test the tool between other theoretical origin-destination pairs and share their thoughts on the score. As noted above, our own conclusion was that Conveyance Operators category pushes the score lower. One tester noted that she tried a very high risk origin-destination pair and only received approximately 70% score. Another tester thought a five-level risk scale is better than a three-level risk scale. The next step is to get initial feedback from the current scoring system, and based on their feedback, create the next guideline on determining what type of scoring scale we should use. Based on the guideline, methods such as focus groups or Delphi-method can be used to get a consensus on the type of scale, and the threshold level between the risk levels.

5.3 Mitigating supply chain disruptions

Professional supply chain organizations, such as APICS, have placed an emphasis on risk management and identifying possible sources of supply chain disruptions. Natural disasters, capacity failures, infrastructure failures, terrorist attacks, labor strikes, price volatility, and military conflicts are all possible disruptive supply chain events (APICS Supply Chain Council, 2015). In this master thesis, we propose that public health events, such as the Ebola and SARS outbreaks, have also demonstrated their ability to disrupt the supply chain, and the movement of people and cargo in the air transportation sector.

The risk assessment tool can be used as a complement to future strategic and operational supply chain planning. For example, if an air cargo operator is choosing a new hub, the possibility of future public health events in the hub region should also be considered. Choosing hubs in high risk VBD regions may result in higher scrutiny and unilateral actions from foreign governments when patterns of disease outbreaks occur at the hub region. High disease morbidity from VBDs can also cause extensive employee absences that can also disrupt the supply chain operation as well. Also, the risk tool can be used to assess the vector control capabilities of the airports that the cargo operators are considering. Is the airport authority competent to control diseases? Does it have the vector control facilities that meets international standards? Would the air cargo operator incur additional expenses to meet international standards? How many high risk routes are planned from this airport hub? These factors should all be considered when it comes to strategic and tactical supply chain planning with regards to mitigating public health supply chain disruptions.

From another perspective, this tool can also be used pre-emptively to examine how to lower the potential risk of vector importation. The knowledge that certain routes are identified as low risk can shift supply chain planning through less-volatile VBD regions than higher risk regions. Also, rather than being caught off-guard by sudden regulatory changes, having higher vector control standards and performing advanced preparation of aircrafts flying to and from high risk areas can avoid supply chain disruption that may be suddenly imposed. In the next section, we examine how users – from international organization, government bodies to aircraft pilots – can utilize this tool.

5.4 Users of the risk tool

At this pilot project phase, we have identified several key stakeholders that would utilize this tool. These include (from highest level):

- International Organizations, such as ICAO and WHO
- Government and governments authorities, such as the Ministry of Health, Civil Aviation Authorities
- Airport and Airline operators
- Pilots and flight operations

At the top, the acceptance and adoption of the risk assessment tool by the WHO is a key priority. As the international organization in charge of international public health, acceptance and cooperation from WHO is part of the directive from the ICAO resolution A39-28. Furthermore, WHO acceptance of the risk tool means broader adoption from governments worldwide, as well as key civil aviation stakeholders. The hope is that this tool could complement existing IHR (2005) as an additional tool to help contain and mitigate the spread of vectors and VBDs. The main goal is that if the tool is accepted, it can be used as a common platform for all stakeholders to use, which can help reduce or eliminate supply chain and passenger operations disruptions caused by unilateral actions of governments. The risk score can be used as a point of discussion when discussing whether countries should impose additional disinsection requirements or not, and approach vector control more collaboratively.

Governments and their civil aviation and public health agencies would also benefit from this tool. This risk tool can help governments and government agencies evaluate their national aviation public health strategy. By looking at the indicators in which the country did poorly, it is easy to strategize how to improve their vector control systems. The other hope is that countries will use this risk tool to evaluate the need to impose further regulations of incoming aircrafts from other countries. By using this standardized tool, every stakeholder – foreign governments and airlines – are on the same standard when evaluating potential escalation due to increased vector threats. There would be less surprises and uncertainty when everyone is on the same standard, which will also decrease the disruption to the supply chain and air transport system.

For airlines and other flight operators, this tool can assist the airlines from the perspectives of the health and safety team. Although airlines typically abide by the rules and regulations of countries they fly to, additional health and safety evaluations – especially for the cabin crew – is good for health and prevents the crew from becoming sick from potential diseases. Human resource depletion due to disease and illness can also increase stress on airlines and cargo operations and cause disruptions to the supply chain when there are no pilots to fly the airplanes. Furthermore, if the health and safety department felt the airports are not in compliance to vector control standards, this tool can be used as a point of discussion for the airports to raise the standards for their airline clients.

On a personal level, individual pilots and flight operators can benefit from this tool as well. The indicators can be filled out based on the observations of the pilots. For example, does the airports and airlines keep the door closed? Do they communicate vector threats to the users of the airport? Are certain services, such as disinsection, available at the airport? Many of the risk indicators can be filled out in real-time. Even if the information is not complete, the approximation of answers can give a general idea on how risky the flights are. One of the delegates mentioned that he would like to see pilots fill out the risk tool before each flight to familiarize oneself with the surrounding environment from a public health perspective.

Since Brisbane and Dhaka share similar risk profile in terms of the region, improvements and strategies on vector control and surveillance can significantly reduce the risk of importing vectors to another region. The risk tool provides an invaluable insight for civil aviation and public health stakeholders to examine where the deficiencies are. Furthermore, the weights for each indicator helps identify and prioritize the most pertinent deficiencies to be fixed. For example, indicator 2.3 on using surveillance results to design and implement airport vector control program is worth 9.542% of the overall risk score. Had Bangladesh's coordination between agencies been better, almost 10% of risks would have been shaven off. In conclusion, the two origin-destination pairings demonstrate that the risk assessment tool can identify the level of risk of importation from a variety of risk indicators.

5.5 Creating a database for the risk tool

In future iterations, we want to develop a database that completes many of the indicator answers. For example, if we enter Montreal (YUL) as the departure airport, then the Region, Surveillance, and Departure category should be automatically filled with data on the region of Québec, Institut national de santé publique du Québec, and the Montréal–Pierre Elliott Trudeau International Airport. Adding that we are flying on Air Canada, for example, would fill-in the risk results for the Conveyance Operator category. Finally, the arrival airport information should be filled-in if we choose an airport within the database. Since it is hard for any stakeholders to have all the information on all these various categories and risk indicators, aggregating the data using a database at the ICAO-level will give access to all stakeholders to make a standardized evaluation. The hope is that once the tool is adopted, resources will be dedicated so that the database information would be continuously updated. Some indicators would be updated along with WHO's advisory warnings, while other indicators, such the Regions Category, would have more static answers. This way, vector importation assessments would always have the best, most up-to-date information available.

5.6 Limitations and outlooks

One of the most important limitations of the AHP methodology is that the weights are not fixed and are subjected to the perception and judgement of the participants. The possibility of survey bias, and failure to properly screen and select our participants may lead to inaccurate responses, which will affect the aggregated weights used by the risk assessment tool. The inaccurate weights can potentially decrease the effectiveness of the risk assessment tool.

We limited these potential biases by implementing different strategies. First, we engaged with the Aviation Medicine section of ICAO to ensure that the potential participants meet the inclusion criteria. Furthermore, the participants were recommended by ICAO from stakeholder organizations that have extensive experience in this field. Second, since our weights were aggregated from all the participants, we can also exclude inputs from certain participants if their answers to the AHP are outliers. We outlined all the inputs from each of our participants and the global average in Tables 20 to 27. We find that even if some participants responded with extreme answers (e.g. a score of 9 from the Saaty Scale), answers from other participants seem to compensate the outlier effects.

In this pilot project, only five participants responded to the AHP questionnaire. The number is sufficient to see how the aggregated average weights works and can be put together as a proof of concept to test out the methodology. For the future extensions and iterations of the risk assessment tool, there are two additions that will make the risk tool more robust and complete.

First, we should expand the questionnaire participants. In this pilot project, the total number of AHP questionnaire participants was five. Although we invited all eight interview participants to again partake in the questionnaire process, not all of them were able to. Retirement and reassignments disallowed some participants to aide with the AHP questionnaire. For the pilot project, we felt five responses were enough due to the final weights being the aggregated average, so any additional responses would simply add into the group's average. For the next iteration, we want to have new participants (e.g. country delegates, government officials, experts from public health and civil aviation, cargo operators) to answer the AHP questionnaire.

Although disaggregated, unprotected answers are not allowed to be revealed here, the individual AHP responses give meaningful insights as to what each stakeholder feels are more important factor than the others.

Second, we are willing to re-open the interview process and invite new stakeholders (e.g. country representatives, WHO, CDC) to re-evaluate the risk indicators and categories. One of the most important determinations is whether the AHP methodology is the correct method to evaluate the weights of indicators through pair-wise comparisons. However, if major stakeholders, such as the WHO, would like to add new or replace existing indicators, they are welcomed to do so. We would simply need to revisit the AHP questionnaire process to re-build the weights.

However, before the next iteration can begin, validation from key stakeholders on the usefulness of the AHP methodology to derive weights will be needed. Some of the key questions include whether the aggregated average for weights is acceptable if different participants had very different answers? How many participants and which participants are necessary to ensure that the weights are accurately captured? What if the indicators need to be updated again? These questions will be answered in a lengthy consultation process with key aviation and public health stakeholders.

Chapter 6 : Conclusion

Increased globalization and trade also increased the probability of global transmission of disease. Air transportation – due to its speed and global hubs – has demonstrated its ability to further accelerate the global dissemination of disease. Although regulatory frameworks have been implemented to curtail this global dissemination, civil aviation and public health stakeholders still have many concerns about vector importation, the efficacy of current vector control methods, and unilateral actions of governments that cause disruptions to supply chains, airlines, and trade.

As a result, the 39th ICAO Assembly adopted a resolution which included the development of a risk assessment tool to calculate the risk of vector importation. In this master's thesis, we developed a pilot risk assessment tool. In the development phase, we took the indicator developed by the ICAO working group in August 2016, and added new indicators through literature review. After that, we interviewed civil aviation and public health stakeholders to further develop and mature the necessary and correct indicators. With a final list of indicators, we incorporated the indicators into the AHP methodology to compare which indicators are more or less important. Based on these pair-wise comparisons made by five industry stakeholders, we were able to derive the risk weights for each indicator. This is then packaged into an Microsfot Excel spreadsheet that allows the users to answer the indicators and receive a risk score.

With the development of this risk assessment tool, we have made several contributions to this field. First, this is a risk tool that can be used to assess public health disruptions in supply chain and air transportation. With governments fearing the importation of disease into their country, barriers and restrictions on incoming aircrafts and cargo can be disruptive to supply chains. Second, this is the first risk assessment model that looks at the vector control capabilities of aircrafts and airports as determinant factors in vector importation risks. As the main vehicle and PoE for vectors and VBDs, the vector control capabilities in these categories have been identified as critical. Third, the indicators list is more approachable for all levels of stakeholders to use, making it highly adaptable to various situations. Lastly, we were able to derive the weights for the indicators, giving us further insights as to the priorities of the stakeholders, and how we can use this information to further develop the next iteration of the tool.

At this juncture, we were able to present the risk tool to key stakeholders, and we also demonstrated the usefulness of this tool by using two origin-destination pairs. Although this risk assessment tool has not been officially approved by key stakeholders, such as the WHO, we are hopeful that this holistic approach in risk assessment will gain momentum and acceptance in the near future.

Chapter 7 : Bibliography

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Appendix

Appendix A. The Structured Interview Form

CONSENT FORM FOR AN INTERVIEW

1. Information on the research project
You have been invited to participate in the following research project:

Infectious Vectors and Supply Chain Disruptions: Development of Air Transportation Risk Assessment Tool using Vector-Control, Public Health Criteria

This project is being conducted by:

Yu-Heng (Andrew) Chou	Julie Paquette	Marie-Ève Rancourt
Master's student	Associate Professor	Assistant Professor
HEC Montréal	HEC Montréal	HEC Montréal
	514-340-6745	514-340-1965
yu-heng.chou@hec.ca	julie.paquette@hec.ca	marie-eve.rancourt@hec.ca

Summary: The purpose of the interview is to determine and validate the vector-control indicators needed to develop a risk assessment tool for use in civil aviation. Below is a list of indicators that has been developed through literature review and a previous focus group. The interview will ask the participants to review and specify whether the indicators are relevant or not, modify the wording if necessary, comment on each particular indicator, and add new indicators as necessary. This validation process will help solidify the indicator lists, which will then be analysed using an Analytical Hierarchy Process (AHP) methodology.

2. Research ethics considerations
Your participation in this research project is strictly voluntary. You have the right to refuse to answer any of the questions. In addition, you may ask to end the interview at any time, in which case the researcher would be prohibited from using the information gathered.

HEC Montréal's Research Ethics Board has determined that the data collection related to this project meets the ethics standards for research involving humans. If you have any questions related to ethics, please contact the REB secretariat at (514) 340-6051 or by email at cer@hec.ca. Do not hesitate to ask the researcher any questions you might have.

3. Confidentiality of personal information gathered
You should feel free to answer the questions frankly. The researcher, as well as all other members of the research team, if applicable, undertake to protect the personal information obtained by ensuring the protection and security of the data gathered from participants, by keeping all recordings in a secure location, by discussing the confidential information obtained from participants only with the members of the research team and by refraining from using in any manner data or information that a participant has explicitly requested be excluded from the research.

Furthermore, the researchers undertake not to use the data gathered during this project for any purpose other than that intended, unless approved by HEC Montréal's Research Ethics Board. **Please note that by consenting to participate in this research project, you also consent that the data gathered may be used for future research projects, subject to approval of any such projects by HEC Montréal's Research Ethics Board.**

All persons who may have access to the content of your interview, as well as the person in charge of transcribing the interview, have signed a confidentiality agreement.

4. Protection of personal information in the publication of research results

The information that you provide will be used to produce a document that will be made public. Although the raw information will remain confidential, the researcher will use this information in the work submitted for publication. It is up to you to indicate the level of protection of your personal information that you would like with regard to the publication of the research results.

- **Level of confidentiality**

Option 1:

☐ **I give my consent for my name and title to be disclosed in the dissemination of the research results.**

If you check this box, the researchers can quote you from your interview and mention your name and title in any documents or research articles produced following this study. In addition, the name of your organization will be mentioned. You should not expect your anonymity to be protected in this case.

Option 2:

☐ **I give my consent for my title only to be disclosed in the dissemination of the research results.**

If you check this box, no information concerning your name will be disclosed in the dissemination of the research results. However, the name of your organization will be mentioned. It is therefore possible that someone could obtain your name by cross-referencing. Consequently, you should not expect your anonymity to be protected.

Option 3:

☐ **I do not want either my name or my title to appear in the dissemination of the research results.**

If you check this box, neither your name nor your title will be disclosed in the dissemination of the research results. However, even if the name of your company is not mentioned, it is possible that someone could obtain your name by cross-referencing. Consequently, complete protection of your anonymity cannot be assured.

- **Consent for audio recording of the interview:**

☐ **I give my consent for the researcher to make an audio recording of this interview.**

- ☐ **I do not give my consent for the researcher to make an audio recording of this interview.**

The information that you provide will be used to produce aggregated information that will be made public. Although the disaggregated information will remain confidential, the researchers and the host organization, International Civil Aviation Organization, will keep the disaggregated information internally. It is up to you to indicate whether the disaggregated information collected can remain as researcher or ICAO property.

- **<u>Consent for keeping the disaggregated information:</u>**
  - ☐ **I give my consent for the researcher to keep the disaggregated information after the research is over**
  - ☐ **I do not give my consent for the researcher to keep the disaggregated information after the research is over**

You can signify your consent either with your signature, by email or verbally at the beginning of the interview.

PARTICIPANT'S SIGNATURE:

First and last name: ____

Signature: _________________________________ Date (dd/mm/yyyy): _____________________________

RESEARCHER'S SIGNATURE:

First and last name: Yu-Heng (Andrew) Chou

Signature: __________________________________ Date (dd/mm/yyyy): ____________________________

YOU MUST SIGN THIS DOCUMENT IN THE PRESENCE OF THE RESPONDENT AND GIVE HIM/HER A SIGNED COPY.

Indicators for Vector Control Risk Model

Vector presence (A# = unique indicator identifier)

1) (A1) Is the period of the mosquito surveillance relevant to the season of their life cycle?

    a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
    b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
    c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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    d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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2) (A2) Are BG Sentinel used for surveillance purposes?

    a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
    b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
    c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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    d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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3) (A3) Is the surveillance conducted by trained personnel or contracted services?

    a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
    b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
    c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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4) (A4) Are the results of surveillance used to assess the need to implement mosquito control programs?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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5) (A5) Are the results and associated risks of vectors communicated to users of the airport?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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6) (A6) Is the region and/or airport under any vector-borne disease advisory or a WHO published list of areas where disinsection or vector control are recommended?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ____________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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7) (A7) Based on vectormap (http://vectormap.nhm.ku.edu/vectormap)

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ____________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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8) (A8) Vector characteristics – What are the vector threats in the region?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ____________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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9) *(A9) Has there been vector-borne disease outbreak or report consistent with WHO definition within the region in the last 6 months?*

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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10) (A10) Absence of vector based on history and environmental conditions for specific period under consideration?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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11) (A11) Absence of vector presence confirmed through surveillance programs

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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12) (A12) Is vector control program implemented and managed in accordance to identified need and recommendations?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)?

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c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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Departure Airport (B# = unique indicator identifier)

1) (B1) Do departing international operations included schedule passenger operations?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)?

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c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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2) (B2) Do departing international operations include cargo aircrafts?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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3) (B3) Do departing international operations include non-scheduled passenger operations?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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4) (B4) Do departing international operations include military or state operations?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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5) (B5) Does the airport provide details of approved disinsection services for aircraft?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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6) (B6) Are jetway or walkways/stairways for passenger loading closed?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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7) (B7) Are the gates/jetways/walkways/stairways equipped with mechanical disinsection capabilities?

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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8) (B8) Is mechanical disinsection equipment that can serve cargo aircrafts available?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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9) (B9) Does the departure airport use any environmental vector-controls?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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10) *(B10) What category is the departure airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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Arrival Airport or Transit Airport (C# = unique indicator identifier)

1) *(C1) Is the arrival airport able to provide minimum distance of 400m from the nearest Point of Entry (PoE) or designated parking position if arriving aircraft may be carrying possible infectious agents or vectors in reference to IHR (2005) Annex 5.1?*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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2) *(C2) Does the arrival airport use any environmental vector-controls?*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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3) *(C3) Are there alternative airports in the region if diversion is necessary as per IHR (2005) Annex 5.7?*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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4) *(C4) What category is the arrival airport's PoE vector program in reference to WHO's IHR (2005) Monitoring Framework Checklist? (Categories are <1, 1, 2, 3)*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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5) *(C5) What category is the arrival airport's "disinfection, decontamination and vector control" program in reference to WHO's IHR (2005) Monitoring Framework Checklist – Response 4 Guidelines? (Categories are <1, 1, 2, 3)*

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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6) *(C6) Is the arrival airport familiar with ICAO PANS-ATM, Doc 4444 procedures on "notification of suspected communicable diseases on board an aircraft, or other public health risk?"*

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
   c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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   d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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Aircraft Operator (D# = unique indicator identifier)

1) *(D1) Is the Operator's vector program consistent with IATA and WHO guidelines?*

   a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
   b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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2) *(D2) Is the Operator in compliance in standards and practices per WHO IHR (2005) Annex IV?*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)?

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c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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3) *(D3) Does the operator have a guideline or policy for cargo and luggage vector-control practices?*

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)?

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c. If the indicator is kept, is the wording correct? If not, enter the new wording below:

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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):

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4) (D4) Does the operator leave aircraft entry points open when airframe is parked and not in preparation for operations?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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5) (D5) Does the operator use self-closing screens for passenger entries?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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6) (D6) Does the operator use self-closing screens for cargo entries?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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7) (D7) Does the operator have personnel that monitor for the presence of insects around and within the aircraft?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
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d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
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8) (D8) Does the operator utilize residual disinsection consistent with WHO or government regulations?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge
b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________
c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
____
____
d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
____
____
____
____

9) (D9) Does the operator use maintenance facilities at the departure airport?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge

b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
____
____

d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
____
____
____
____

10) (D10) Does the maintenance facility utilize chemical or mechanical disinsection when servicing aircraft?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge

b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
____
____

d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
____
____
____
____

11) (D11) Does the maintenance facility conduct repair in a closed hangar?

a. Is the indicator relevant (Circle or Highlight Answer)? Keep… Delete… Merge

b. Compared to other indicators in the **Vector Presence Criteria**, how would you rank the importance of this indicator (1 out of 11, 1 being most important)? ___________

c. If the indicator is kept, is the wording correct? If not, enter the new wording below:
____
____

d. Further comments (rationale, measurements, consideration, interpretations, background, deletion, modification, etc.):
____

Additional Questions

If you have additional indicators that should be included in this risk assessment, please enter it below:

1) Additional question 1 and add unique identifier
   - **a.** Indicator text
   - b. Further comments (rationale, measurements, consideration, interpretations, background, etc.):

2) Additional question 2 and add unique identifier
   - **a.** Indicator text
   - b. Further comments (rationale, measurements, consideration, interpretations, background, etc.):

3) Additional question 3 and add unique identifier
   - **a.** Indicator text
   - b. Further comments (rationale, measurements, consideration, interpretations, background, etc.):

4) Additional question 4 and add unique identifier

   a. Indicator text

   ____
   ____
   ____

   b. Further comments (rationale, measurements, consideration, interpretations, background, etc.):

   ____
   ____
   ____
   ____

5) Additional question 5 and add unique identifier

   a. Indicator text

   ____
   ____
   ____

   b. Further comments (rationale, measurements, consideration, interpretations, background, etc.):

   ____
   ____
   ____
   ____

Appendix B. The complete AHP online questionnaire

Pairwise Comparison AHP-OS

Pairwise Comparison V-Risks between XXX & YYY Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *V-Risks between XXX & YYY Airport*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt *V-Risks between XXX & YYY Airport* - or B?		Equal	How much more?
1	◉ 1. Region	or ○ 2. Surveillance	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 1. Region	or ○ 3. Departure Airport	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 1. Region	or ○ 4. Arrival Airport	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 1. Region	or ○ 5. Conveyance Operators	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 2. Surveillance	or ○ 3. Departure Airport	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 2. Surveillance	or ○ 4. Arrival Airport	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ 2. Surveillance	or ○ 5. Conveyance Operators	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ 3. Departure Airport	or ○ 4. Arrival Airport	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ 3. Departure Airport	or ○ 5. Conveyance Operators	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ 4. Arrival Airport	or ○ 5. Conveyance Operators	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 1. Region

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *1. Region*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *1. Region* - or B?		Equal	How much more?
1	◉ 1.1 Vector map indicate vectors?	or ○ 1.2 Vector in-season?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 1.1 Vector map indicate vectors?	or ○ 1.3 Under Vector advisory?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 1.1 Vector map indicate vectors?	or ○ 1.4 Previous outbreak?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 1.1 Vector map indicate vectors?	or ○ 1.5 Volume of flights?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 1.1 Vector map indicate vectors?	or ○ 1.6 Sur confirms no vector?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 1.2 Vector in-season?	or ○ 1.3 Under Vector advisory?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ 1.2 Vector in-season?	or ○ 1.4 Previous outbreak?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ 1.2 Vector in-season?	or ○ 1.5 Volume of flights?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ 1.2 Vector in-season?	or ○ 1.6 Sur confirms no vector?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ 1.3 Under Vector advisory?	or ○ 1.4 Previous outbreak?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
11	◉ 1.3 Under Vector advisory?	or ○ 1.5 Volume of flights?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
12	◉ 1.3 Under Vector advisory?	or ○ 1.6 Sur confirms no vector?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
13	◉ 1.4 Previous outbreak?	or ○ 1.5 Volume of flights?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
14	◉ 1.4 Previous outbreak?	or ○ 1.6 Sur confirms no vector?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
15	◉ 1.5 Volume of flights?	or ○ 1.6 Sur confirms no vector?	◉ 1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 2. Surveillance

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *2. Surveillance*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *2. Surveillance* - or B?		Equal	How much more?
1	◉ 2.1 Approved Sur traps used?	or ○ 2.2 Sur done by pros?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	◉ 2.1 Approved Sur traps used?	or ○ 2.3 Sur results used for v-ctrl?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	◉ 2.1 Approved Sur traps used?	or ○ 2.4 S Sur results communicated?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
4	◉ 2.2 Sur done by pros?	or ○ 2.3 Sur results used for v-ctrl?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
5	◉ 2.2 Sur done by pros?	or ○ 2.4 S Sur results communicated?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	◉ 2.3 Sur results used for v-ctrl?	or ○ 2.4 S Sur results communicated?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 3. Departure Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *3. Departure Airport*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *3. Departure Airport* - or B?		Equal	How much more?
1	◉ 3.2 Provide diss. service?	or ○3.3 Jetway etc. closed?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 3.2 Provide diss. service?	or ○3.4 Jetway etc. with mechanical diss.?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 3.2 Provide diss. service?	or ○3.5 400m v-free zone?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 3.2 Provide diss. service?	or ○3.6 V-ctrl implemented?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 3.2 Provide diss. service?	or ○3.1 Have intl/non-endemic ops?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 3.3 Jetway etc. closed?	or ○3.4 Jetway etc. with mechanical diss.?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
7	◉ 3.3 Jetway etc. closed?	or ○3.5 400m v-free zone?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
8	◉ 3.3 Jetway etc. closed?	or ○3.6 V-ctrl implemented?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
9	◉ 3.3 Jetway etc. closed?	or ○3.1 Have intl/non-endemic ops?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
10	◉ 3.4 Jetway etc. with mechanical diss.?	or ○3.5 400m v-free zone?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
11	◉ 3.4 Jetway etc. with mechanical diss.?	or ○3.6 V-ctrl implemented?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
12	◉ 3.4 Jetway etc. with mechanical diss.?	or ○3.1 Have intl/non-endemic ops?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
13	◉ 3.5 400m v-free zone?	or ○3.6 V-ctrl implemented?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
14	◉ 3.5 400m v-free zone?	or ○3.1 Have intl/non-endemic ops?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
15	◉ 3.6 V-ctrl implemented?	or ○3.1 Have intl/non-endemic ops?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 3.1 Have intl/non-endemic ops?

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *3.1 Have intl/non-endemic ops?*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *3.1 Have intl/non-endemic ops?* - or B?		Equal	How much more?
1	◉ 3.1.1 Scheduled	or ○3.1.2 Cargo	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 3.1.1 Scheduled	or ○3.1.3 Non-scheduled	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 3.1.1 Scheduled	or ○3.1.4 Govt Mil	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 3.1.2 Cargo	or ○3.1.3 Non-scheduled	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 3.1.2 Cargo	or ○3.1.4 Govt Mil	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 3.1.3 Non-scheduled	or ○3.1.4 Govt Mil	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 4. Arrival Airport

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *4. Arrival Airport*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *4. Arrival Airport* - or B?			Equal	How much more?
1	◉ 4.1 >400M distance from PoE?	or	○4.2 V-ctrl implemented?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
2	◉ 4.1 >400M distance from PoE?	or	○4.3 Diversion airport avail?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
3	◉ 4.1 >400M distance from PoE?	or	○4.4 JEE PoE score?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
4	◉ 4.2 V-ctrl implemented?	or	○4.3 Diversion airport avail?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
5	◉ 4.2 V-ctrl implemented?	or	○4.4 JEE PoE score?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9
6	◉ 4.3 Diversion airport avail?	or	○4.4 JEE PoE score?	◉1	○2 ○3 ○4 ○5 ○6 ○7 ○8 ○9

CR = 0% Please start pairwise comparison

Check Consistency

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 5. Conveyance Operators

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *5. Conveyance Operators*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *5. Conveyance Operators* - or B?		Equal	How much more?
1	◉ 5.1 Use residual diss.?	or ○ 5.2 Cargo/luggage vector ctrl?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	◉ 5.1 Use residual diss.?	or ○ 5.3 Door closed when not-in-use?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	◉ 5.1 Use residual diss.?	or ○ 5.4 Screens for passenger door?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
4	◉ 5.1 Use residual diss.?	or ○ 5.5 Use MX at dep. airport?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
5	◉ 5.2 Cargo/luggage vector ctrl?	or ○ 5.3 Door closed when not-in-use?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	◉ 5.2 Cargo/luggage vector ctrl?	or ○ 5.4 Screens for passenger door?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
7	◉ 5.2 Cargo/luggage vector ctrl?	or ○ 5.5 Use MX at dep. airport?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
8	◉ 5.3 Door closed when not-in-use?	or ○ 5.4 Screens for passenger door?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
9	◉ 5.3 Door closed when not-in-use?	or ○ 5.5 Use MX at dep. airport?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
10	◉ 5.4 Screens for passenger door?	or ○ 5.5 Use MX at dep. airport?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
CR = 0% Please start pairwise comparison				
Check Consistency				

Pairwise Comparison AHP-OS

V-Risks between XXX & YYY Airport: Pairwise Comparison 5.5 Use MX at dep. airport?

Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *5.5 Use MX at dep. airport?*, which criterion is more important, and how much more on a scale 1 to 9 for V-Risks between XXX & YYY Airport?

	A - wrt *5.5 Use MX at dep. airport?* - or B?		Equal	How much more?
1	◉ 5.5.1 Dissection during MX?	or ○ 5.5.2 Repair A/C in closed hangar?	◉ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
CR = 0% Please start pairwise comparison				
Check Consistency				