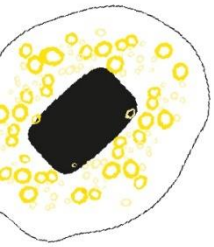
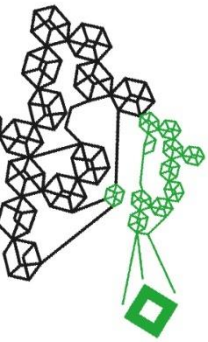
UNIVERSITY OF TWENTE.

Faculty of Science and Technology
Health Sciences



Infectious disease vulnerability assessment of points of entry

Ilse J.M. Fransen, s1762354
MSc Thesis, September 2020



Supervisors UT
Dr. S. Amer, dr. J.A. van Til
Dr.ir. P.W.M. Augustijn

External supervisor
Doret de Rooij
RIVM (LCI)
JA Healthy Gateway Consortium

Abstract

Background: Increased global connectivity enables diseases to spread across the globe in a short period of time. Points of Entry (PoE) – entrances locations of a country – have an important role in the international spread of infectious diseases. To manage the international spread of infectious diseases, the International Health Regulations (IHR) were established. Participating countries of the IHR obliged to introduce specific measures, including measures for PoE. These measures are meant to diminish the impact of infectious diseases on an international scale, but do not guide countries on which PoE to target. Several countries have not yet implemented the measures and outbreaks of diseases have taken place since then. The vulnerable PoE and emerging diseases are of concern for diminishing the international spread of infectious diseases. Vulnerabilities in this study are split into introduction and transmission characteristics. We define introduction of infectious disease as an infectious disease being introduced in a new area. We define transmission of infectious disease as the transmission of infectious diseases between people, animals or goods during travel. With additional information on the vulnerabilities of a PoE, countries can target the PoE accordingly and subsequently minimize the international spread of infectious diseases. Therefore, this study focusses on identifying and weighting PoE characteristics that influence the international spread of infectious diseases.

To assess the goal of this study a MCDA method is used. The study consisted of three phases: 1; literature study, 2; expert elicitation, 3; evaluation. In phase 1 scientific studies regarding PoE characteristics that influence the international spread of infectious diseases were reviewed. Resulting in a set of seven PoE characteristics which were discussed in phase 2 in a panel of experts to determine the usability and levels of these PoE characteristics. Phase 2 resulted in eight final PoE characteristics, separated into four characteristics about introduction into area and four characteristics about transmission during travel. These PoE characteristics were valued in an online questionnaire using the PAPRIKA method to determine their weight. In phase 3 the outcomes from the online questionnaire were analyzed. In total 20 respondents started the questionnaire and 14 were included in the study (airport; n=6, port; n=4. Ground crossing; n=4). For airports, the characteristic '*Travelers from risk areas*' was valued as most important, with '*Contact between local community and travelers*' as the least important. When assessing the concordance between respondents, only airports reached almost 0.5, indicating moderate agreement among experts. Regarding the international spread of infectious diseases, the characteristics in the introduction combination are valued as most influencing the international spread. Experts on ports valued '*Type of conveyance*' as most influencing the vulnerability and experts on ground crossings valued '*Type of imported cargo*' as most important. The concordance between respondents for ports and ground crossings was around 0.2, indicating a low level of agreement. Therefore, the reliability of the outcome is low.

Conclusion: This study evaluated the PoE characteristics of importance for the international spread of infectious disease at PoE. An important future step for this study will be to involve more experts in the questionnaire and provide clearer information to the respondents regarding the non-involvement of the preparedness of a PoE in this study. Our results already provide more insight into what describes vulnerability of PoE to infectious diseases. If we succeed in assessing and integrating expert's opinions on this topic, we create insights into the vulnerability of our PoE.

Table of Contents

Abstract 2
1. Introduction 4
2. Method and results 6
MCDA and PAPRIKA 6
Phase 1: Literature study 7
Phase 2: Expert elicitation 10
Phase 3: Evaluation 14
Method 14
Results 15
3. Discussion 21
4. References 26
Appendix A Search strategy 29
Appendix B Data extraction 36
Appendix C Preliminary list of characteristics and information for panel 39
Appendix D Suggestions panel airports 53
Appendix E: suggestions panel ports 57
Appendix F: suggestions panel ground-crossings 61
Appendix G: suggestions panel 65
Appendix H: Respondents 68
Appendix I: Final characteristics and levels 69

1. Introduction

Infectious diseases are spreading more rapidly, due to humans, animals and goods travelling more often and over greater distances (1). The increased global connection enables diseases to spread across the globe in a short period of time (2, 3), as is shown by the recent COVID-19 outbreak (4) (5). Between January 2020 and September 2020, the COVID-19 outbreak resulted in more than 27 million confirmed cases worldwide, including over 4.5 million cases in Europe (6). Points of entry (PoE) – meaning the locations where a country can be entered such as airports, ports and ground crossings – play an important role in the spread of infectious diseases. At these locations, potentially infected people can enter a country. Additionally, travelers from different places in the world could infect others before, during and after travel. In Europe, the connectivity between countries is even higher, as the borders between European countries are open due to the Schengen agreement (7). This possibility for unrestricted travel of people and goods allows the unguarded spreading of infectious diseases within Europe. Europe is also shown as one of the hotspots where the highest concentrations of emerging infectious diseases have been found (8). The combination of unrestricted traveling and emerging hotspots makes Europe particularly vulnerable to the spread of infectious disease.

To manage the global control of the international spread of diseases, the International Health Regulations (IHR) were established in 1969 and last revised in 2005 (9). With the IHR, 196 countries have committed to strengthening the response to serious cross-border health threats. The implementation of the IHR is supported by the World Health Organization (WHO), which establishes continued collaboration between countries to maintain and improve their national preparedness plans and requirements at PoE (5). The countries that signed the IHR are obliged to introduce measures to minimize the spread of health risk to other countries. These measures address countries in general and core capacity requirements for PoE in particular. The general measures are that countries should ensure strong national structures and sufficient resources. Countries should also have the ability to detect infectious disease events, enforce control measures to prevent international spread, and they should maintain an up-to-date national health emergency plan (9). Regarding the specific core capacities of PoE, each country should designate at least one port and one airport that have the core capacities implemented (10). Examples of core capacity requirements at designated PoE are the capability to promptly assess and care for ill travelers at the PoE location, access to medical equipment, access to personnel for transport, and the ability to ensure a safe environment for travelers (9).

These core capacities are meant to diminish the impact of infectious diseases on an international scale, but do not guide countries on which PoE they have to focus. Furthermore, at the end of 2015, only 65 countries had met all core capacity criteria (11, 12). This leaves them particularly vulnerable to possible spread of infectious diseases. In addition to the previous, since the implementation of IHR several outbreaks, epidemics and pandemics have been declared public health emergencies of international concern (8, 13, 14). The combination of vulnerable PoE and the increase of emerging infectious diseases are a risk to diminish the international spread of infectious diseases. Currently, information regarding specific vulnerabilities at PoE is not available. Indexes exist that indicate the vulnerability of a country or region (13, 14), and major projects, such as AIRSAN (15), SHIPSAN (16) and JA Healthy Gateways (17), have been performed to prepare PoE for health risk outbreaks. However, these indexes and projects have not yet shown the vulnerability of a PoE and, as a result, the contribution of that PoE to the spread of infectious diseases is unknown.

With additional information on the vulnerabilities of a PoE, countries can choose the PoE accordingly and subsequently minimize the international spread of infectious diseases. Vulnerability of a PoE depends on multiple factors and can be defined by a weakness area where you are exposed or at risk (18). Vulnerabilities can be assessed in terms of risk of introduction and risk of transmission of a disease. We define introduction of infectious disease as an infectious disease being introduced in a new area (19). We define transmission of infectious disease as the transmission of infectious diseases between people, animals or goods during travel (20). Introduction is a new disease entering a country or area. Via introduction at the PoE, its passengers and the country can be exposed to (new) infectious diseases. Exposure can also occur via transmission. Transmission of diseases occur after introduction of a disease in a country has happened via incoming, infected people, animals or goods (21). In this way, preventing both the introduction and transmission of infectious diseases are relevant for minimizing the international spread.

Besides the increased connectivity and mobility of population resulting in more easy introduction of infectious diseases, an introduction can also occur due to climate change, which results in the expansion of the geographical distribution of (vector-borne) diseases (22). Vectors are living organisms that can transmit infectious pathogens between humans, or from animals to humans (23). Transmission of infectious diseases during travel occurs more frequently with the increased (short term) travel across countries through passengers that became infected before or during the journey (24). Besides the introduction and transmission of infectious diseases via travelers and vectors, cargo facilitates the movement of pathogens across the globe (25). The combination of different 'PoE characteristics' and the 'level of exposure' to this PoE characteristic creates a different vulnerability for every PoE.

Knowledge of the PoE characteristics and their influence on the vulnerability of PoE regarding the international spread of infectious diseases is scarce. Additional information, especially for the particularly vulnerable countries in Europe, would be of great value to gaining knowledge and in counteracting this spread at PoE. Therefore, this study aims 1) to identify PoE characteristics that define vulnerability to international spreading of infectious diseases either via 'introduction in an area', or 'transmission during travel', 2) to subcategorize these 'PoE characteristics' further into 'levels of exposure' that lead to either a higher or lower vulnerability, and 3) to assess relative importance of these PoE characteristics regarding their influence on the vulnerability of PoE regarding the international spread of infectious disease. The research question of this study is:

Which characteristics affect the vulnerability of PoE (ports, airports and ground-crossings) the most regarding the international spread of infectious diseases?

- Which PoE characteristics influence the vulnerability of points of entry regarding international infectious disease spread?
- How can the 'levels of exposure' for these PoE characteristics be defined?
- To what extend is the vulnerability to international spreading of infectious diseases defined by the introduction of disease in areas and/or the transmission of diseases among international traveler?
- How does the vulnerability to the international spreading of infectious diseases differ for ports, airports and ground crossings?

2. Method and results

To answer the research questions, a multi-criteria decision analysis (MCDA) is used to help systematically weight the PoE characteristics. According to Marsh et al. (26) a MCDA requires eight steps: defining the problem selecting and structuring criteria, measuring performance, scoring alternatives, weighting criteria, calculating aggregate scores, dealing with uncertainty, and reporting of finding. We performed these eight steps in the following three phases (figure 1). First, a literature study was conducted, which resulted in a preliminary list of PoE characteristics. Secondly, experts were consulted in a panel to provide input on the found PoE characteristics, resulting in the reformulation of the PoE characteristics. The reformulated PoE characteristics were subsequently used in an online questionnaire in which experts where asked to rank PoE characteristics (in a pairwise way). Thirdly, an evaluation of the data was done. Per phase the method and results will be presented below.

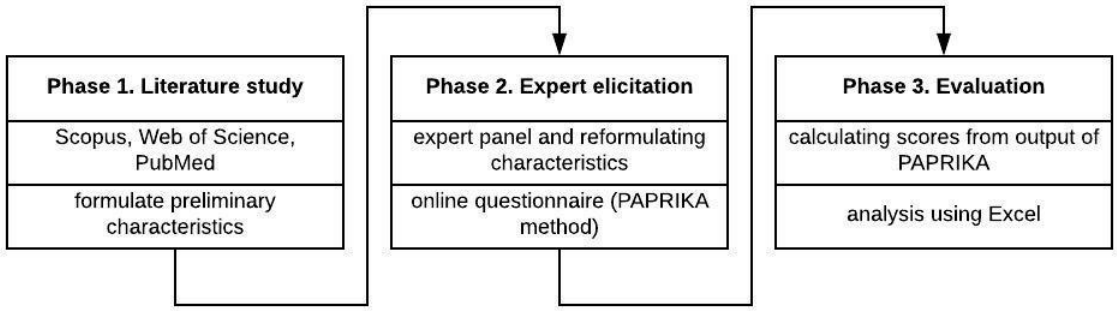


Figure 1. Development and validation of PoE characteristics influencing international spread of infectious diseases via points of entry

MCDA and PAPRIKA

MCDA is a methodology increasingly used in health care and public health with positive contributions to decision making and choosing preferred alternatives (26, 27). This method can help decision makers evaluate alternatives in the context of considering multiple characteristics simultaneously (28). This method can be used in a broader range as well. As is the case in this study where it is used to evaluate the weights of the PoE characteristics and rank and subsequently identify the most vulnerable characteristics. The use of MCDA results in a explicit and structured evaluation of multiple characteristics (29). The characteristics in MCDA can be based upon literature and this information can be complemented with expert knowledge in a structured manner (24). Expert knowledge is crucial in the field of infectious diseases at PoE, because of the lack of available information regarding PoE characteristics. The result from the input of experts in MCDA show weight per characteristics, indicating the relative importance of the characteristics (26). Combining these weights results in a score for the alternatives, indicating the aggregate score of a set of characteristics (26).

Within MCDA, several methods can be used to determine weights of the PoE characteristics. These scores are translated to performance measures, such as 0 to 100 scale or zero to one scale and show the strength of preference for characteristics (26). Within MCDA two main categories can be indicated: compositional and decompositional (26). With decompositonal methods the combined weights for characteristics are derived simultaneously, whereas in compositional methods the scoring and weighting takes place seperately. Subdivision within

these two categories are choice-based (decompositional method) and ranking, direct rating, pairwise comparison, swing weighting and scoring functions (all compositional methods). In this study we are restricted to a scoring method useful for a few respondents because experts in the field of infectious diseases at PoE are scarce. Furthermore, we are interested to assign a weight to the characteristics and provide a low cognitive burden to the respondents. This resulted in the choice for the Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) method.

The method used in this study is more related to the natural habit of people to choose between two alternatives compared to rating or scaling the characteristics as used in other weight-elicitation technique, such as AHP (30-32).

The PAPRIKA method is a choice based method where respondents have to choose between two combinations of characteristics (33). Within these characteristics different levels are assigned to provide a scale. This method helps to indicate relevant characteristics and the relative importance attached to it and the alternatives (30-32). A choice-based method is less of a cognitive burden and a more natural choice compared to other methods, because an ordinal judgment is used (31-34). Weights can be assigned to the characteristics without explicitly ask the respondents to assign the weight (34). Furthermore, the software of PAPRIKA (1000minds.com) also supports the reduction of questions by transitivity which results in a lower burden for the respondents (33). Also, an explicit trade-off might increase the level of precision since it shows the true trade-off value from the expert, compared to rating methods which tend to generate more similar weights among characteristics (26). Lastly, PAPRIKA provides a low chance of bias due to the complex approach, but requires more resources and use of software is necessary (34).

Functioning of PAPRIKA

PAPRIKA involves the respondent make a trade-off between potentially all undominated pairs of all alternatives available (35). The scores are based upon a higher or lower ranking within the characteristics. The number of pairs to be explicitly ranked is minimized by identifying and eliminating all pairs implicitly ranked as corollaries by transitivity of the additive value models, which are a result of the explicitly ranked pairs. Transitivity occurs when characteristic A is connected to B, and B to C, A and C also are connected and therefore the combination does not have to occur in the questionnaire (33). From the indifferences and strict preferences related to the characteristics, relative scores are obtained via linear programming (35). Also, the relative scores obtained per characteristic reflect the relative importance and summed up provide a total score for the alternatives.

The amount of indifferences and the order in which characteristics are presented can influence the amount of choice-tasks the respondent is presented with. (35) In case of choosing indifference will result in less explicitly ranked pairs compared to strict preference in characteristics. Indifferent ranking generates more corollaries. In case of the order of presentation of the levels of exposure, this depends on the ranking itself. However, the ranking is not yet known prior to the choice-task.

Phase 1: Literature study

A literature study was done to identify PoE characteristics that influence the vulnerability of PoE worldwide. The search was conducted in Scopus, Web of Science, and PubMed in March and April 2020. Also, grey literature was searched from the websites of WHO, ECDC, and Healthy Gateways. The search strategy contained the following terms: infectious disease,

points of entry, vulnerability, and synonyms or terms related to these words. Also, several diseases that were epidemic or endemic were included in the search strategy. A broad search strategy was chosen to find all relevant articles on the topic. Separate searches were performed for airports, ports, and ground-crossings. The period covered in this search was from January 2005 until April 2020. As the IHR was revised in 2005, which boosted the attention of research and practice on preventing the international spread of diseases, we expected the majority of relevant information for this study to be available after 2005. The results of the searches were combined and duplicates deleted. More detailed information on the search strategy can be found in Appendix A.

The search in the databases resulted in 817 unique studies (figure 2), Additionally, nine studies were found in grey literature. First, titles and abstracts were screened, using the following criteria. Studies were included that contained synonyms of vulnerability and infectious diseases or contained point of entry or synonyms of airport, port, and ground crossings or any related words to one of these. Studies that focused on chemical or vector-borne diseases, illegal transport of goods and animals, and the vaccination status at the population were excluded. Articles without an abstract were screened full text.

Secondly, the selected articles (*n=110*) were screened full text for eligibility, using the following criteria. We included articles focusing on the introduction into an area of infectious diseases at PoE which indicates PoE characteristics that influence the vulnerability of PoE. Articles were excluded if they did not contain a relevant PoE characteristic. Articles related to vessels and preparedness were considered irrelevant when determining the general PoE characteristics of the introduction into an area of the infectious diseases at PoE and were therefore also excluded. This strategy resulted in 16 included articles. Thirdly, the 16 included articles were screened on relevant articles in the references, resulting in four additional studies for full-text screening. After the full-text screening, two of these four were included.

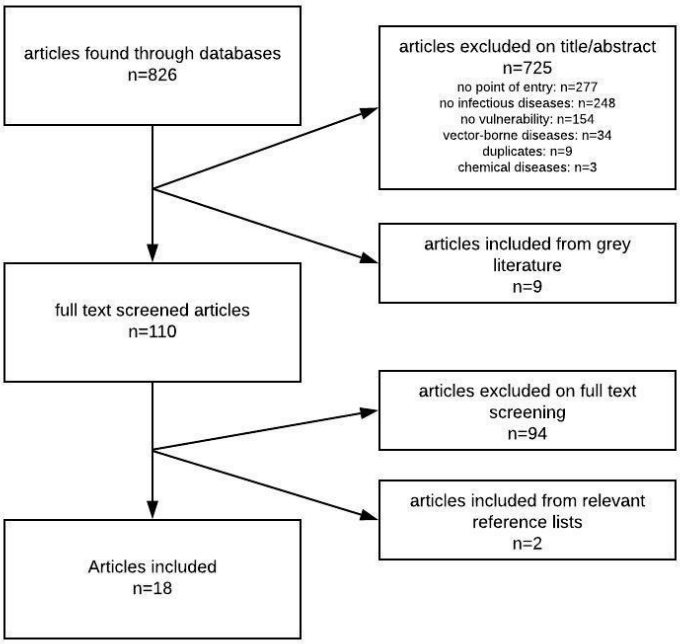


Figure 2. Literatures search and selection strategy

Regarding both title/abstract screening and full-text screening, the first 10% were independently done by two researchers. After the screening, results were compared, and disagreements were discussed until consensus was reached. This was done to make sure the search would be reproducible, and the selection of the articles was consistent among researchers. The other 90% was screened by one researcher. Subsequently, paragraphs describing a possible PoE characteristic were extracted and collected in a data collection sheet (appendix B).

To extract defined PoE characteristics from these paragraphs, the following steps were performed. First, the pieces of text were marked as containing a possible PoE characteristic. Secondly, these texts where given a topic name, such as vaccination status, risk areas and volume of travelers and resulted in combined topics. These topics were used in the PoE characteristics of the literature study. The identified PoE characteristics were discussed between two researchers until consensus was reached. A result of this discussion was to combine the close contact and duration of journey topics for the PoE characteristics, due to overlap. In literature, the close contact was mentioned in relation to seat proximity and duration of the journey and therefore the two topics are not sufficiently independent mentioned to be separate PoE characteristics. This resulted in seven PoE characteristics (figure 3): '*Travelers from endemic areas*' *(number of studies mentioning PoE characteristic*; *n=8*), '*Vaccination status of travelers*' (*n=5*), '*Volume of travelers*' (*n=5*), '*Climate*' (*n=2*), '*Duration of the journey*' (*n=2*), '*Different conveyances at PoE*' (*n=2*) and '*Trade via PoE*' (*n=2*).

Characteristic	Description	Levels
travelers from endemic areas	travelers from geographic areas where other infectious disease are endemic than in the country of origin	0: few travelers from areas with different endemic diseases 1: many direct travelers from areas with different endemic diseases
vaccination status of traveler	travelers' vaccination status	0: high percentage of travelers is vaccinated 1: low precentage of travelers is vaccinated
volume of travelers	the average volume of travelers at the PoE per year	0: low amount of travelers for your PoE 1: high amount of travelers for your PoE
climate	the local climate at the PoE location	0: oceanic 1: mediterranean
duration of the journey	the duration of the travelers' journey	0: a lot short distance travelers 1: a lot of long distance travelers
conveyances at PoE	types of conveyance at PoE	0: ferries, cars 1: cruise ships, trains
trade via PoE	type of cargo between countries	0: the marjority of the cargo involves treated and non-biological goods 1: the majority of the cargo involves live stock and biological goods

Figure 3. preliminary list of PoE characteristics and levels of exposure (0=low vulnerability, 1=high vulnerability)

Each PoE characteristic has two levels of exposure that indicate a low and high vulnerability of the PoE (e.g., '*Volume of travelers*' can be a low number of travelers at PoE and a high number of travelers at a PoE). Where possible, the levels of exposure for each PoE characteristic were based on the literature. First, several articles showed that a high vaccination status of the population decreases the risk of the spread of infectious diseases (33-35). Secondly, a high volume of travelers was indicated as a vulnerability for the international spread of infectious diseases. Browne et al. indicated that high passenger throughput enhances opportunities for infectious disease to spread (36). In addition to the previous, compared to 2003, the amount of air passengers in China has quadrupled (37). Thirdly, literature also showed that travelers from risk areas indicate a higher vulnerability. Lawyer et al. showed in their study that the development of a pandemic is strongly related to the connectivity of the seed location (38). This is substantiated by the information from WHO which showed that flights from risk areas are of risk for importation of viruses (39). Fourthly, Semenza et al. mention that climate is one of the top drivers for infectious disease threats and dry, warm climates can increase the spread (40). Fifthly, long duration of journey of long distance seat proximity indicates a higher risk of spread of infectious diseases (36). Sixthly, literature mentioned ferries posing a higher risk of legionella diseases compared to cruise ships (41). However, passenger ships are mentioned as more at risk for spread of infectious diseases and importation of diseases at PoE and travel and tourism is one of the main drivers for infectious disease threats (39, 42). Lastly, global trade is mostly associated with infectious disease threats in Europe (61% of the threats) (42). Especially, contact with live animals can be of risk for spreading infectious diseases (43).

If levels of exposure could not be formulated directly from literature, the levels of exposure were stated as low or high amounts or percentages compared to the average found in literature (e.g., the average amount of travelers at a given PoE). The information from literature was documented separately for airports, ports, and ground-crossings and combined in one overview document.

Phase 2: Expert elicitation

In the following phase, first, the preliminary PoE characteristics formulated in phase 1 were discussed with nine experts on infectious diseases at PoE. The panel aimed to assess the practical relevance of the PoE characteristics, to indicate their completeness, and to determine the missing information of the levels of exposure.

Study population panel

The experts involved in phase two were all validated or put forward by the JA healthy gateways consortium, consisting of international experts in the field of international spread of infectious diseases operating at national or international level. The aim of the consortium is to support cooperation and coordinated action to improve the preparedness and response capacities at points PoE (17). The consortium consists of several work packages of which three focus specifically on airports, ports or ground-crossings respectively (17). Contact was sought via e-mail and meetings took place via telephone or Skype.

Procedure

We contacted the JA Healthy Gateways work package leaders of the airports, ports and ground crossings (n=3) and experts they recommended (n=6). All nine accepted to participate. All

participants received an overview of the PoE characteristics and levels of exposure extracted from literature prior to the meeting. During the meeting, we first discussed the objective of the study, followed by a discussion of the PoE characteristics. Experts were asked to deliver input based on their experience of the stated PoE characteristics and their levels of exposure. They were asked if they recognize the PoE characteristics from their experience or knowledge, if they associated the PoE characteristics with vulnerability for the international spread of infectious diseases, and if any PoE characteristics were missing. The first three meetings focused on the specific type of PoE- airport, port, ground crossing. We expected that the experts would only be able to provide input on their specific PoE. However, their knowledge clearly extended beyond their specific type of PoE, whereupon subsequent meetings focused on all types of PoE. Each meeting started with a brief explanation of the study and the goal of the meeting. Followed by requesting general suggestions regarding the PoE characteristics. Next, each PoE characteristic was discussed individually: suggestions for levels of exposure were requested and considerations (e.g. is duration of journey an introduction into an area PoE characteristic, is having a connection with a risk area a vulnerability) were discussed. After each meeting, suggestions were added to the document to provide new topics of discussion in the following meetings. Appendix C provides an overview of the document provided to the panel.

After all meetings, input from the experts was compared. In case overlap in comments existed, the suggestions were adopted and additional literature was searched to substantiate the suggestions. The final adjusted document was sent to the participants to confirm their suggestions and these of subsequent participants.

Outcome

The input from the nine experts resulted in the final PoE characteristics (figure 4). Changes of the PoE characteristics derived from Phase 2 compared to those from Phase 1 can be summarized as follows. First, '*Vaccination status*' and '*Local climate*' were removed, because '*Vaccination status'* cannot be controlled or known by the PoE. The local climate mainly affects the survival of vectors, such as mosquitoes, and is therefore outside the scope of this study. Second, the levels of exposure of the PoE characteristic '*Travelers from endemic areas*' were changed. Instead of 'low and high number of travelers from risk areas', they were formulated as having a connection or not to an endemic area. Experts stated that having a connection to an endemic area is a risk on itself and therefore having a connection is already a vulnerability. Third, the levels of exposure of '*Cargo*' were changed into '*Non-biological goods*', '*Biological goods*' and '*Livestock*'. Fourth, the experts suggested that '*Type of conveyances*' is not relevant for airports, because there are not many recreational flights and clear start and end points of the journey. Lastly, suggestions were made to add PoE characteristics. The panel suggested to separate the transit passengers from the passengers entering the country. A layover is a risk to develop and transmit a disease. This is different from introducing the disease at the PoE from travelers entering the country.

Furthermore, '*Transit passengers*' are not relevant for ports, because there is not a clear separation between the two PoE characteristics: '*Volume of travelers*' and '*Transit passengers'*. Whereas '*Volume of travelers*' indicates the amount of travelers per month entering the country and '*Transit passengers*' the amount of transit hours passengers spend per month at the PoE. Passengers from ships mostly enter the country when arriving at the port, even just for a short time and this is taken into account with volume of travelers which is defined by the amount of passengers entering the country. Therefore, '*Transit passengers*' is

added as a PoE characteristic for airports and ground crossings. Also, '*Density of population at PoE*' and '*Contact between local community and travelers at PoE*' were added as a separate PoE characteristics based on the suggestions from the panel. Population density at PoE, so close proximity to others in certain areas, is a risk for international spread of infectious diseases. Appendix D, E, F and G provide an extensive overview of the suggestions made by the panel and a summary of their suggestions.

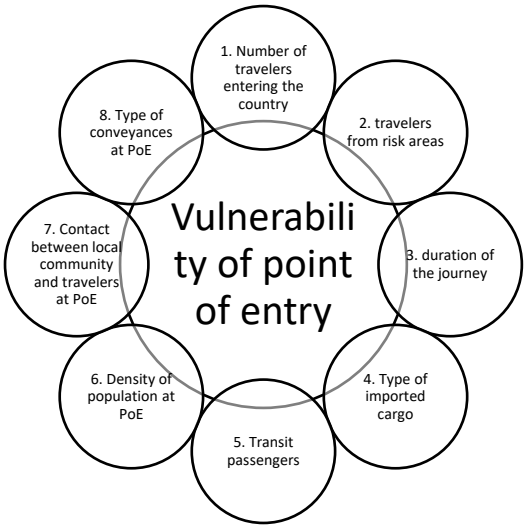


Figure 4. Final PoE characteristics: detailed description and levels of exposure in Appendix G.

As an addition to the previous paragraph we intended to only investigate PoE characteristics that influence the vulnerability of PoE regarding the introduction of infectious diseases into an area. However, the panel pointed out the relevance of the transmission during travel PoE characteristics. Transmission during travel PoE characteristics are important to formalize a complete value of the vulnerability of PoE. Based on these suggestions, both the introduction into an area and transmission during travel PoE characteristics were considered and PoE characteristics were allocated among them (figure 5). We appointed as PoE characteristics of introduction into an area: '*Number of travelers entering the country*', '*Travelers from risk areas*', '*Type of imported cargo*', '*Type of conveyances*'. We appointed as PoE characteristics of transmission during travel: '*Duration of the journey*', '*Transit passengers*', '*Population density at PoE*', '*Contact between local community and travelers'*. Some PoE characteristics could have been placed in both categories but we, then, chose the most important one based

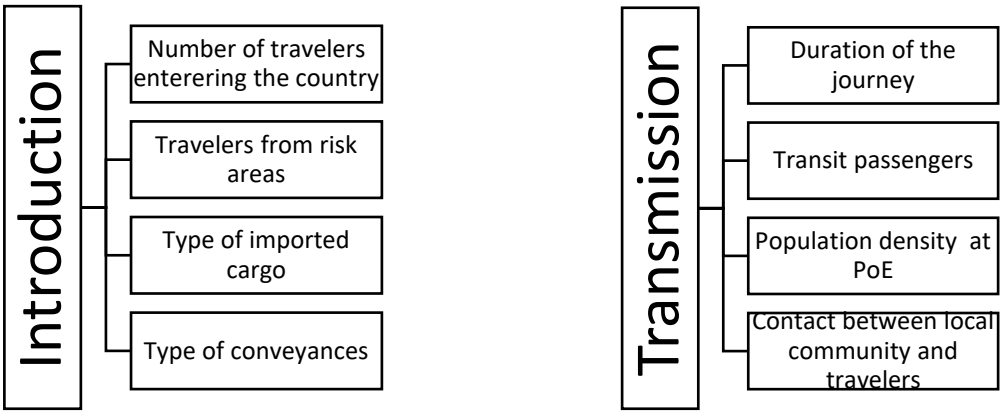


Figure 5. PoE characteristics in relation to either the introduction into an area or transmission during travel of infectious diseases

the expert's input. For example, the '*Duration of the journey*' is both a risk for introduction into an area – more time spend on board leads to a higher chance an infectious disease reveals, as for transmission during travel. However, '*Duration of the journey*' increases the possibility to develop and transmit the disease and is therefore more relevant to the transmission of infectious diseases during travel. The same is true for '*Contact between local community and travelers*'. This PoE characteristic could be an introduction into an area PoE characteristic – the infectious disease can set foot in the country. However, by the panel it was pointed out as a transmission during travel PoE characteristic, due to the possibility for the local community to spread the disease at the PoE.

The final PoE characteristics based on the expert panel (*figure 4; more detailed description and levels of exposure in appendix I*) concentrated exclusively on the PoE characteristics defining vulnerability to the international spread - both introduction into an area and transmission during travel - of infectious diseases at PoE and these PoE characteristics' feasibility for assessing at a PoE.

Study population online questionnaire

The sample consisted of public health experts at PoE on national and international level, who were selected in correspondence with the work package leaders of the JA Healthy Gateways.

Questionnaire design

After identification of the PoE characteristics and levels of exposure, we aimed to assign weights to the different PoE characteristics using the PAPRIKA method with 1000minds software (*1000minds.com*). For the method, the PoE characteristics and levels of exposure identified previously were used in a questionnaire with hypothetical scenarios for a PoE (figure 6). Separate questionnaires were conducted for airports, ports and ground crossings, because each PoE had differences between PoE characteristics and levels of exposure influencing their vulnerability. First, the respondents received information regarding the objective and aims in an attachment and in the questionnaire of 1000minds. Also, the indication of time, 30 minutes, was mentioned before entering the questionnaire. Second, demographic questions (e.g. country they are employed, years of experience) were asked, followed by the choice task. Respondents were asked to make a number of trade-offs based on their expert knowledge with the following question in mind: *Which of these two PoE is more vulnerable for the international spread of infectious disease?*. The option to value them as equal was also available. Afterwards, the respondents were asked to fill out their feeling of competence to fill out the questionnaire with their expert knowledge on a scale of one to ten and the possibility was provided to make suggestions per PoE characteristics and in general. The questionnaires were available until 16th of July and reminders were sent once to all the respondents which to our knowledge did not finalizing the questionnaire.

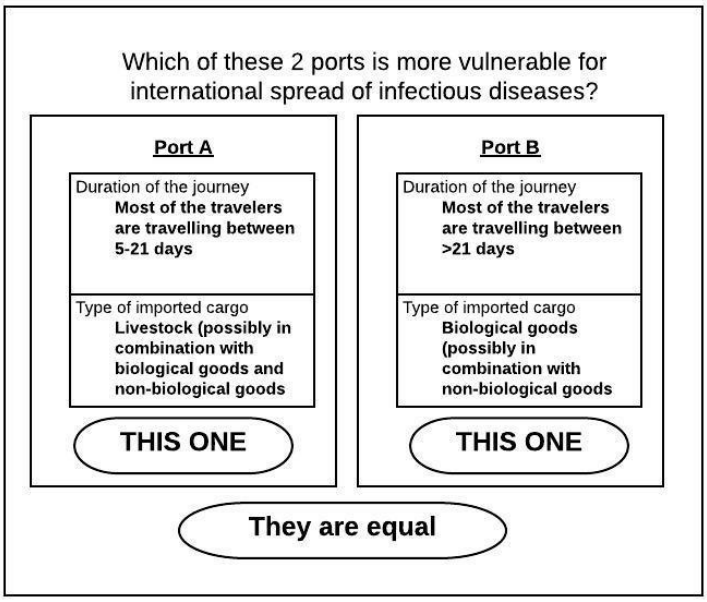


Figure 6. Example PAPRIKA question (1000minds.com)

Phase 3: Evaluation

In this phase, the data from the online questionnaire is analyzed. First, the methods of analysis will be explained and, secondly, the results of the analysis will be presented.

Method

PoE characteristics and levels of exposure

The outcome of the questionnaire presents the PoE characteristics with the associated weights between zero and one per respondent and the mean weights of all respondents per questionnaire. The weights per respondent sum to one. The highest score presented the PoE characteristic that influences the vulnerability of points of entry the most regarding the international spread of infectious diseases. An overall ranking of the characteristics is also an outcome of the 1000minds.com questionnaire.

In addition to the previous, the slope of the PoE characteristics with three or more levels of exposure was visualized. In case the angle of the slope deviates from the scope could indicate that the value between the three (or more) levels of exposure is not equally divided from low to high vulnerability. Furthermore, the overall value of the introduction into an area and transmission during travel combination is calculated. This is done by summing up the scores assigned by the PoE characteristics related to introduction into an area and transmission during travel combinations.

To assess if there is overlap in the outcome of the comparable PoE characteristics between airport, port and ground crossing, the ranking of the outcomes is compared between the PoE. In this case, the results from the PoE characteristics is not isolated, because in the method all the PoE characteristics are compared to each other, thwarting absolute scores that can be

compared. Therefore, the average of the position in the ranking of the PoE characteristics is calculated to assess which PoE characteristics score the highest overall.

Agreement among experts

To assess if the answers of the experts are consistent to each other, the level of agreement among the experts was assessed with the Kendall's coefficient of concordance W (Kendal & Smith, 1939):

$$W = \frac{12S}{m^2(n^3 - n)} \quad (1)$$

In equation (1), n criteria are ranked by m respondents and S stand for the sum of squares of deviations. If W equals 1, there is absolute consensus across the respondents. A high consensus among experts will provide more value to the assigned weights of the characteristics.

Sample

In total 35 experts respondents were contacted to participate in the questionnaire and a total of 20 experts started the questionnaires during June and July 2020. Fourteen respondents finalized the questionnaire and were included in the study *(airport; n= 6, port; n=4 , ground crossing; n=4).* Six respondents were excluded, because they did not meet the consistency check (*n=2*) or answered the questionnaire with a median of two seconds per answer (*n=1*) or did not finalize the survey (*n=3*). The consistency check and time frame were reasons to exclude, because this indicated the respondent was not consistent in choice of PoE characteristics or answered the questions too fast. An overview of respondents can be found in appendix H.

Each person answered, on average, approximately 28 pairwise ranking questions (*ground n=27.5; airport n=28.7; port n=27.7*) with an average time of 29.7 seconds per choice (*ground n=35.1; airport n=30.0; port n=24.0*). The software derived the individual's relative weights for the criteria.

Results

Airports

The mean relative importance of PoE characteristics per group of experts can be found in figure 7. Weights ranged from 0.03 to 0.30 In general, all respondents indicated that '*Travelers from risk areas*' (0.23) was the PoE characteristic influencing the vulnerability of an airport the most. All respondents scored '*Contact between local community and travelers*' (0.05) with the lowest weight, indicating that this does not influence the vulnerability of the airport much. '*Duration of the journey*' has been valued by most respondents with a relative importance of 0.2 or more. However, one respondent valued this PoE characteristic with 0.02, which influences the mean of the PoE characteristic (0.18). The same accounts for '*Number of travelers entering the country*'. Most experts value the PoE characteristic 0.2 or higher, however, one respondent values it with 0.04. This results in a mean of 0.17 for the PoE characteristic. This can indicate that some experts have different knowledge or experience with these PoE characteristics and therefore value this different compared to other experts. Between experts who value their competence as high and low, not much consistency can be seen (*figure 7*). Showing that between experts feeling of high competence and low competence there is no

difference in valuing the PoE characteristics with other scores. Among the six experts, the coefficient of concordance was 0.47, which suggests that there is some level of agreement.

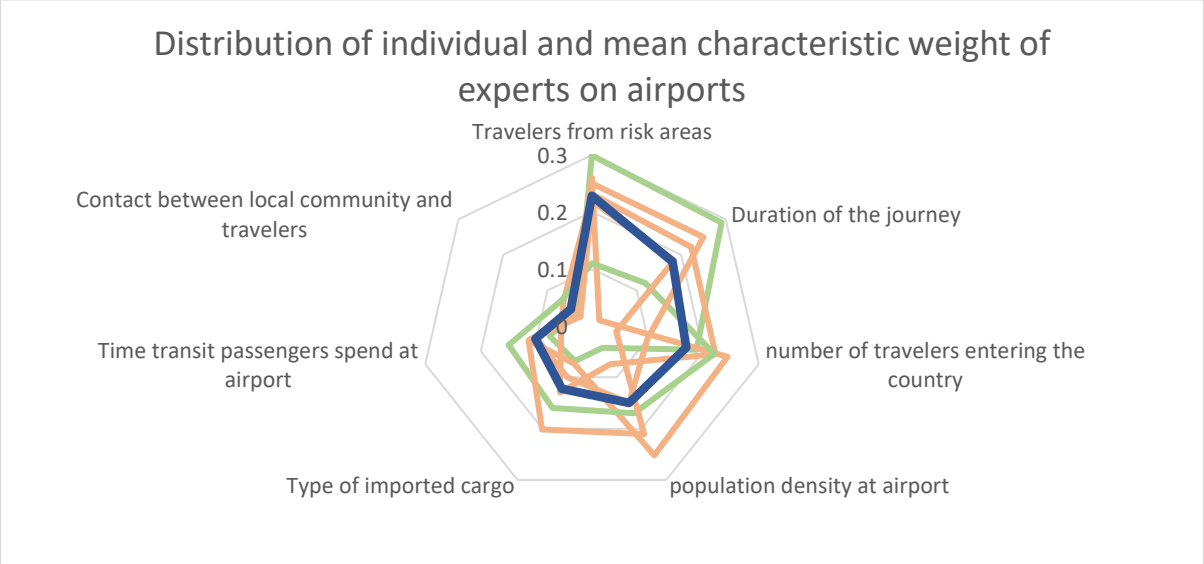


Figure 7. Relative weight of PoE characteristics from six experts at airports, shown by self-assessed competence: green is high feeling of competence (score >8), orange is low feeling of competence (score <8). Blue indicates the mean relative weight provided by the experts.

1. Levels of exposure

For two PoE characteristics, '*Time transit passengers spend at airport*' and '*Duration of the journey*', the slope of the line does not deviate from the scope. Interesting is the slope of '*Type of imported cargo*' which becomes steeper. This could indicate that the experts assign a higher value to the higher levels of exposure ('*livestock possibly in combination with (non-)biological goods*') of vulnerability within the PoE characteristic. Furthermore, the slope of '*Number of travelers entering the country*' decreases. This could indicate that at some point the influence of more travelers entering the country reduces according to experts.

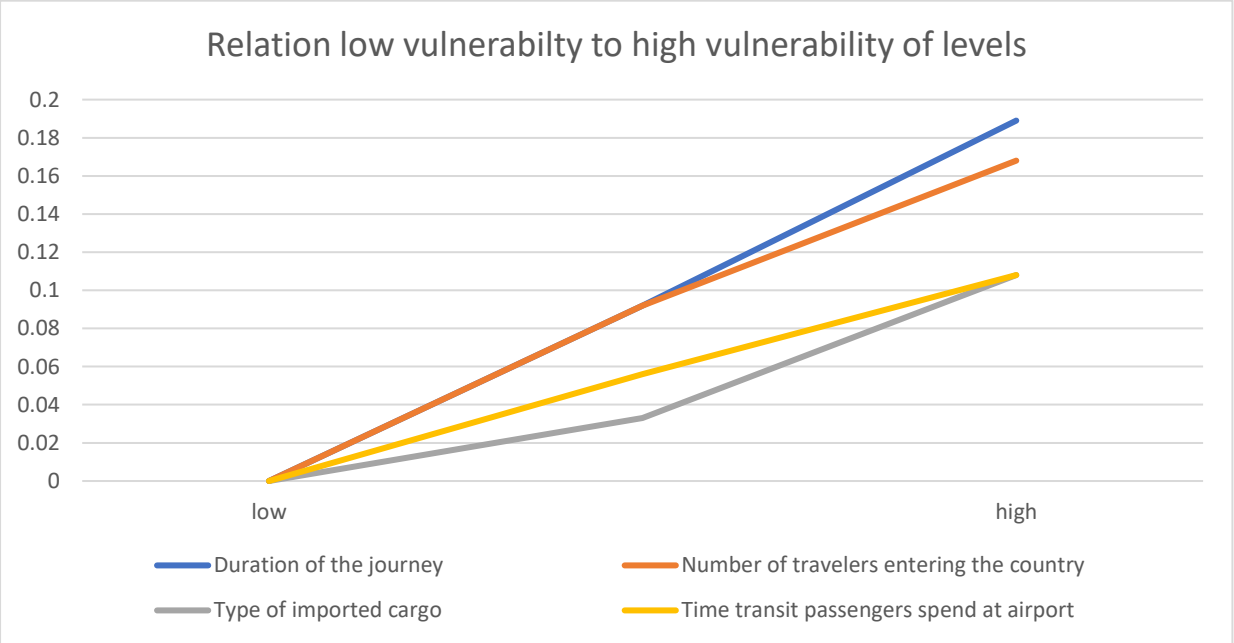


Figure 8. Increase of relative weights from the levels of exposure from low vulnerable PoE characteristics to high vulnerable PoE characteristics

1. *Introduction into an area and transmission during travel*

When comparing the combined characteristics of introduction into an area PoE and transmission during travel PoE characteristics, evaluating the weights of the introduction into an area and transmission during travel PoE characteristics combined, the introduction into an area PoE characteristics are more important for the international spread of infectious diseases than the transmission during travel (*figure 9*). This result is especially influenced by the combined importance of '*Travelers from risk areas*' and '*Number of travelers entering the country*', which contribute almost 0.4 out of one to the overall weight. Within the transmission during travel combination, the '*Density of population at airport*' and '*Type of imported cargo*' influence the overall value the most with almost 0.35. Showing that some PoE characteristics can have a strong influence on the overall value.

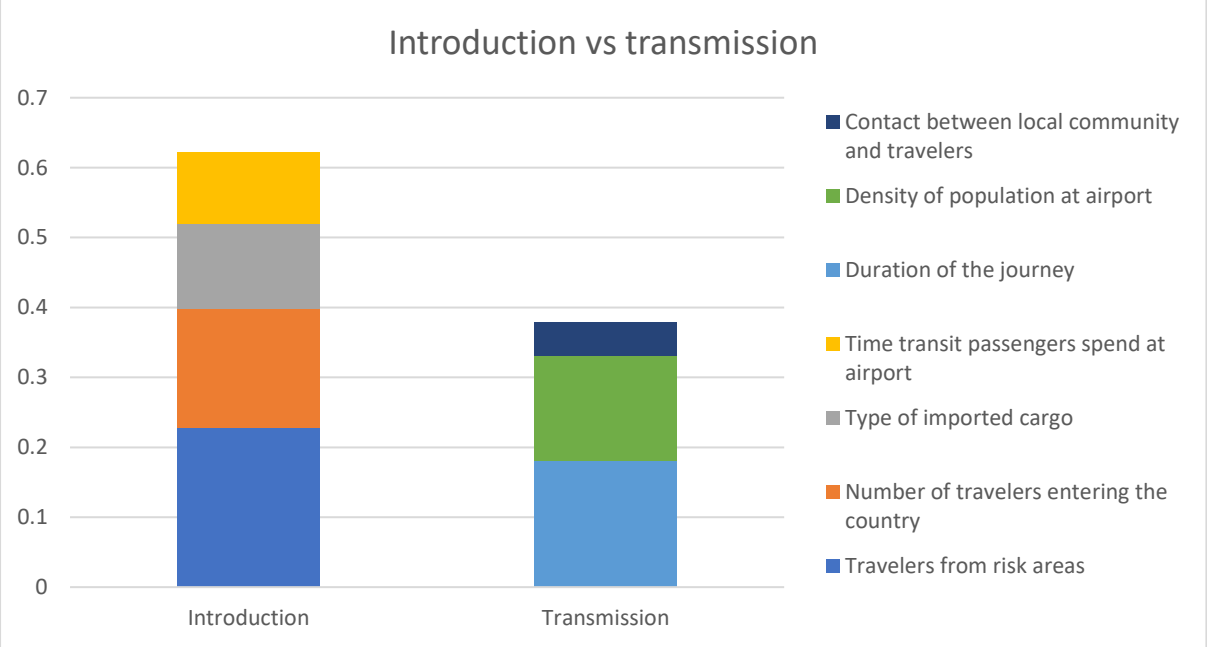


Figure 9. Overall value, sum of the relative importance of introduction into an area and transmission during travel for airports

Ports

The mean relative importance of the experts representing ports can be found in figure 10. Scores ranged from 0.03 to 0.27. In general, '*Type of conveyance*' was indicated as the PoE characteristics influencing the vulnerability of ports the most. Furthermore, all experts scored '*Contact between local community and travelers*' with the lowest average weight, indicating that this influences the vulnerability of ports the least, according to the experts. '*Type of conveyances*' is valued by most experts with an importance of 0.2 or higher, however, one respondent valued the PoE characteristics with 0.03. This influences the mean of the PoE characteristic (0.18). In addition to the previous, the value of the PoE characteristic '*Duration of the journey*' is divided. The upper values for this PoE characteristic are 0.18 and 0.27 and the lower values 0.04 and 0.02, leaving a mean of 0.13. This can indicate that some experts have different knowledge or experience with these PoE characteristics leading to different values. Among the four expert respondents, the coefficient of concordance was 0.20, which

suggests that the level of agreement is relatively low. Between experts who value their competence as high and low, not much consistency can be seen. Showing that experts that feel competent and less competent have value PoE characteristics with the same weights. Due to the low number of respondents and the low concordance of the respondents regarding the PoE characteristics, the analysis between levels of exposure and the comparison of introduction into an area and transmission during travel was not performed.

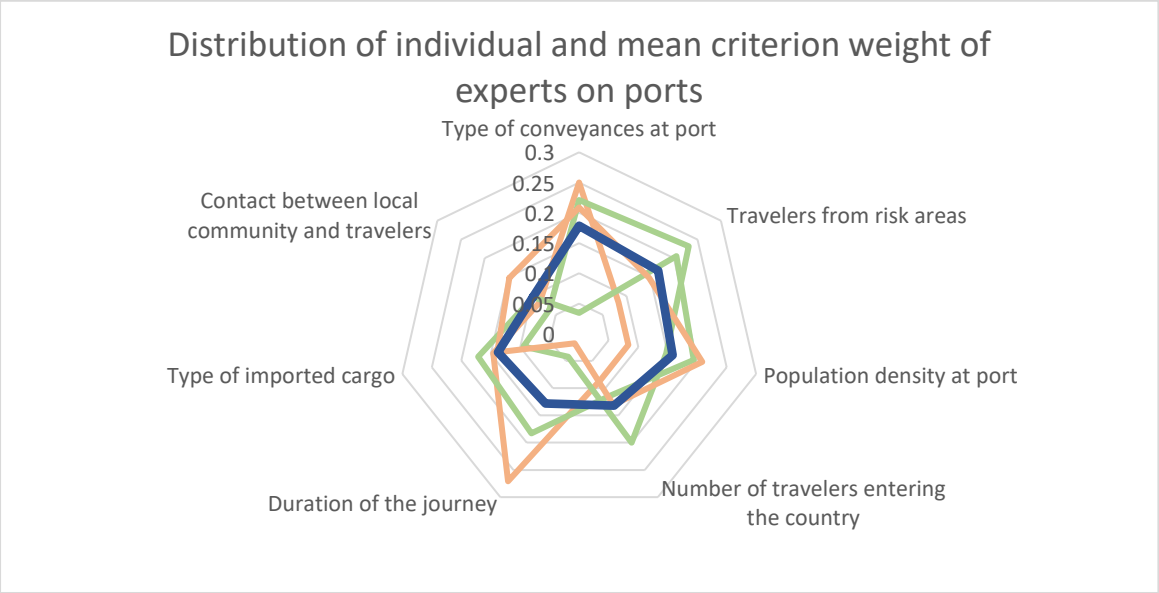


Figure 10. Relative weight of PoE characteristics from six experts at airports, shown by self-assessed competence: green is high feeling of competence (score >8), orange is low feeling of competence (score <8). Blue indicates the mean relative weight provided by the experts.

Ground crossings

The mean relative importance of experts representing the ground crossings can be found in figure 11. Scores ranged from 0.04 to 0.23. In general, '*Type of imported cargo*' was indicated as the PoE characteristics influencing the vulnerability of ground crossings the most. Furthermore, all respondents scored '*Time transit passengers spend at ground crossing*' with a lowest average weight (0.09), indicating that this PoE characteristic has the least influence on the vulnerability of ground crossings. However, '*Contact between local community and travelers*' is also valued by experts with a mean of 0.09. Most of the experts value the PoE characteristic with 0.07 or lower. One respondent valued the PoE characteristic with 0.21, which influences the mean of the PoE characteristic. This could indicate that the expert had different knowledge or experience with the PoE characteristics compared to other experts. Among the four expert respondents, the coefficient of concordance was 0.21, which suggests that the level of agreement is relatively low. Due to the low number of respondents and the low concordance of the respondents regarding the PoE characteristics, the analysis between levels of exposure and the comparison of introduction into an area and transmission during travel is not performed.

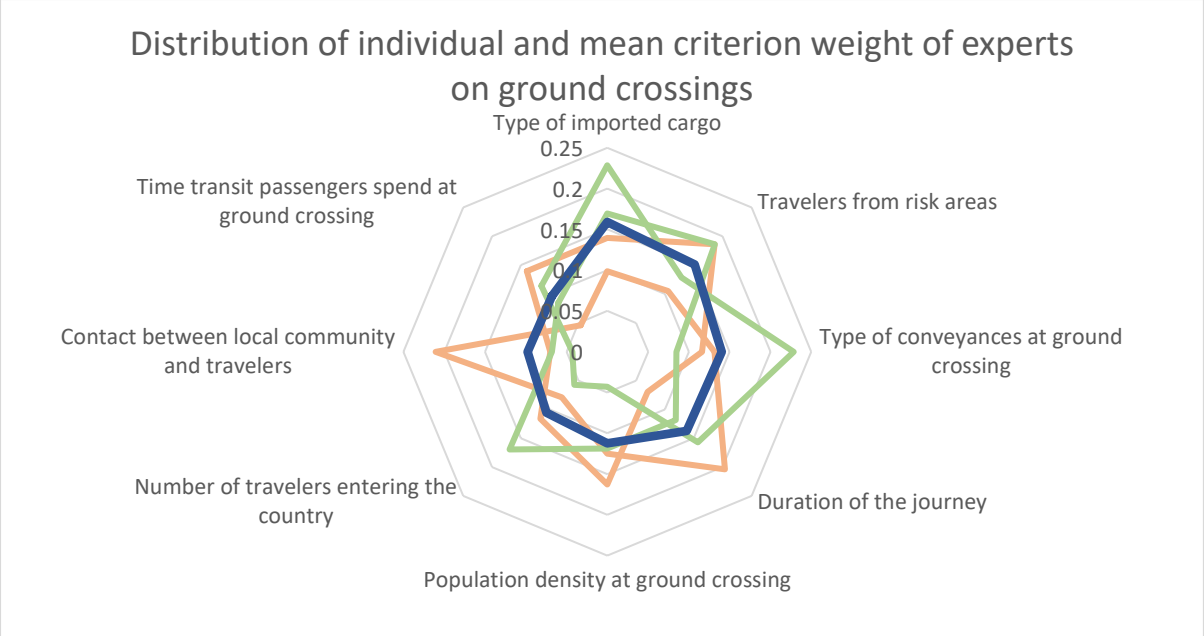


Figure 11. Relative weight of PoE characteristics from six experts at airports, shown by self-assessed competence: green is high feeling of competence (score >8), orange is low feeling of competence (score <8). Blue indicates the mean relative weight provided by the experts.

Comparing between PoE

When comparing the ranking of the PoE characteristics based on the relative weight, the characteristic 'travelers from risk areas' is rated as the most important for all the PoE (*average rank: 1,67*) as shown in table 1. Overall, contact between local community and travelers is ranked lowest for all the PoE, indicating that this PoE characteristic is least relevant regarding the vulnerability of the PoE. For the other PoE characteristics, there is a variety between the ranking of different PoE regarding the importance of the PoE characteristic, ranging from position 1 to 5 within one PoE characteristic (table 1). This shows the importance of separating the different PoE when evaluating the vulnerability of the PoE.

Table 1. Ranking of the PoE characteristics and average overall ranking based on expert input

PoE characteristics	**Ground**	**Airport**	**Port**	**Average**	**Overall Ranking**
Travelers from risk areas	2	1	2	1,67	**1**
Type of imported cargo	1	5	4	3,33	**2**
Duration of the journey	4	2	6	4	**3**
Density of population at PoE	5	4	3	4	**3**
Number of travelers entering the country	6	3	5	4,67	**5**
Contact between local community and travelers	7	7	7	7	**6**
Type of conveyances	3		1	2	
Time transit passengers spend at PoE	8	6		7	

Suggestions from respondents

All specific suggestions or comments are presented in table 2. None of the suggestions were made by more than one expert but summarizing there is one overlapping topic: focus more on contact between people and movement of people instead of a time related levels of exposure.

Table 2. Quotes of suggestions from experts regarding the questionnaire

Topic	Suggestion
Missing PoE characteristics	Airport *"mobility of passengers at airport and mixture of passenger flows: do they need to cross the whole airport"* "*Enough space per passenger to keep distance to other passengers"* Ground crossing "*rate of vaccination"*
Comment regarding duration of the journey	Ground crossing *"amount of interaction the travelers may have with others"*
Comment regarding type of imported cargo	Airport *"kind of and amount of livestock and biological goods is also important"*
Comment regarding transit passengers	Airport *"The time itself is not the most important thing. Infectious diseases are being transferred during the contact between people"*
Comment regarding contact with local population	Airport Questionable if this happens: "*Airside part is never available to people who are not travelling and doubt the use of landside facilities*"
Comment regarding type of conveyances	Ground *"Smaller conveyances makes me think of more informal movement and elevated risk. Truckers make me think of long distance movement and connectivity with more outbreak areas."*
General comments	Port "*Mingling on board – hard to capture -Eating, entertainment, cabins, crew sharing etc"*

3. Discussion

A MCDA involving a small selection of Europe's experts on infectious diseases at PoE was performed to identify the main PoE characteristics which were based on literature influencing the vulnerability of PoE regarding the international spread of infectious disease. First, literature was searched to identify PoE characteristics. Secondly, the PoE characteristics were discussed with experts resulting in the final PoE characteristics. These characteristics were evaluated by experts in an online questionnaire which resulted in weights per characteristic and introduction and transmission combinations. Lastly, the results from the questionnaire were evaluated. We identified eight PoE characteristics of which '*Travelers from risk areas*' pose the highest vulnerability for international spread of infectious disease, followed by '*Type of imported cargo*'. The '*Contact between local community and travelers*' was seen as the PoE characteristic least defining the vulnerability. Each of these PoE characteristics were subdivided into two or three levels of exposure, further defining a low or high vulnerability per PoE characteristic. Interesting was the high weight attributed to the transport of '*livestock*' to the vulnerability of airports. Characteristics differed among ports, airports and ground-crossings, as did the weight that could be attributed to overlapping PoE characteristics. The results of this study provide insight in the PoE characteristics influencing the vulnerability of PoE regarding the international spread of infectious diseases and can be of importance to countries assessing their most vulnerable PoE. Knowing what defines the vulnerability may also guide preparations to avert these characteristics. As a result, this can contribute to the prevention of the international spread of infectious diseases.

Relevance

This is not the first study focusing on the vulnerability to infectious diseases. Several existing indexes were identified from literature which already indicate the vulnerable countries and regions (13, 14). The Infectious Disease Vulnerability Index (IVFI), for example, identified factors influencing vulnerability of infectious disease outbreaks from literature and organized them into seven broad domains: demographic, health care, public health, disease dynamics, political-domestic, political-international and economic. However, these factors are determined based on the country's factors and no differentiation in vulnerable entry spots of the country is determined. Furthermore, the INFORM Risk Index is a global, open-source risk assessment for humanitarian crises and disasters. It can support decisions about prevention, preparedness, and response. A sub-part of the Risk Index is the Epidemic Risk Index, which is the implementation of the Epidemic Risk Index (ERI) into a quantitative model for the INFORM Global Risk Index (13). Both indexes utilize a broad quantity of characteristics influencing the risk of for infectious diseases outbreak but focus on the PoE and their influence on the international spread of infectious diseases is not present. Besides, vulnerability for both indexes is a part of the risk, because except vulnerability they also consider the hazard, exposure, and lack of coping capacity. In contrast to these indexes, this study used a separation between airports, ports and ground crossings with partly new PoE characteristics and levels of exposure. In both indexes the focus was on broader characteristics influencing the whole country without a focus on PoE.

All PoE characteristics in this study were pointed out by literature or the expert panel as important for the international spread of infectious diseases via PoE. However, three PoE characteristics were pointed out as most important per PoE. The results of the online questionnaire show that 'travelers from risk areas' was evaluated as most important. Many

other studies and international sources (37-39) show that connectivity with other countries is one of the PoE characteristics that indicates the international spread of infectious diseases. Human mobility is associated with the spread of infectious diseases. The increased travel and transportation networks provides more opportunities for the spread of pathogens to remote location (44). In daily practice, travelers from risk areas cannot be prevented as the free travel and trade across the world is of great value (9). However, during an outbreak, decision-makers could adapt to this knowledge by imposing travel restrictions. Banning travelers from risk areas can delay the epidemic peak up to two weeks and slow pandemic growth (45).

Furthermore, the results show that several PoE characteristics are of importance to PoE, but they differ greatly in terms of relative importance. This difference can be accounted for by the lack of convincing evidence and, therefore, the value of the PoE characteristics is not merely based on evidence, but also on experts' experience, which can differ among experts. According to the experts on ports, the type of conveyances define vulnerability the most for ports. This is supported by literature. Ships can transport infected humans and vectors between ports, and therefore act as a mean by which infections can be transmitted internationally (46, 47). Humans from different geographical origins gather on cruise ships for (many) days and then divide to multiple locations. Cruise ships may also pick up new passengers from different places who join the cruise. Besides, shore excursion can be responsible for some of the outbreaks. Introducing infectious diseases in a new area is therefore easy by ship.

Experts on ground crossings valued the type of imported cargo as the characteristics most of influence on the vulnerability of ground crossings. Besides connectivity of the trade and travelers, zoonoses should not be forgotten. Emerging infectious disease (EID) events in Europe are dominated by zoonoses (60.3% of the EIDs) (8). In the Netherlands, one strong reason to reduce uncertainty regarding future livestock import is the risk of importing animal diseases into the Netherlands (48). As an addition to the previous example, in Saudi Arabia travelers are requested to not come in contact with the animals in the country (43). These examples and the dominance of zoonoses in Europe substantiate the importance of imported cargo as a PoE characteristic defining vulnerability.

Alternative explanations of the finding

Travelers from risk areas was one of the PoE characteristics put forward in the literature study the most and was valued by experts as most important PoE characteristic. Because not much literature is available, it could be that experts relate the most familiar PoE characteristic as most important. Since travelers from risk areas is most mentioned in (grey) literature this could influence the familiar PoE characteristics, but it can also be due to personal experiences. In case a characteristic becomes familiar, preference towards certain characteristics can develop. According to the mere-exposure effect, preference is not more than 'I like tat' and not only based on knowledge. People tend to develop a preference for things merely because they are familiar with them (49).

Also, the description of the PoE characteristics was presented to the respondents and, therefore, we suspect that everyone interpreted the PoE characteristics the same. However, the interpretation can still be subjective and therefore respondents could imagine a specific scenario or relate the situation to COVID-19, as some respondents mentioned in their suggestions afterwards. This could indicate that respondents interpreted or expanded the description of the PoE characteristic.

Method

A potential limitation of this technique could have been the large number of comparisons required. However, in this study, the participants had on average 28 trade-offs with on average around 30 seconds per trade-off and no suggestions were made afterwards to shorten the questionnaire or indicated that the questionnaire was too long. Interesting would be to evaluate if experts who feel less competent have to answer more questions. In case more questions are needed, this could mean respondents were less concise in the trade-offs.

Furthermore, the same participants from the panel in Phase 2 were invited for the online questionnaire. In the first panel meeting, the suggestion was made to put the easy discussible subjects first in the document. Volume of travelers and travelers from endemic areas was indicated as easy discussable. This could also have biased the participants of the panel in their response to the questionnaire, because of the mere-exposure effect. However, it is not possible to differentiate between the results of the panel members and other experts, because the questionnaire is anonymized. Also, there was overlap between experts in the study and questionnaire sample. This could have influenced the interpretation of the characteristics from experts participating in the panel. Furthermore, a general limitation of methods with subjective interpretation from experts can lead to biases, such as overconfidence and personal experiences (50).

Besides the choice of method, some remarks on the analysis of the data can be made. First, we first intended to only assess the weights per PoE. Eventually, also the interest to evaluate the overall score for all PoE arose and therefore we investigated the rankings of the characteristics. With this method we weren't able to calculate the scores between the different questionnaires, because of the relative importance within the questionnaire. In future research it could be of interest to assess the overall importance separately. Furthermore, the questionnaire provided the relative scores per characteristic and therefore no other calculations could be made from the outcomes of the questionnaire.

Strengths and Limitations

This study knows several strengths and limitations. First, we see as a strength the literature that is reviewed to find the preliminary list of PoE characteristics. Even though not many articles eventually were included, the comprehensive search tried to cover all available literature on PoE characteristics influencing the vulnerability of infectious diseases. The low number of included studies shows that not many studies are available that indicate PoE characteristics of influence on the international spread of infectious diseases at PoE. We studied why, then, such a broad first selection of studies was found. First, it became clear that 'point of entry' also is used as a place in which a medical instrument or disease enters into the body. Also, many studies focused on specific animals such as harbor seals, non-communicable diseases, studies just mentioning traveling from PoE towards another location in the country, and in studies a vehicle was defined differently. This resulted in a large group of studies to be reviewed. The two studies included via reference lists mentioned travel and tourism and not an airport, port or ground-crossing and were therefore missed in the primary search. However, we believe most of the available literature has been found with this strategy.

A second strength of this study is the critical evaluation of the members included in the panel and online questionnaire. The number of experts in this field is very small. We succeeded in including the leading experts in the field of infectious diseases at PoE in Europe, which resulted

in helpful insight for the development of the PoE characteristics and levels of exposure. Although, the subjective interpretations of the researchers, which were required due to limit in available knowledge from literature, are a limitation of the study, the chance on bias was kept to a minimum. In all phases and at decision moments, two or more researchers were involved.

We faced several challenges leading to study limitations. First, the qualitative nature of the study and the uncertainties in the trade-off analysis made it difficult to deduce quantifiable claims about the magnitude of the impact of the PoE characteristics on the vulnerability. However, not much information is yet available, thus a quantifiable method would not be feasible. Also, the concordance between the experts for ports and ground crossings was very low, indicating that there is not much consistency between the experts regarding the vulnerability of the PoE characteristics. This can be caused by an unclear explanation towards the respondents, but also because respondents have experienced other infectious disease threats and therefore developed a different view on the influence of the PoE characteristic on the vulnerability. The main point of improvement is to involve more respondents. However, including respondents was very challenging due to the COVID-19 crisis and the limited time and energy respondents had to spend on research. This was mentioned by several experts in Phase 2. We consider, therefore, the possibility to continue with the study already a positive outcome.

Furthermore, due to the amount of, and concordance between respondents, the airports are the only results we can make statements about. For future research, an improvement could be to ask respondents to forward the questionnaire to colleagues. However, this could pose the risk of not including the real experts on this topic. Also, respondents pointed out in the remark section of the questionnaire suggestions relevant to the preparedness and COVID-19, indicating that the goal of the study was not clear. Even though the goal of the study was mentioned both in the attachment to the invitation and at the start of the questionnaire, this was still insufficient. Lastly, two out of four PoE characteristics showed almost no deviation of the slope of the levels of exposure. This could indicate that the levels of exposure of the PoE characteristics are divided equal within the PoE characteristics. However, it could also indicate that respondents were not able to value the levels of exposure individually and only assumed that a levels of exposure with a less amount would indicate more vulnerability.

Suggestions for future research

Future research should focus on more in-depth interviews with experts. This could provide more insight in, possibly, other PoE characteristics of relevance that are not available in the literature yet. The current study has identified multiple PoE characteristics that relate to the international spread of infectious diseases via PoE regarding the introduction into an area and transmission during travel of the PoE characteristics, but not all these criteria were included in the final set of criteria. The most important reason was, because the panel indicated that they were not relevant to the current situation. Also, even with the amount of literature searched, the final number of included articles was low, indicating that not much information is yet available.

In further research, the above-mentioned ERI could be used to define the combinations of PoE characteristics: hazard assessment, context assessment and exposure assessment (51). Here, hazard assessment can be defined as the identification of a hazard or hazards causing event and of the associated adverse health effects. A distinction between biological, vector and chemical can be made here. Exposure assessment can be evaluated by the exposure of individuals and

population to possible hazards (number of people exposed or susceptible). Context assessment is the evaluation of the environment in which the event is taking place. This assesment can be physical environment (climate, vegetation, land use), as well as health of the population and infrastructure. With this additional information, a tool could be developed that matches existing indexes to assess the vulnerability of a PoE. This tool can be used by countries or infectious disease control at PoE to evaluate the vulnerability of a specific PoE. However, literature regarding vector-borne diseases and chemical diseases needs to be evaluated first.

Conclusions

Concluding, this study has evaluated the PoE characteristics of importance for the international spread of infectious disease at PoE. The PoE characteristics suggest that the '*Travelers from risk areas*' pose the highest vulnerability PoE characteristic overall and the introduction into an area group of characteristics was evaluated as most important for the international spread of infectious disease for airports. An important next step for this study will be to involve more experts in the questionnaires and provide clearer information to the respondents regarding the non-involvement of the preparedness of a PoE in this study. Our results already provide more insight into what defines vulnerability of PoE to infectious diseases. If we succeed in combining the experts on this topic, we create even more insight into our most vulnerable PoE. Integrating this knowledge is important on our way to the prevention of societal disruption and lost lives from pandemics, such as COVID-19, as we are pityingly witnessing today.

4. References

1. Findlater ABI. Human Mobility and the Global Spread of Infectious Diseases: A Focus on Air Travel. Cellpress. 2018;34(9):772-83.
2. Tatem AJ, Rogers, D.J., Hay, S.I. Global transport networks and infectious disease spread. Advances in Parasitology. 2006;62:293-343.
3. Tatem AJ. Mapping population and pathogen movements. International Health. 2014;6(1):5-11.
4. Who. Coronavirus disease 2019 (COVID-19) Situation Report – 43. In: Who, editor. WHO. who.int2020.
5. Who. Coronavirus disease (COVID-19): European Region focusing on readiness WHO: WHO; 2020 [updated 14-02-2020. Available from: http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/2/coronavirus-disease-covid-19-european-region-focusing-on-readiness.
6. WHO. WHO Coronavirus Disease (COVID-19) Dashboard covid19.who.int2020 [Available from: https://covid19.who.int/.
7. Commission E. Migration and Home Affairs: Schengen Area ec.europa.eu: EC 2020 [Available from: https://ec.europa.eu/home-affairs/what-we-do/policies/borders-and-visas/schengen_en.
8. Jones K, Patel, N., Levy, M., Storeygards, A., Balk, D., Gittleman, J., Daszak, P. Global trends in emerging infectious diseases. Nature. 2008;451:990-3.
9. Who. International health regulations (2005). WHO website: WHO; 2016.
10. Who. Points of entry: IHR, Annex 1b and relevant articles who.int: WHO; 2020 [Available from: http://www.euro.who.int/en/health-topics/health-emergencies/international-health-regulations/points-of-entry/points-of-entry.
11. Who. Implementation of the International Health Regulations (2005). who.int; 2016 13-05-2016.
12. Who. IHR core capacities implementation status: Points of entry who.int: WHO; 2018 [Available from: https://www.who.int/gho/ihr/monitoring/points_of_entry/en/.
13. Poljansek K, Marin-Ferrer, M., Vernaccini, L., Messina, L. Incorporating epidemics risk in the INFORM Global Risk Index. Luxembourg: Publications Office of the European Union; 2018. Contract No.: ISBN 978 92 79 98669 7.
14. Moore M, Gelfeld, B., Adeyemi, O., Paul, C. Indentifying future disease hot spots: infectious disease vulnerability index. Santa Monica, Californie: RAND Corporation; 2016. Contract No.: ISBN: 978-0-8330-9574-9.
15. AIRSAN. AIRSAN: about the project http://www.airsan.eu/AboutTheProject.aspx2020 [Available from: http://www.airsan.eu/AboutTheProject.aspx.
16. SHIPSAN. EU Shipsan ACT Joint Action shipsan.eu2020 [Available from: http://www.airsan.eu/AboutTheProject.aspx.
17. Gateways EH. EU Healthy Gateways healthygateways.eu2020 [Available from: https://www.healthygateways.eu/.
18. yourdictinonary. Vulnerability yourdictionary.com2020 [Available from: https://www.yourdictionary.com/vulnerability.
19. Dictionary. Introduction dictionary.com2020 [Available from: https://www.dictionary.com/browse/introduction.
20. CDC. Section 10: Chain of infection. Principles of Epidemiology in Public Health Practice. third ed. CDC2012.

21. Cdc. Section 10: chain of infection cdc.gov: CDC; 2012 [Available from: https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html.
22. McMichael AJ. Human frontiers, environments, and disease: past patterns, uncertain futurs. Cambridge University Press. 2001.
23. WHO. Vector-borne diseases who.int2020 [Available from: https://www.who.int/news-room/fact-sheets/detail/vector-borne-diseases.
24. Wilson ME. Travel and the emergence of infectious diseases. Emerging Infectious Diseases. 1995;1:39-46.
25. Aron JL, Patz, J.A. Ecosystems change and public health: a global perspective. John Hopins University Press. 2001.
26. Marsh K, et al. Multiple Criteria Decision Analysis for Health Care DecisionMaking—Emerging Good Practices: Report 2 of the ISPOR MCDAEmerging Good Practices Task Force. Value in Health. 2016;19:125-37.
27. Goetghebeur M, Wagner, M., Khoury, H., Levitt, R., Erickson, L., Rindress, D. Bridging Health Technology Assessment (HTA) and Efficient Health Care Decision Making with Multicriteria Decision Analysis (MCDA): Applying the EVIDEM Framework to Medicines Appraisal. Medical Decision Making. 2012:376-89.
28. Thokala P, Duenas, A. Multiple criteria decision analysis for health technology assessment. Value in Health. 2012;15:1172-81.
29. Franco LA, Montibeller, G. Problem structuring for multicriteria decision analysis interventions. Wiley Encyclopedia of Operations Research and Management Science. 2010.
30. Drummond M, Sculpher, M., Claxton, K., Stoddart, G. Methods for the economic evaluation of health care programmes. Oxford: Oxford University Press; 2015.
31. Ritrovato M, Faggiano, F., Tedesco, G., Derrico, P. Decision-oriented Health Technology Assessment: One Step Forward in Supporting the Decision-Making Process in Hospitals. Value in Health. 2015;18(4):505-11.
32. Martelli N, Hansen, P., Van den Brik, H., Boudard, A., Cordonnier, A., Devaux, C., Pineau, J., Prognon, P., Borget, I. Combining multi-criteria decision analysis an mini-health tehcnology assessment: A funding decision-support tool for medical devices in a university hospital setting. Journal of biomedical informatic. 2016;59:201-8.
33. Hansen P. PAPRIKA method 1000minds.com2020 [Available from: https://www.1000minds.com/about/paprika.
34. Nemeth BMABSWKIACJDKZ. Comparison of weighting methods used in multicriteria decision analysis frameworks in healthcare with focus on low- and middle-income countries. Journal of comparative effectviness research. 2019;8(4):194-204.
35. Hansen P, Ombler, F. A New Method for Scoring Additive Multi-attribute Value Models Using Pairwise Rankings of Alternatives. Journal of multi-criteria decision analysis. 2009;15:87-107.
36. Browne A, Ahmad SSO, Beck CR, Nguyen-Van-Tam JS. The roles of transportation and transportation hubs in the propagation of influenza and coronaviruses: a systematic review. Journal of travel medicine. 2016;23(1).
37. Haider N, Yavlinsky A, Simons D, Osman AY, Ntoumi F, Zumla A, et al. Passengers' destinations from China: Low risk of Novel Coronavirus (2019-nCoV) transmission into Africa and South America. Epidemiology and Infection. 2020.
38. Lawyer G. Measuring the potential of individual airports for pandemic spread over the world airline network. Bmc Infectious Diseases. 2016;16.
39. WHO. rapid risk assessment outbreak ebola virus disease west africa fourth update 3 who.int2014 [Available from: https://www.ecdc.europa.eu/en/publications-data/rapid-risk-assessment-outbreak-ebola-virus-disease-west-africa-fourth-update-3.

40. Semenza JC, Sewe MO, Lindgren E, Brusin S, Aaslav KK, Mollet T, et al. Systemic resilience to cross-border infectious disease threat events in Europe. Transboundary and Emerging Diseases. 2019;66(5):1855-63.
41. Lagana P, Gambuzza ME, Delia S. Legionella risk assessment in cruise ships and ferries. Annals of Agricultural and Environmental Medicine. 2017;24(2):276-82.
42. Semenza JC, Sewe MO, Lindgren E, Brusin S, Aaslav KK, Mollet T, et al. Systemic resilience to cross-border infectious disease threat events in Europe. Transboundary and Emerging Diseases. 2019;66(5):1855-63.
43. Algarni H, Memish ZA, Assiri AM. Health conditions for travellers to Saudi Arabia for the pilgrimage to Mecca (Hajj) - 2015. Journal of Epidemiology and Global Health. 2016;6(1):7-9.
44. Merrill RD, Rogers K, Ward S, Ojo O, Kakai CG, Agbeko TT, et al. Responding to Communicable Diseases in Internationally Mobile Populations at Points of Entry and along Porous Borders, Nigeria, Benin, and Togo. Emerg Infect Dis. 2017;23(13).
45. Chong KC, Ying Zee BC. Modeling the impact of air, sea, and land travel restrictions supplemented by other interventions on the emergence of a new influenza pandemic virus. BMC Infectious Diseases. 2012;12.
46. Mouchtouri V, et. al. State of the art: public health and passenger ships. Int Marit Health. 2010;61:49-98.
47. Iteraera R. Infectious diseases and maritime law. un.org: United Nations 2010.
48. Achterbosch T, Dopfer, D. Cattle trade and the risk of importing animal diseases into the Netherlands. LEI, The Hague: Agricultural Economics Research Institute; 2005.
49. Bornstein R, Craver-Lemley, C. Mere exposure effect. Cognitive Illusions. 2. East Sussex, UK: Taylory & Francis/ Psychology Press.; 2017. p. 256-75.
50. O'Hagan A. Expert knowledge elicitation: subjective but scientific. The American Statistician. 2019;73(1):69-81.
51. Who. Rapid Risk Assessment of Acute Public Health Events. WHO: WHO; 2012.

Appendix A Search strategy

Search terms		
Infectious disease	**Point of entry**	**Vulnerability**
infectious disease*	Airp*	Vulnerab*
communicable disease*	Airdrome*	Exposure*
disease outbreak*	Aerodrome*	Weakness*
Outbreak*	Flying field*	Danger*
2019-n-cov	Landing field*	Risk*
covid-19	Air station*	Hazard*
SARS*	Air terminal*	Liabilit*
Middle East Respiratory Syndrome Coronavirus	Aviation*	
MERS*	Air transport*	
ebola	Passageway*	
measles	Aircraft*	
H1N1	Airliner*	
Influenza virus	Port	
Preparedness	Ports	
	Dock	
	Docks	
	Port side*	
	Marina*	
	Harbor*	
	Ship*	
	Cruise*	
	Cruise ship*	
	Boat*	
	Tanker*	
	Water vessel*	
	Ground crossing*	
	Crossroad*	
	Car	
	Cars	
	Vehicle*	
	Auto	
	Autos	
	Bus	
	Busses	
	Motor	
	Motors	
	Conveyance*	
	Point of entry	
	Points of entry	
	Automobile*	
	Motor vehicle*	

Database	**Search terms**	**# of records**
Scopus	(TITLE-ABS-KEY (*"infectious disease*"* OR *"communicable disease*"* OR *"disease outbreak*"* OR *outbreak** OR *2019-n-cov* OR *covid-19* OR *sars** OR *"middle east respiratory syndrome coronavirus"* OR *mers** OR *ebola* OR *measles* OR *preparedness* OR *h1n1* OR *"influenza virus"*) AND TITLE-ABS-KEY (*"point of entry"* OR *"points of entry"*) AND TITLE-ABS-KEY (*vulnerab** OR *exposure** OR *weakness** OR *danger** OR *risk** OR *hazard** OR *liabilit**)) AND ACCESSTYPE (*OA*) AND PUBYEAR > *2004*	30
Scopus	(TITLE-ABS-KEY (*"infectious disease*"* OR *"communicable disease*"* OR *"disease outbreak*"* OR *outbreak** OR *2019-n-cov* OR *covid-19* OR *sars** OR *"middle east respiratory syndrome coronavirus"* OR *mers** OR *ebola* OR *measles* OR *preparedness* OR *h1n1* OR *"influenza virus"*) AND TITLE-ABS-KEY (*vulnerab** OR *exposure** OR *weakness** OR *danger** OR *risk** OR *hazard** OR *liabilit**) AND TITLE (*airp** OR *aerodrome** OR *airdrome** OR *"flying field*"* OR *"landing field*"* OR *"air station* "* OR *"air terminal*"* OR *aviation** OR *" air transport "* OR *passageway** OR *aircraft** OR *airliner**) OR KEY (*airp** OR *aerodrome** OR *airdrome** OR *"flying field*"* OR *"landing field*"* OR *"air station* "* OR *"air terminal*"* OR *aviation** OR *" air transport "* OR *passageway** OR *aircraft** OR *airliner**)) AND ACCESSTYPE (*OA*) AND PUBYEAR > *2004*	159
Scopus	(TITLE-ABS-KEY (*"infectious disease*"* OR *"communicable disease*"* OR *"disease outbreak*"* OR *outbreak** OR *2019-n-cov* OR *covid-19* OR *sars** OR *"middle east respiratory syndrome*	119

	coronavirus" OR *mers** OR *ebola* OR *measles* OR *preparedness* OR *h1n1* OR *"influenza virus"*) AND TITLE-ABS-KEY (*vulnerab** OR *exposure** OR *weakness** OR *danger** OR *risk** OR *hazard** OR *liabilit**) AND TITLE (*port* OR *ports* OR *dock* OR *docks* OR *"port side*"* OR *marina** OR *harbor** OR *ship** OR *cruise** OR *" cruise ship*"* OR *boat** OR *tanker** OR *" water vessel*"*) OR KEY (*port* OR *ports* OR *dock* OR *docks* OR *"port side*"* OR *marina** OR *harbor** OR *ship** OR *cruise** OR *" cruise ship*"* OR *boat** OR *tanker** OR *" water vessel*"*)) AND ACCESSTYPE (*OA*) AND PUBYEAR > *2004*	
Scopus	(TITLE-ABS-KEY (*"infectious disease*"* OR *"communicable disease*"* OR *"disease outbreak*"* OR *outbreak** OR *2019-n-cov* OR *covid-19* OR *sars** OR *"middle east respiratory syndrome coronavirus"* OR *mers** OR *ebola* OR *measles* OR *preparedness* OR *h1n1* OR *"influenza virus"*) AND TITLE-ABS-KEY (*vulnerab** OR *exposure** OR *weakness** OR *danger** OR *risk** OR *hazard** OR *liabilit**) AND TITLE (*"ground crossing*"* OR *crossroad** OR *car* OR *cars* OR *vehicle** OR *auto* OR *autos* OR *bus* OR *busses* OR *motor* OR *motors* OR *conveyance** OR *auto mobile** OR *"motor vehicle*"*) OR KEY (*"ground crossing*"* OR *crossroad** OR *car* OR *cars* OR *vehicle** OR *auto* OR *autos* OR *bus* OR *busses* OR *motor* OR *motors* OR *conveyance** OR *auto mobile** OR *"motor vehicle*"*)) AND ACCESSTYPE (*OA*) AND PUBYEAR > *2004*	197
PubMed	((((((((((vulnerab*[Title/Abstract]) OR exposure*[Title/Abstract]) OR weakness*[Title/Abstract]) OR danger*[Title/Abstract]) OR risk*[Title/Abstract]) OR hazard*[Title/Abstract]) OR liabilit*[Title/Abstract]) OR "Risk"[MeSH Terms]) AND free full text[sb] AND ("2005/01/01"[PDat] : "2020/12/31"[PDat]))) AND	172

	((airp*[Title]) OR airdrome*[Title]) OR aerodrome*[Title]) OR flying field*[Title]) OR landing field*[Title]) OR air station*[Title]) OR air terminal*[Title]) OR aviation*[Title]) OR air transport*[Title]) OR passageway*[Title]) OR aircraft*[Title]) OR airliner*[Title]) OR port[Title]) OR ports[Title]) OR dock[Title]) OR docks[Title]) OR port side*[Title]) OR marina*[Title]) OR harbor*[Title]) OR ship*[Title]) OR cruise*[Title]) OR cruise ship*[Title]) OR boat*[Title]) OR tanker*[Title]) OR water vessel*[Title]) OR ground crossing*[Title]) OR crossroad*[Title]) OR car[Title]) OR cars[Title]) OR vehicle*[Title]) OR auto[Title]) OR autos[Title]) OR bus[Title]) OR busses[Title]) OR motor[Title]) OR motors[Title]) OR conveyance*[Title]) OR point of entry[Title]) OR points of entry[Title]) OR automobile*[Title]) OR motor vehicle*[Title]) OR "Airports"[MeSH Terms]) OR "Aviation"[MeSH Terms]) OR "Aircraft"[MeSH Terms]) OR "Ships"[MeSH Terms]) OR "Automobiles"[MeSH Terms]) OR "Motor Vehicles"[MeSH Terms]) AND free full text[sb] AND ("2005/01/01"[PDat] : "2020/12/31"[PDat]))) AND ((((((((((((((((((((((((infectious disease*[Title/Abstract]) OR communicable disease*[Title/Abstract]) OR disease outbreak*[Title/Abstract]) OR Outbreak*[Title/Abstract]) OR 2019-n-cov[Title/Abstract]) OR covid-19[Title/Abstract]) OR SARS*[Title/Abstract]) OR MERS*[Title/Abstract]) OR ebola[Title/Abstract]) OR measles[Title/Abstract]) OR influenza virus[Title/Abstract]) OR H1N1[Title/Abstract]) OR Preparedness[Title/Abstract]) OR "civil defense"[MeSH Terms]) OR "Communicable Diseases/epidemiology"[MeSH Terms]) OR ("Communicable Diseases/prevention and control"[MeSH Terms])) OR "Communicable Diseases/transmission"[MeSH Terms]) OR "Influenza, Human/economics"[MeSH Terms]) OR ("Influenza, Human/organization and administration"[MeSH Terms])) OR ("Influenza, Human/prevention and control"[MeSH Terms])) OR ("Influenza, Human/statistics and numerical data"[MeSH Terms])) OR "Influenza, Human/transmission"[MeSH Terms]) OR "SARS	

	Virus"[MeSH Terms]) OR "Middle East Respiratory Syndrome Coronavirus"[MeSH Terms]) OR "Influenza A Virus, H1N1 Subtype"[MeSH Terms]) OR Measles[MeSH Terms]) AND free full text[sb] AND ("2005/01/01"[PDat] : "2020/12/31"[PDat]))	
Web of Science	(TS=(vulnerab* OR exposure* OR weakness* OR danger* OR risk* OR hazard* OR liabilit*)) AND LANGUAGE: (English) AND (TS=(point of entry OR points of entry)) AND LANGUAGE: (English) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=2005-2020 AND (TS=(infectious disease* OR communicable disease* OR disease outbreak* OR outbreak* OR 2019-n-cov OR covid-19 OR sars* OR middle east respiratory syndrome coronavirus OR mers* OR ebola OR measles OR preparedness OR h1n1 OR influenza virus)) AND LANGUAGE: (English)	107
Web of Science	(TS=(vulnerab* OR exposure* OR weakness* OR danger* OR risk* OR hazard* OR liabilit*)) AND LANGUAGE: (English) AND (TS=(infectious disease* OR communicable disease* OR disease outbreak* OR outbreak* OR 2019-n-cov OR covid-19 OR sars* OR middle east respiratory syndrome coronavirus OR mers* OR ebola OR measles OR preparedness OR h1n1 OR influenza virus)) AND LANGUAGE: (English) AND (TI=(airp* OR aerodrome* OR airdrome* OR flying field* OR landing field* OR air station* OR air terminal* OR aviation* OR air transport OR passageway* OR aircraft* OR airliner*)) AND LANGUAGE: (English)	94
Web of Science	(TS=(vulnerab* OR exposure* OR weakness* OR danger* OR risk* OR hazard* OR liabilit*)) AND LANGUAGE: (English) AND (TS=(infectious disease* OR communicable disease* OR disease outbreak* OR outbreak* OR 2019-n-cov OR covid-19 OR sars* OR middle east respiratory syndrome coronavirus OR mers* OR ebola OR measles OR preparedness OR h1n1 OR influenza virus)) AND LANGUAGE: (English) AND (TI=(port OR ports OR dock OR docks OR port side* OR marina* OR harbor* OR ship* OR cruise* OR cruise ship* OR boat* OR tanker* OR water vessel*)) *AND* **LANGUAGE:** (English)	149
Web of Science	(TS=(vulnerab* OR exposure* OR weakness* OR danger* OR risk* OR hazard* OR liabilit*)) AND LANGUAGE: (English) AND (TS=(infectious disease* OR communicable disease* OR disease outbreak* OR outbreak* OR 2019-n-cov OR covid-19 OR sars*	80

	OR middle east respiratory syndrome coronavirus OR mers* OR ebola OR measles OR preparedness OR h1n1 OR influenza virus)) AND LANGUAGE: (English) AND (TI=(ground crossing* OR crossroad* OR car OR cars OR vehicle* OR auto OR autos OR bus OR busses OR motor OR motors OR conveyance* OR automobile* OR motor vehicle*)) *AND* **LANGUAGE:** (English)	

Appendix B Data extraction

Author	**Year**	**PoE**	**Country**	**Characteristic**
Algarni	2015	All	Saudi Arabi	High vaccination status decreases spread of infectious disease (**vaccination status**) Contact with animals should be limited, due to change of contracting infectious disease (**contact animals – livestock**) Travelers in close contact (per m2) can increase spread of infectious disease (**close contact**)
Askling	2009	Airport	Sweden/ Europe	Information about amount of infections from countries and age (**travelers from risk areas)** high vaccination (immunization) status of travelers can decrease spread of infectious disease (**vaccination status**)
Bednarczyk	2016	All	USA	Low incidence of infectious diseases outbreaks at PoE with high vaccination status of country (**vaccination status**)
Browne	2016	All	/	high crowd density & enclosed spaces provide conditions for person-to-person transmisstion via inhalation, aerosols and/or droplets; Crowded (m2), enclosed spaces (**close contact**) high passenger throughput provides enhanced opportunities for indirect transmission (**volume of travelers**) long distance, seat proximity & duration increase spread of infectious diseases (**duration of journey**)
Gilbert	2020	Airport	China/ Afrika	combination of capacity and risk areas determines the likelihood of importation**risk areas**)

Haider	2020	Airport	China	number of travelers to destination countries are confirmed cases of the departed city (reported by WHO) (**risk areas**) more air passengers (4x in China) compared to 2003 (SARS) - more travel poses a high risk (**volume of travelers**)
Harley	2010	Ground crossing	South America	tropical climates (dry climate and warm temperature pose higher risk) (**climate**)
Ikonen	2018	Airport	Finland	Enclosed spaces and close contact can increase spread of infectious diseases – virus can stay in air for some time (**close contact**) plastic surfaces at airport contaminated with virus (frequently touched surfaces)
Lagana	2017	Port	Italy	ferries higher risk contamination of legionella then cruise ships (**type of conveyance**)
Lawyer	2016	Airport	World wide	connectivity of seed location (**risk areas**) Individual role of airports in pandemic diffusion. AEF = expected force of infection - AEF Is strongly predictive of an outbreak's invasive threshold: the early development of a pandemic is not stochastic, but strongly structured by local connectivity of seed location (**risk areas**) (**volume of travelers**)
Nah	2016	Airport	World wide	effective distance (minimum effective length of a path from origin to destination) good indicator of importation (**duration of journey**)

Watanabe	2016	Airport	Japan	vaccination status - airport acting as hotspot for travelers from measles endemic countries and unvaccinated persons (**vaccination status**)
ECDC	2014	All	Africa	Fligths (direct and indirect) - importation of virus (**risk areas**) passenger ships - importation of virus (**type of conveyance**)
WHO	2019	All	Europe	vaccination status: no vaccination increases nonimmunized population (**vaccination status**) Movement and close contact increases risk (**population density**)
ECDC	2020	All	China/ Europe	volume of travelers from areas with presumed ongoing community transmission (**risk areas**)
ECDC	2019	Airport	Africa	introduction by infected people travelling to the EU (by flight) (**risk areas**)
Merler	2010	All	Europe	West Europe more risk of importation compared to east due to connectivity (**volume of travelers**) (**risk areas**)
Semenza	2016	All	Europe	climate, natural environment, human-made environment, travel and tourism, migration, global trade - most frequently involved in sigled IDTE (61%): sociodemographics, public health system (second most involved (21%) top 5 drivers: travel and tourism, food and water qualtiy, natural environment, global trade, climate Food and waterborne IDTE's were most frequently occuring events (followed by vectors) (**volume of travelers**) (**climate**) (**trade**)

Appendix C Preliminary list of characteristics and information for panel

Characteristics infectious diseases

In previous discussions a distinction between general and flexible characteristic were mentioned. The following table contains the general characteristics. These characteristics look at the vulnerability of a point of entry in situations where no event occurs. For example: volume of travelers – General: A higher number of travelers at the point of entry, pose a higher risk of importation. The suggestion for flexible will be shown as an Indicator to re assess the vulnerability of the PoE: in case of summer holiday or other peak moments, some points of entry can receive a substantial amount of travelers compared to the regular situation. This can pose a higher risk of importation. The second table contains characteristics that are relevant for transmission. Such as populations density. Third, a table with the mentioned indicator characteristics is shown. Lastly, some addition suggestions are mentioned.

General characteristics

Airports			**Ports**			**Ground-crossings**		
Characteristic influencing the vulnerability	**Level (low vulnerability – high vulnerability)**	**Considerations**	**Characteristic influencing the vulnerability**	**Level (low vulnerability – high vulnerability)**	**Considerations**	**Characteristic influencing the vulnerability**	**Level (low vulnerability – high vulnerability)**	**Considerations**
Volume of travelers *Description*: The average volume of travelers at the airport at the moment you fill out the tool	Low amount of travelers for your airport High amount of travelers for your airport	Should the characteristic be defined: Per year Per month Should the characteristic be defined relatively (low vs. high amount of travelers) or absolutely stating	**Volume of travelers** *Description*: The average volume of travelers at the moment you fill out the tool	Low amount of travelers for your port High amount of travelers for your port	Should the characteristic be defined: Per year Per month Should the characteristic be defined relatively (low vs. high amount of travelers) or absolutely stating absolute numbers of travelers	**Volume of travelers** *Description*: The average volume of travelers at the moment you fill out the tool	Low amount of travelers for your ground crossing High amount of travelers for your ground crossing	Should the characteristic be defined: Per year Per month Should the characteristic be defined relatively (low vs. high amount of travelers) or absolutely stating

		absolute numbers of travelers How do we distinguish between travelers entering the country and transit travelers? How does these two groups of travelers influence the risk on introduction of infectious diseases?			How do we distinguish between travelers entering the country and transit travelers? How does these two groups of travelers influence the risk on introduction of infectious diseases? Would the type of travelers have additional value? Type of travelers - Low risk group (young travelers/business (?)) - High risk group (old travelers/compromised immune system/leisure (?))			absolute numbers of travelers How do we distinguish between travelers entering the country and transit travelers? Or between European travelers and non-European travelers? How does these two groups of travelers influence the risk on introduction of infectious diseases?
Travelers from endemic areas *Description:* Travelers from	Few travelers from areas with different endemic diseases	How would you assess other options to define this characteristic?: The number of direct	**Travelers from endemic areas** *Description:* Travelers from	Few travelers from areas with different endemic diseases	How would you assess other options to define this characteristic?: Direct connections between the port and endemic areas	**Travelers from endemic areas** *Description:* Travelers from	not many direct travelers from areas with different endemic diseases	How would you assess other options to define this characteristic?: Direct connections

geographic areas where other infectious diseases are endemic or epidemic than in the country of origin	Many direct travelers from areas with different endemic diseases	connections between the airport and endemic areas - No direct connections - Direct connections OR Travelers from areas with an international spreading disease (e.g. PHEICs) - No travelers from areas with an international spreading - Travelers from areas with an international spreading disease	geographic areas where other infectious diseases are endemic or epidemic than in the country of origin	Many travelers from areas with different endemic diseases	- No direct connections - Direct connections OR Travelers from areas with an international spreading disease (e.g. PHEICs) - No travelers from areas with an international spreading - Travelers from areas with an international spreading disease Is it important to look at the incidence in the country? And does a separation between European and non European need to be made? Or maybe specific hubs with higher risk?	geographic areas where other infectious diseases are endemic or epidemic than in the country of origin	Many direct travelers from areas with different endemic diseases	between the ground crossing and endemic areas - No direct connections - Direct connections OR Travelers from areas with an international spreading disease (e.g. PHEICs) - No travelers from areas with an international spreading - Travelers from areas with an international spreading disease

		Is it important to look at the incidence in the country? And does a separation between European and non European need to be made? Or maybe specific hubs with higher risk?						Is it important to look at the incidence in the country? And does a separation between European and non European need to be made? Or maybe specific hubs with higher risk?
Duration of the journey *Description:* The duration of the traveler's journey	Most of the travelers are short duration travelers Most of the travelers are long durations travelers	Should this characteristic be considered? A basic discussion here is to what extent the duration of the journey adds to the risk on introduction of an infectious disease via a POE, or that it only increases the risk on transmission to others, not directly adding to the risk for an individual POE.	**Duration of the journey** *Description:* The duration of the traveler's journey	There is knowledge of the duration of the journey of arriving travelers There is no knowledge of the duration of the journey of arriving travelers	The levels differ from airports, because in previous pilots it was mentioned that the actual journey duration of travelers is (most of the time) hardly known. Besides, short journey travelers and duration can also be of risk. A lot of different people from different places together and daily or few day rotation of the group. Should this characteristic be considered?	**Duration of the journey** *Description:* The duration of the traveler's journey	There is knowledge of the duration of the journey of arriving travelers There is no knowledge of the duration of the journey of arriving travelers	The levels differ from airports, because in previous pilots it was mentioned that the actual journey duration of travelers is (most of the time) hardly known. Should this characteristic be considered? A basic discussion here is to what extent the

		Other level: The amount of international flights: - Low amount - High amount However, you could also state that the duration might add to the chance that: - Someone develops symptoms during a journey - Transmission during the journey How would you assess another way of defining the levels of this risk			A basic discussion here is to what extent the duration of the journey adds to the risk on introduction of an infectious disease via a POE, or that it only increases the risk on transmission to others, not directly adding to the risk for an individual POE. Other level: The amount of international cruises: - Low amount - High amount However, you could also state that the duration might add to the chance that: - Someone develops symptoms during a journey - Transmission during the journey			duration of the journey adds to the risk on introduction of an infectious disease via a POE, or that it only increases the risk on transmission to others, not directly adding to the risk for an individual POE. Other level: The amount of international traffics: - Low amount - High amount However, you could also state that the duration might add to the chance that: - Someone develops sympto

		characteristic, such as: - There is knowledge of the duration of the journey of arriving travelers - There is no knowledge of the duration of the journey of arriving travelers						ms during a journey - Transmission during the journey
Vaccination status of travelers *Description:*	There is knowledge at the airport regarding vaccination status	Would this characteristics be more practically covered in other levels? such as: Standard flight connections	**Vaccination status of travelers** *Description:*	There is knowledge at the port regarding vaccination status There is no knowledge	Would this characteristics be more practically covered in other levels? such as: Other level: Standard travel connections between countries	**Vaccination status of travelers** *Description:*	There is knowledge at the ground crossing regarding vaccination status	Would this characteristics be more practically covered in other levels? such as: Other level:

Travelers' vaccination status	There is no knowledge at the airport regarding vaccination status	between countries - Little permanent connections with areas with a low vaccination status - Many permanent connections with areas with a low vaccination status In a previous pilot it was suggested to distinct for: Amount of income in country - Low income	Travelers' vaccination status	at the port regarding vaccination status	- Little permanent connections with areas with a low vaccination status - Many permanent connections with areas with a low vaccination status This characteristic is very specific. It could be of importance to a disease specific tool. However, it is hardly generalizable (flexible).	Travelers' vaccination status	There is no knowledge at the ground crossing regarding vaccination status	Standard travel connections between countries - Little permanent connections with areas with a low vaccination status - Many permanent connections with areas with a low vaccination status

		countries - High income countries Other input included: This characteristic is very specific. It could be of importance to a disease specific tool. However, it is hardly generalizable. (flexible). This characteristic is not really linked to the point of entry, but more to the country itself.						This characteristic is very specific. It could be of importance to a disease specific tool. However, it is hardly generalizable.
Trade *Description:* The type of cargo	The majority of cargo involves treated and non-	Can this attribute be included even if the amount of imported and exported	**Trade** *Description:* The type of cargo	The majority of cargo involves treated and non-	Is this characteristic related to infectious disease or more relevant for chemical and vectors? In the infectious diseases	**Trade** *Description:* The type of cargo	The majority of cargo involves treated and non-	Is the risk of importation at the ground crossing or at warehousing points? Is this

between countries	biological goods The majority of cargo involves life stock and biological products	products is not always known? Is this relevant for infectious diseases importation? Does a differentiation between export and import need to be made? Is this attribute relevant for infectious diseases?	between countries	biological good The majority of cargo involves life stock and biological products	food borne diseases and life stock are taken into account. Can this attribute be included even if the amount of imported and exported products is not always known? Is this relevant for infectious diseases importation? Does a differentiation between export and import need to be made? Is this attribute relevant for infectious diseases?	between countries (most cargo is transported by maritime routes (95%), 2% by air and rest by road. Road transport is growing)	biological good The majority of cargo involves life stock and biological products	in all countries or at all ground crossings the same? Is this relevant for infectious diseases importation? Does a differentiation between export and import need to be made? Is this attribute relevant for infectious diseases?
Different conveyances at airport *Description:* Types of conveyance at airport		Previous pilotters suggested that this is not relevant for airports. Suggestion would be to remove this characteristic Is this relevant for airports?	**Different conveyances at port** *Description:* Types of conveyance at port	Ferries (few hours) Cruise ships (longer time)	A suggestion would be to remove this characteristic because the risk is related to the type of cargo and duration of the journey and not to the type of conveyance. Also, there are many different risk profiles for type of vessels. This is difficult to standardize.	**Different conveyance at ground crossing** *Description:* Types of conveyance at ground crossing	Trains have more high volume of cargo Lorries have less volume of cargo, but a broader spectrum of cargo	Already covered in duration of journey? Train and cars/busses may have separate entry points. Can't be compared in this characteristic. Or can a distinction be made between

		Is there overlap with trade in this characteristic?			Is the risk related to infectious diseases for ports? Does this characteristic relates to the age of a ship? Does this characteristic overlap with trade?			the different conveyances? Does this characteristic overlap with trade?
Climate *Description :* The local climate at the airport location		Suggestions made by previous pilots: This is relevant for vectors and not too much for infectious diseases. In case a certain vector is in the country, but the disease not yet, there is potential for settlement. For example: the tiger mosquito can be present in a country, but the Zika virus not yet. A	**Climate** *Description :* The local climate at the port location		Suggestions made by previous pilots: This is relevant for vectors and not too much for infectious diseases. In case a certain vector is in the country, but the disease not yet, there is potential for settlement. For example: the tiger mosquito can be present in a country, but the Zika virus not yet. A person with the virus enters the country and this can cause importation of the virus. This might be something to consider.	**Climate** *Description :* The local climate at the ground crossing location		Suggestions made by previous pilots: Probably not needed. Delete attribute for ground crossing. In case a certain vector is in the country, but the disease not yet, there is potential for settlement. For example: the tiger mosquito can be present in a country, but the Zika virus not yet. A

		person with the virus enters the country and this can cause importation of the virus. This might be something to consider.						person with the virus enters the country and this can cause importation of the virus. This might be something to consider.

Transmission characteristic

These characteristics were found in literature or discussed in previous pilots. A distinction is made between characteristics that are of value for the importation of the infectious disease and the vulnerability of transmission at the point of entry of infectious disease. The table below shows the characteristics regarding the transmission of the infectious disease at the point of entry.

- Do the following characteristics influence the risk of importation of infectious diseases or only their transmission during travel?
- Should transmission be taken into account in the scope of the study and tool?

Characteristic	**Level (low vulnerability – high vulnerability)**	**Considerations**
Density of population at point of entry *Description* Amount of travelers per m2 at the point of entry at a specific time	Low amount of travelers High amount of travelers	Density can matter, but it is mostly regarding the density of people living nearby the PoE. If introduction is measured, it is maybe not the most important characteristic. Can it indicate the impact of the importation and therefore show more vulnerability?
Contact between local community and travelers at the point of entry *Description* Possibilities for frequent contact of the local community with travelers at the point of entry	No frequent contact between the local community and travelers at the point of entry Frequent contact between the local community and travelers at the point of entry	
Duration of the journey	Short duration of the journey	

Description The duration in hours from start to end point. Including the transfers and time spend at the point of entry.	Long duration of the journey	
Transit passengers at point of entry Description The amount of time transit passengers spend at point of entry	Low amount of time High amount of time	Transit passengers contribute less to the introduction than other travelers. It is also depended on different factors, such as the contact a passenger had with others and the amount of time they had contact. Is this characteristic measurable at PoE?

Indicators to reevaluate the vulnerability of PoE

The following table show characteristics that influence the vulnerability of a point of entry, but their weight differs per moment in a year or per disease. They can't ben generalized and therefore are taken apart from the general characteristics. These characteristics can be seen as indicators to use the tool again and evaluate the vulnerability of a PoE. The input into the tool can change when an event or season occurs

- Are these characteristics different per time of year or disease specific?
- Do they need to be included in a generic tool to assess the vulnerability of a point of entry?
- Do you have additional characteristics for this table?
- What would be a time when the tool would be of value?
- What would be a adequate time to reuse the tool?

Characteristic	**Level (low vulnerability – high vulnerability)**	**Considerations**
Seasonality *Description* Periods with higher or lower amount of travelers, because of vacation, seasons, events etc.	Lower amount of travelers Higher amount of travelers	Season depends on disease and location. It is difficult to separate it in four seasons.
Neighboring countries of a country with a health event *Description* An outbreak of an infectious disease in a country increase the risk of importation in neighboring countries.	Point of entry is located in a country with no borders to a country with an infectious disease outbreak Point of entry is located in a country with borders to a country with an infectious disease outbreak	

(Ground crossings specific are in terms of higher proportion of short-distance travel and transport and therefore the epidemiological situation of a country adjacent to a ground crossing point of entry is of higher relevance)		
Disease specific *Description* Characteristics can be (partly) disease specific	Duration of the journey This can depend on the incubation time, the spread of the disease, survival time of disease outside the host etc. Type of travelers Different diseases have different type of travelers that are more vulnerable for the disease. Vaccination status Differs per disease what percentage of the population needs to be vaccinated to provide security. This is also more relevant for transmission at point of entry	

Other suggestions made by previous pilots

- The preparedness level of the airport is of importance for the risk. The current assessment looks at the vulnerability of the PoE and didn't take into account characteristics that are related to the preparedness of a point of entry. Other pilots suggested to include the level of preparedness as well, to outweigh vulnerabilities. However, at the moment we restrict the tool to assess the vulnerabilities, leading to required preparedness. Advice on preparedness could be an outcome of the tool; we do not aim to include it in the analysis.
- In previous pilots it is mentioned that his tool could be used in combination with other indexes or tools. Examples of tools or indexes can be the infectious disease vulnerability index and INFORM global risk index. These ubdexes both take into account several characteristics that influence the risk for an outbreak per country. The information is not related to points of entry, but a general tool to assess the vulnerability of a point of entry in combination with the risk of outbreak from another index can be of great value for public healthcare workers at points of entry.

- In previous pilots it is mentioned that It is country-specific what a high and what a low amount of travelers is and therefore hard to standardize. A high an low amount also depends on the population of the country, density, capacity and other factor. A high amount will be different for Norway compared to Spain.

Questions for you:

- What would an idea risk tool for PoEs look like, according to your experience?
- What would you like to find out with this tool?
    - Compare different PoE in your country? (relative vulnerability)
    - Identify the vulnerability of an individual POE? (absolute vulnerability)
- Do you have suggestions how to classify the different parts of the tool?
    - Would a distinction between ports, airports and ground-crossing valuable,
    - a distinction between generic and disease-specific occasions? This may be related to the way the tool is used, if you wish to assess the generic and long term vulnerability than use generic characteristics. However, if you would wish to assess per occasion the flexible and generic characteristics are both eligible.
    - a distinction between vectors, infectious diseases, and chemical threats?

Appendix D Suggestions panel airports

General suggestions
- Write/use threshold; what is low what is high 3 2 4 5
- Separate in flexible (events) and generic characteristics and transmission 2
- Include seasons (summer, winter, holidays), but it is depended on the disease and place 3 5
- It is country specific what is high and low. This is hard to standardize an depends on preparedness 2 3 5
- Exclude the transmission characteristics, because they don't add to introduction 3
- Density is relevant for when introduction occurs, what the impact will be. Same for contact between community and travelers 3
- Flexible characteristics can indeed be an indication for reassessing vulnerability. Name it in the introduction of the tool for example 3'
- Transmission characteristics are important to take into account 4
- Include transmission. Both are important 5
- Difficult to state high a low amount: suggestion; amount compared to normal 3
- I would go for absolute number of travelers, but difficult to define what is low and what is high 4

Original characteristic airport	**Pilot suggestions** - **More suggestions in favor: take over suggestion** - **Equal amount in favor and against: look at literature** - **If not applicable to the aim of the study or not practical for the tool: exclude suggestion**	**Literature**	**New characteristic**
Volume of travelers Description The average volume of travelers at the airport per year Level Low amount of travelers High amount of travelers	- number of travelers entering the country (contrary to transit passengers) 1 2 - Transit passengers are different from passengers entering the country 1 2 - Everybody coming to your airport can be of risk 3 - Type of traveler is irrelevant 2 3 - Airport itself is of more importance than the airplane 2 - 95 million per year Schiphol 1 - Count in groups. Depends on airport what is much. 0-1000, 1000-2000 etc per day. 5	According to Eurostat 1.1 billion passengers travelled by air in the EU. The largest number of airpassengers: UK (272 million), Germany (222 million), Spain (221 million). Airports with the highest numbers of arrivals and departures in 2018: Heathrow UK (80 million), Paris (FR) 72 million, Schiphol (NL) 71 million. (https://ec.europa.eu/eurostat/documents/2995521/10265946/7-06122019-AP-EN.PDF/8f2c9d16-c1c4-0e1f-7a66-47ce411faef7) In the Netherlands the second largest airport Eindhoven processed around 6 million arrival and departure passengers in 2017 https://www.cbs.nl/en-gb/faq/luchtvaart/how-many-passengers-travel-through-dutch-airports-	**Number of travelers entering the country (excluding transit passengers)** Description The number of travelers entering the country via your airport (Introduction vulnerability) Levels <1 million/month 1-2 million/month >2 million/month
Travelers from endemic areas Description Travelers from geographic areas where other infectious diseases are endemic of epidemic than in the country of origin Level Not many (<%) direct travelers from areas with different endemic diseases Many (>%) direct travelers from areas with different endemic diseases	- Direct connections between the airport and endemic areas 1 2 3 4 - Very important to know the direct connections, not only the areas, but also mean of transport (related to vectors; cargo flights) 4 - Travelers from areas with an international spreading disease 1 - Travelers via hub do not act upon at Schiphol 1 - The world isn't divided in high and low risk areas 1 - Knowledge of travelers from endemic areas is available; not on daily level, but in case of an outbreak and permanent connections are known 2 - Look at incidence level n the endemic country 3 - Difficult to say within EU from which country they came, other continents can be checked by passport, however, sometimes you don't know (hub; via Istanbul can come from Africa and be of risk). 3 - Establish a list with airports that have a higher risk as hub. 3	Direct connectivity can be related to direct connections, but also frequency of travel. A tool that could be used is the airport industry connectivity report (www.seo.nl/uploads/media/2018-61_Airport_Industry_Conductivity_Report_2018_01.pdf) This report shows that Frankfurt, Amsterdam and Heathrow are the most direct connected airports. Some airports are not flying outside Europe or to other endemic areas (e.g. Linz has only one connection: Vienna) The top 100 airports based on flights range from almost 600 flights to 41 flights per day. It can differ greatly between airports if an airport has connections with endemic areas. https://www.flightsfrom.com/top-100-airports-in-europe No literature found on the extra risk at hubs.	**Travelers from risk areas** Description Travelers via direct flights from geographic areas where other infectious diseases are endemic or epidemic than in the country of origin (Introduction vulnerability) Levels No direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country Direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country

	- Also important is the epidemic situation in country of the airport. It helps to define the risk to my country (no incidents in your country, the risk is higher). 5		
Duration of the journey Description The duration of the traveler's journey. Levels A lot (%) short distance travelers A lot (%) of long distance travelers	- the longer you are on your journey, the more chance to develop symptoms/the diseases 2 3 - Outside EU much easier to check the origin of travelers than inside EU. When travelling via hubs or different ways of travelling the duration is hard to know. Level could be: do you receive many international flights 3 - Difficult to standardize; duration is disease specific 3 5 - Might not be relevant, only for transmission on the inside of an airplane 1 - Vulnerability can increase when a neighboring country has an outbreak; however this is not a standard vulnerability - The information regarding the duration in airplanes in based on outdated research (ragida protocol); more research regarding the effect of airco on spread is needed 1 - not sure if the travelers journey is important 4 - Create categories with e.g. flu, covid shorter time and tuberculosis longer time 5	Duration of exposure is of importance to the risk of infectious disease transmission (De Cao, 2014: the relative importance of frequency of contacts and duration of exposure to the spread of directly transmitted infections There is no standard international definition of long and short duration. However, many airlines use time or geographic boundaries instead. (https://en.wikipedia.org/wiki/Flight_length)	**Duration of the journey** *Description* The average duration of the traveler's total journey including transfers. (Transmission vulnerability) Levels: Most of the travelers are travelling < 3 hours Most of the travelers are travelling between 3-8 hours Most of the travelers are travelling > 8 hours
Vaccination status of travelers Description Traveler's vaccination status Levels High percentage of travelers is vaccinated Low percentage of travelers is vaccinated	- Use standard flight connections between countries 2 - Vaccination status is hardly generalizable. It is very disease specific. 1 - More important is vaccination status of country of origin 4 - airport doesn't act on vaccination status; only advice to get vaccinated. More related to departing travelers 1 3 - is not really related to airport. It is also a challenge, because not every country has information regarding the vaccination status 2 - Use incidence in the country travelers come from as level instead of vaccination status 2 3 - This characteristic has overlap with endemic areas. Difficult to measure the vaccination status of travelers 3 4 - change the level/characteristic to high/low income countries 2 - No information of this at the airport 5 - data on vaccination status of country is available 5		*Combine with endemic areas*
International trade via airport Description The type of cargo between countries Levels The majority of cargo involves treated and non-biological good – absolute value of imported and exported life stock and biological products is lower than	- The amount of imported and exported products is not always know, but can be of great importance to the vulnerability of an airport 2 - A lot of animals are shipped via Schiphol 1 - Foodborne/life stock: mostly only exported from Europe, not imported. Differentiate between import and export 3 - Important. Animals, life animals, products from animals are of high risk 4	Global trade, import and export of good and services across international borders pose higher risk of imported diseases. Most infectious disease threat events in Europe occur by food and water borne diseases, trade and tourism (Semenza, 2016: Determinants and drivers of infectious disease threat events in Europe)	**Trade** Description The type of cargo imported via the airport. Types of cargo are: non-biological goods, biological, animal products, life stock (Introduction vulnerability) Biological = e.g. plants, wood, pertaining to biology (e.g. products from animals (food: eggs, meat, milk), products

The majority of cargo involves life stock and biological products – absolute value of imported and exported life stock an biological products is lower than ___	- Threshold will be hard to find. Use big amount or most of the cargo and change it to trade. National trade can also occur 2 - Content always needs to be known at Schiphol 1 - Mosquitos (vectors) are also a risk of trade 1 - Look at hospitals located close to the airport 2 - Important for vectors and maybe on chemical 3 - Trade of food/life stock is not relevant 5		from animals which have not been treated (e.g. heated, cleaned)) Non-biological = non pertaining to biology (e.g. furniture, clothes, books) Livestock = defined as domesticated animals raised in an agricultural setting to produce labor and commodities such as meat, eggs, milk, fur, leather, and wool. Levels non-biological goods biological goods (possibly in combination with non-biological goods) livestock (possibly in combination with biological goods and non-biological goods)
Different vessels at airport Description Types of vessels at airport Levels ...% of ___	- This is not relevant for airports, because the amount of travelers per vessel is of importance and not the type 1 3 4 - More related to spread in airplane; airplane is to go from A to B. Not many 'pleasure flights' compared to ships. The goal of the journey is different. 1 - Change vessels into conveyance 2 - From technical point; much easier to deny airplanes that don't meet the technical fit (the same with ships). It doesn't happen often 2 - Not changing the HEPA filter is of more risk than an old airplane; maintenance is crucial 2 - Amount of vectors can be a characteristic; Transfer of vectors from country of origin to country where the vector is not located 2		X
Climate Description The local climate at the airport location Levels ..... climate	- Is important for vectors, but probably not for infectious diseases 2 3 4 5 - In case a certain vector is in the country, but the disease not yet, there is potential for settlement. For example: the tiger mosquito can be present in a country, but the Zika virus not yet. A person with the virus enters the country and this can cause importation of the virus. This might be something to consider.1 - Less important for airports (more for ports) 3		X
	- layovers are of risk; spend a lot of time at airport then the disease can be transmitted at the airport (especially in closed spaces). 1 3 4 5 - Transit passengers contribute much less than other travelers. It also depends on the contact transit passengers have (time, close contact etc). 3		**Transit passengers** Description The average duration transit passengers spent at the airport. (Transmission vulnerability) Duration = average time of transit passengers at airport * amount of passengers per month Levels: ≤ 3 million transit hours 3-6 million transit hours >6 million transit hours

	- not only amount of travelers, but also density of travelers are of importance to the spread at airport (this is in line with time spend on airport) 1 2 3 4 5 - Large airports with a lot of movement can also increase the risk of transmission 1	Transmission with light activity can increase the transmission compare to resting conditions. Therefore, movement can be of importance for transmitting diseases (Buonanno, 2020: Estimation of airborne emission)	**Density of population at airport** Description Places where travelers are close to each other at the airport (e.g. check in desk, douane, waiting areas) (Transmission vulnerability) Levels There are not many places where travelers are in close contact to other travelers There are many places where travelers are in close contact to other travelers
	- Facilities on the airport used by local community. Frequent contact between travelers and local community can pose a risk 2 3 4 5 - People working at the airport are of the highest risk 5		**Contact between local community and travelers at the airport** *Description* Some airports allow the local community that will not travel to use the airport facilities, such as shops. Local community = citizens who can shop at the facilities of the airport and are not planning to travel. This excludes employees of the airport (Transmission vulnerability) Levels The local community can not use facilities at the airport The local community can use the facilities at the airport

1. Expert 3
2. Expert 4 & 5
3. Expert 6
4. Expert 7
5. Expert 8 & 9

Appendix E: suggestions panel ports

General suggestion
- Write threshold; what is low what is high 3 2 4 5
- Separate in flexible (events) and generic characteristics and transmission 2
- Include seasons (summer, winter, holidays), but it is depended on the disease and place 1 3 5
- It is country specific what is high and low. This is hard to standardize and depends on preparedness 2 3 5
- Exclude the transmission characteristics, because they don't add to introduction 3
- Density is relevant for when introduction occurs, what the impact will be. Same for contact between community and travelers 3
- Flexible characteristics can indeed be an indication for reassessing vulnerability. Name it in the introduction of the tool for example 3'
- Transmission characteristics are important to take into account 4
- Include transmission. Both are important 5
- Many of the characteristics can't be standardized with low, middle, high vulnerability. Difficult to put scores and be very inclusive. 1
- Difficult to state high a low amount: suggestion; amount compared to normal 3
- I would go for absolute number of travelers, but difficult to define what is low and what is high 4

Original characteristic	**Pilot suggestions** - **More suggestions in favor: take over suggestion** - **Equal amount in favor and against: look at literature** - **If not applicable to the aim of the study or not practical for the tool: exclude suggestion**	**Literature**	**New characteristic**
Volume of travelers Description The average volume of travelers at the port per year Level Low amount of travelers <... High amount of travelers >...	- number of travelers entering the country (contrary to transit passengers) 2 - Type of traveler is irrelevant 2 3 - Everybody coming to your port can be of risk 3 - Difficult to state high a low amount: suggestion; amount compared to normal 3 - Count in groups. Depends on port what is much. 0-1000, 1000-2000 etc per day. 5 - The capacity is also of influence regarding the risk of importation at ports 1 - It is not possible to standardize with numbers. This depends on the country and capacity 1	Number of cruise passengers in Hamburg (2019) is 810,000, in 2018: 900,000 https://www.statista.com/statistics/426398/port-of-hamburg-number-of-cruise-passengers/ busiest passengers ports differs from 4.7 million to 13.1 million (1-20 ports in 2015) per year. 13 million passengers is the port of Dover https://en.wikipedia.org/wiki/List_of_busiest_ports_in_Europe Currently, the port of Dover transports almost 11 million passengers per year. A decrease compared to 13 million. https://www.doverport.co.uk/about/performance/	**Number of ships** Description The number of travelers entering the country via your port (Introduction vulnerability) Levels < 300 thousand/month 300- 800 thousand/month > 800 thousand/month
Travelers from endemic areas Description Travelers from geographic areas where other infectious diseases are endemic of epidemic than in the country of origin Level Low/no number of travelers from areas with different endemic diseases (≤...%) High number of travelers from areas with different endemic diseases (>...%) OR Level Separated based on countries/areas	- Direct connections between the port and endemic areas 1 3 4 - Very important to know the direct connections, not only the areas, but also mean of transport (related to vectors; cargo) 4 - Also important is the epidemic situation in country of the port. It helps to define the risk to my country (no incidents in your country, the risk is higher). 5 - Other events than standard routes need to be monitored. Can't be standardized. Differentiate between ongoing connections and events. 1 - It can be asked where ships come from; cruise and cargo ships can be asked where it has been at which pot and which date 3 - Take into consideration ships that come from Africa and Asia and don't direct come to the port 3 - Include season 1 - Look at incidence level n the endemic country 3 - Difficult to say within EU from which country they came, other continents can be checked by passport, however, sometimes you don't know 3 - Declaration of health can be checked and make up for investigation 3	Most found literature was regarding air travel, which is a risk characterization for importation (Zhang, 2016), but also general importation is mentioned in the found literature. This involves also other forms of transportation then air travel, such as automobile, train and ship (Semenza, 2016). International travel from areas with epidemic and endemic diseases has resulted in continuous importation of infected person into Europe (Semenza, 2016).	**Ships from risk areas** Description Ships with connections to geographic areas where other infectious diseases are endemic or epidemic than in the country of origin (Introduction vulnerability) Levels Not many ships from geographic areas where other infectious diseases are endemic or epidemic than the ones in your country Many ships from geographic areas where other infectious diseases are endemic or epidemic than the ones in your country

Duration of the journey Description The duration of the traveler's journey between the start and end location Levels A lot (%) short distance travelers A lot (%) of long distance travelers OR Levels More than__ % arrives after a travel of ≤__ hours in a vehicle shared with others More than__ % arrives after a travel of …. -… hours in a vehicle shared with others More than__ % arrives after a travel of ≥__ hours in a vehicle shared with others	- the longer you are on your journey, the more chance to develop symptoms/the diseases 2 3 - Difficult to standardize; duration is disease specific 3 5 - Outside EU much easier to check the origin of travelers than inside EU. When travelling via hubs or different ways of travelling the duration is hard to know. Level could be; do you receive many international ships 3 - levels: do you receive many international cruises 3 - not sure if the travelers journey is important 4 - Create categories with e.g. flu, covid, shorter time and tuberculosis longer time 5 - Overlap with type of conveyance (also important here) 1. - Disease depended. Can't be standardized. 1 - Short duration can also be of risk, even higher if there is an outbreak (more people in close contact) 1	Duration of exposure is of importance to the risk of infectious disease transmission (De Cao, 2014: the relative importance of frequency of contacts and duration of exposure to the spread of directly transmitted infections) Mini cruises 1-5 nights https://www.cruiseandmaritime.com/destination/mini-cruises/ World cruisese range from 22 days over 100 days https://www.princess.com/cruise-search/results?trade=W&ship=CP&date=0521,0621,0721,0821	**Duration of the journey** *Description* The average duration of the travelers' total journey including transfers. Levels Most of the travelers are travelling < 5 days Most of the travelers are travelling between 5 - 21 days Most of the travelers are travelling > 21 days
Vaccination status of travelers Description The percentage of travelers that received the vaccination for the vaccine-preventable diseases Levels High percentage of travelers is vaccinated Low percentage of travelers is vaccinated OR Levels High control on vaccination status of travelers Low control on vaccination status of travelers	- More important is vaccination status of country of origin 4 - This characteristic has overlap with endemic areas. Difficult to measure the vaccination status of travelers 3 4 - Crew members of risk, guess can be made on nationality. It is complicated and vaccination is not obligatory. Passengers on a cruise ship are from all over the world. 1 - There are traditional connections, so there is knowledge from certain amount of people from certain parts of the year where they come from 1. - More related to departing travelers 3 - Use incidence in the country travelers come from as level instead of vaccination status 3 - data on vaccination status of country is available 5 - You can know where crew members bordered the ship 4		X
International trade via port Description The amount of trade (cargo) between countries. Levels Low amount (%) of imported and exported products (life stock and biological products)* High amount (%)of imported and exported products (life stock and biological products)* OR Levels	- Threshold will be hard to find. Use big amount or most of the cargo and change it to trade. National trade can also occur 2 - Important for vectors and maybe on chemical 3 - Foodborne/life stock: mostly only exported from Europe, not imported. Differentiate between import and export 3 - Important. Animals, life animals, products from animals are of high risk 4 - Important, but for infectious disease risk of importation low. Affects chemical and vectors 1. - Foodborne diseases and animals is very specific with type and cargo 1 - People working at the port are of the highest risk 5 - Trade of food/life stock is not relevant 5	Global trade, import and export of good and services across international borders pose higher risk of imported diseases. Most infectious disease threat events in Europe occur by food and water borne diseases, trade and tourism (Semenza, 2016: Determinants and drivers of infectious disease threat events in Europe)	**Trade** Description The type of cargo imported via the port. Types of cargo are: non-biological goods, biological, animal products, life stock (Introduction vulnerability) Biological = e.g. plants, wood, pertaining to biology (e.g. products from animals (food: eggs, meat, milk), products from animals which have not been treated (e.g. heated, cleaned)) Non-biological = non pertaining to biology (e.g. furniture, clothes, books)

Absolute value of imported and exported products (life stock and biological products) is lower than Absolute value of imported and exported products (life stock and biological products) is higher than …	- There is knowledge (more or less) at ports regarding the content of the trade 1		Livestock = defined as domesticated animals raised in an agricultural setting to produce labor and commodities such as meat, eggs, milk, fur, leather, and wool. Levels non-biological goods biological goods (possibly in combination with non-biological goods) livestock (possibly in combination with biological goods and non-biological goods)
Different vessels at port Description Certain type of vessels at point of entry can accelerate the importation of infectious diseases Levels …% of …	- Change vessels into conveyance 2 - From technical point; much easier to deny ships that don't meet the technical fit (the same with ships). It doesn't happen often 2 - Vessels is related to type of cargo (ferries, cruises, cargo ships). 1 - Daily cruises (small ships) can pose risk. Many people from different areas, therefore more opportunities for everyday interactions among different people. Different risk profiles for types of vessels. Difficult to standardize. 1 - High risk for port depends on kind of ship. Old ships have lesser firefighting system, but not related much with infectious diseases, more with chemical 3 - Overlaps much with trade. Trade is more important than conveyance. 3 - Can't compare cruises vs cargo. They are different and can't be compared. 3 - Ferries not much of risk, just a few hours, compared to cruises which stay longer together. 3 - Ferries pose high risk, transport a lot of people. Cruises have better health conditions compared to ferries. 4 - Maybe some overlap with number of travelers and endemic areas 4 - Cruises pose high risk with a lot of people 5 - Amount of vectors can be a characteristic; Transfer of vectors from country of origin to country where the vector is not located 2 - Maybe cargo more of risk because they stay on water during pandemic 5	Ferries have a higher risk of contamination of legionella then cruise ships (Pasqualina, 2017: legionella risk assessment in cruise ships and ferries). 91% of the ferries samples tested positive compared to 9% of the cruise ships. Earlier studies found 86% positive tested ferries and 40% of positive tested yachts. In cruises an infected person can cause an off season outbreak among travelers (Miller, 2000: cruise ships: high-risk passengers and the global spread of new influenza viruses) It is disease depended which conveyances are of more risk. This is in line with the information from the pilots. However, a distinction can be made between the recreational ships and ferries/cruises	**Type of conveyance at port** Description: Types of conveyances at port. Levels (low to high vulnerability): The majority of the ships are recreational ships (e.g. yachts, sailboats) The majority of the ships are cargo ships The majority of the ships are ferries The majority of the ships are cruise ships
Climate Description The local climate in the region where the point of entry is located Levels ….. climate	- Is important for vectors, but probably not for infectious diseases 1 2 3 4 5 - Most important for ports 3 - Local climate can be of importance. In a good climate new vectors can survive 3		X
	- Transit passengers are different from passengers entering the country 2 - Transit passengers contribute much less than other travelers. It also depends on the contact transit passengers have (time, close contact etc). 3		X

	- layovers are of risk; spend a lot of time at port then the disease can be transmitted at the port (especially in closed spaces). 3 4 5		
	- not only amount of travelers, but also density of travelers are of importance to the spread at port (this is in line with time spend on port) 2 3 4 5		**Density of population at port** Description Places where travelers are close to each other at the port (e.g. check in desk, customs, waiting areas) (Transmission vulnerability) Levels There are not many places where travelers are in close contact to other travelers There are many places where travelers are in close contact to other travelers
	- Facilities on the port used by local community. Frequent contact between travelers and local community can pose a risk 2, 3, 4, 5		**Contact between local community and travelers at port** *Description* Some ports allow the local community that will not travel to use the port facilities, such as shops. Local community = citizens who can shop at the facilities of the port and are not planning to travel. This excludes employees of the port (Transmission vulnerability) Levels The local community can not use facilities at the port The local community can use the facilities at the port

6. Expert 1
7. Expert 4 & 5
8. Expert 6
9. Expert 7
10. Expert 8 & 9

Appendix F: suggestions panel ground-crossings

General suggestions
- Write threshold; what is low what is high 1 3 2 4 5
- Separate in flexible (events) and generic characteristics and transmission 2
- Include seasons (summer, winter, holidays), but it is depended on the disease and place 1 3 5
- It is country specific what is high and low. This is hard to standardize 2 3 5
- Exclude the transmission characteristics, because they don't add to introduction 3
- Density is relevant for when introduction occurs, what the impact will be. Same for contact between community and travelers 3
- Flexible characteristics can indeed be an indication for reassessing vulnerability. Name it in the introduction of the tool for example 3'
- Transmission characteristics are important to take into account 4
- Include transmission. Both are important 5
- Specific PoE handle specific vehicles (some just trains, some only road or certain types of cargo) 1
- Travelers can combine different means of transportations 1

Original characteristic	**Pilot suggestions** - **More suggestions in favor: take over suggestion** - **Equal amount in favor and against: look at literature** - **If not applicable to the aim of the study or not practical for the tool: exclude suggestion**	**Literature**	**New characteristic**
Volume of travelers Description The average volume of travelers at the ground crossing per year Level Low amount of travelers <…. Medium number of travelers …-…. High amount of travelers >….	- Type of traveler is irrelevant 2 3 - Definition of small and big PoE depends on connectivity with country (.lot of roads or small roads, city centre at the border etc). 1 - A lot of big busses can be indicator for more vulnerable ground crossing 1 - Number of passengers is easier to report than number of cargo 1 - A lot of countries have only ground crossings within Europe 3 - Count in groups. Depends on airport what is much. 0-1000, 1000-2000 etc per day. 5 - Difficult to state high a low amount: suggestion; amount compared to normal 3 - Everybody coming to your ground crossing can be of risk 3 - I would go for absolute number of travelers, but difficult to define what is low and what is high 4 - Extra number of people increases risk (exact number). Each person can bring an infectious disease 1	Some ground crossings can have 30-50,000 travelers per day. https://www.euro.who.int/en/health-topics/health-emergencies/international-health-regulations/points-of-entry/points-of-entry/ground-crossings Number of travelers crossing Polish border: 3.5 million (Russia), 8.9 million (Belarus), 21.5 million (Ukrain), Number of road transports crossing polish border: 2 million (Russia), 4.4 million (Belarus), 6 million (Ukrain) (200128 Ground crossings state of the art report)	**Number of incoming travelers** Description The number of travelers entering the country via the ground crossing (introduction vulnerability) Levels < 300 thousand per month 300- 900 thousand per month >900 thousand per month
Travelers from endemic areas Description The number of travelers that arrive from geographic areas where other infectious diseases are endemic or epidemic than in the country of origin Level Low/no number of travelers from areas with different endemic diseases (<…%) Any number of travelers from areas with different endemic diseases (…-…%) High number of travelers from areas with different endemic diseases (>…%) OR Level	- Direct connections between the ground crossing and endemic areas 1 2 3 4 - Difficult to say within EU from which country they came, other continents can be checked by passport, however, sometimes you don't know 3 - Knowledge of travelers from endemic areas is available; not on daily level, but in case of an outbreak and permanent connections are known 2 - Look at incidence level o the endemic country 3 - Very important to know the direct connections, not only the areas, but also mean of transport (related to vectors; cargo) 4 - Also important is the epidemic situation in country of the ground crossing. It helps to define the risk to my country (no incidents in your country, the risk is higher). 5 - Identify outbreak spreading 1	Most found literature was regarding air travel, which is a risk characterization for importation (Zhang, 2016), but also general importation is mentioned in the found literature. This involves also other forms of transportation then air travel, such as automobile, train and ship (Semenza, 2016). International travel from areas with epidemic and endemic diseases has resulted in continuous importation of infected person into Europe (Semenza, 2016).	**Travelers from risk areas** Description Transportation via direct connections with geographic areas where other infectious diseases are endemic or epidemic than in the country of origin (Introduction vulnerability) Levels No direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country Direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country

Separated by countries/areas			
Duration of the journey Description The duration of the vehicle on the road between the start and end location Levels More than__ % arrives after a travel of <…. hours in a vehicle shared with others More than__ % arrives after a travel of …. -… hours in a vehicle shared with others More than__ % arrives after a travel of >…. hours in a vehicle shared with others	- the longer you are on your journey, the more chance to develop symptoms/the diseases 2 3 - Difficult to standardize; duration is disease specific 3 5 - Duration in the vehicle only increases the transmission in the vehicle. Does not change the risk of importation. Some ground crossings may be aware that they serve the same bus companies on a regular bases, so aware of the location of origin of the travelers 1 - Levels could be: do you know which countries are coming by your ground crossing or do you receive a lot of long journey travelers (long train, local train, bus companies, distances etc) 1 - Outside EU much easier to check the origin of travelers than inside EU. When travelling via hubs or different ways of travelling the duration is hard to know. Level could be: do you receive many international flights 3 - not sure if the travelers journey is important 4 - Create categories with e.g. flu, covid shorter time and tuberculosis longer time 5 - Neighboring countries from an outbreak country can be more at risk for importation 1 - Maybe overlap with endemic areas 1	Duration of exposure is of importance to the risk of infectious disease transmission (De Cao, 2014: the relative importance of frequency of contacts and duration of exposure to the spread of directly transmitted infections) Netherlands to Russia by car is 25 hours, by bus 2 days. https://www.rome2rio.com/s/Netherlands/Russia	**Duration of the journey** *Description* The average duration of the traveler's total journey including transfers. Levels Most of the travelers are travelling < 3 hours Most of the travelers are travelling between 3 - 24 hours Most of the travelers are travelling > 24 hours
Vaccination status of travelers Description The percentage of travelers that received the vaccination for the vaccine-preventable diseases Levels High percentage of travelers is vaccinated Low percentage of travelers is vaccinated OR High control on vaccination status of travelers Low control on vaccination status of travelers	- This characteristic has overlap with endemic areas. Difficult to measure the vaccination status of travelers 3 4 - Might be relevant in case you know there is an outbreak, to ask for vaccination status of travelers. But mostly only advise and provide information 1 - Not involved, only for providing information 3 - not feasible to know percentages or amount of at border control. It would be ideal. More realistic: knowledge at poe of the vaccination status (yes/no) 1 - People working at border control need to be vaccinated 1 - No information of this at the ground crossing 5 - More important is vaccination status of country of origin 4 - It is also a challenge, because not every country has information regarding the vaccination status 2 - Use incidence in the country travelers come from as level instead of vaccination status 2 3 - data on vaccination status of country is available 5 - Migrants overcomplicate things. Add as disclaimer to the tool 1		X

International trade via ground crossing Description The type of cargo between countries Levels <30% of GDP is low amount of trade 30-90% of GDP is medium amount of trade >90% is high amount of trade OR Low amount (%) of imported and exported products (life stock and biological products)* High amount (%)of imported and exported products (life stock and biological products)*	- The amount of imported and exported products is not always know, but can be of great importance to the vulnerability of an airport 2 - Foodborne/life stock: mostly only exported from Europe, not imported. Differentiate between import and export 3 - Important. Animals, life animals, products from animals are of high risk 4 - Designated points of entry accept certain kind of cargo and animals and take random samples. Most of the time cargo passes the border and certificates are checked. Risk might not be at the ground crossing, but more at the warehousing point. This probably varies from country and cargo 1 - Threshold will be hard to find. Use big amount or most of the cargo and change it to trade. National trade can also occur 2 - Important for vectors and maybe on chemical 3 - Trade of food/life stock is not relevant 5	Global trade, import and export of good and services across international borders pose higher risk of imported diseases. Most infectious disease threat events in Europe occur by food and water borne diseases, trade and tourism (Semenza, 2016: Determinants and drivers of infectious disease threat events in Europe)	**Type of imported cargo** Description The type of cargo imported via the port. Types of cargo are: non-biological goods, biological, animal products and live stock (Introduction vulnerability) Biological = e.g. plants, wood, pertaining to biology (e.g. products from animals (food: eggs, meat, milk), products from animals which have not been treated (e.g. heated, cleaned)) Non-biological = non pertaining to biology (e.g. furniture, clothes, books) Livestock = defined as domesticated animals raised in an agricultural setting to produce labor and commodities such as meat, eggs, milk, fur, leather, and wool. Levels non-biological goods biological goods (possibly in combination with non-biological goods) livestock (possibly in combination with biological goods and non-biological goods)
Different vessels at ground crossings Description Certain type of vessels at point of entry can accelerate the importation of infectious diseases Levels ...% of ___	- Change vessels into conveyance 2 - Maybe already covered in length of journey. Partly covered by journey length. Small busses is mostly locally, big busses mostly long distance. Some train points of entry also are complete separate from road part. People working on trains are not involved with road and vice versa. 1 - Amount of vectors can be a characteristic; Transfer of vectors from country of origin to country where the vector is not located 2	Public transportation (bus, tram) can pose a higher risk for transmission https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6280530/ https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-11-16 Trains also can accelerate the spread of influenza (Browne, 2016)	**Type of conveyance at ground crossings** Description Types of conveyances at ground crossing Levels: The majority of the transportation vehicles are small busses and cars The majority of the transportation vehicles are large busses, trains
Climate Description The local climate in the region where the ground crossing is located Levels ..... climate	- Is important for vectors, but probably not for infectious diseases 1 2 3 4 5		X
	- Transit passengers contribute much less than other travelers. It also depends on the contact transit passengers have (time, close contact etc). 3 - layovers are of risk; spend a lot of time at ground crossing then the disease can be transmitted at the ground crossing (especially in closed spaces). 3 - Transit passengers are different from passengers entering the country 2		**Number of transit passengers** Description The average duration transit passengers spent at the ground crossing (Transmission vulnerability) Duration = average time of transit passengers at ground crossing * amount of passengers per month Levels: ≤ 900 thousand transit hours 900 – 2400 thousand transit hours > 2400 thousand transit hours

	- not only amount of travelers, but also density of travelers are of importance to the spread at ground crossing (this is in line with time spend) 2 3 5		**Density of population at ground crossing** Description Places where travelers are close to each other at the ground crossing(e.g. check in desk, customs, waiting areas) (Transmission vulnerability) Levels There are not many places where travelers are in close contact to other travelers There are many places where travelers are in close contact to other travelers
	- Facilities at poe used by local community. Frequent contact between travelers and local community can pose a risk 2 5		**Contact between local community and travelers at ground crossing** *Description* Some ground crossings allow the local community that will not travel to use the port facilities, such as shops. Local community = citizens who can shop at the facilities of the port and are not planning to travel. This excludes employees of the port (Transmission vulnerability) Levels The local community can not use facilities at the ground crossing The local community can use the facilities at the ground crossing

11. Expert 2
12. Expert 4 & 5
13. Expert 6
14. Expert 7
15. Expert 8 & 9

Appendix G: suggestions panel

3.2.1. Volume of travelers

Based on the suggestions of the panel a differentiation between number of travelers entering the country and transit passengers had been made for all PoE. Also, several pilots suggested to define low and high in numbers. In previous versions of the characteristics the option to divide the levels in type of travelers was suggested. However, most of the pilots indicated that this is not the best way to divide the levels. It is disease specific which type of traveler is at risk. From literature and the pilots the remark was made that everyone entering the PoE can be a risk. This substantiates the division between transit passengers and travelers entering the country made by the panel. Besides, a new characteristic was suggested: contact between local community and travelers at the airport. Contact between travelers and local community can increase the risk of the disease spreading at the PoE and even entering the country.

3.2.2. Travelers from endemic areas

The levels of this characteristic are changed to connection or no connections with endemic areas for airports and ground crossings. For ports this is changed to not many and many ships from endemic areas, because ships often travel via a majority of ports. The amount of travelers could also be overlapping with the volume of travelers and according to the panel, a connection with an endemic area is already a risk. In the panel suggestions in favor of looking into hubs and against them are mentioned. There is no conclusive literature found that showed hubs would be of more risk and also for practicality it is not in favor to add this characteristic to the questionnaire. If a hub receives travelers from endemic countries, this will also be shown in the connectivity between the hub and endemic areas. Besides, the epidemic situation of a country is not related to the vulnerability of the PoE. Therefore, this suggestion is not taken into account for the questionnaire. However, the risk can be higher in case a disease is not in the country yet. Therefore, the characteristics will mention other infectious diseases than the ones in your country.

3.2.3. Duration of the journey

The panel suggested to define ‘duration of the journey’ as a transmission characteristics instead of an introduction characteristic. The longer a passenger is on journey, the more chance (s)he develops symptoms or spreads a carrying disease. However, this is disease specific and difficult to standardize. Both arguments were mentioned by an equal amount of pilots. Based on literature, the duration of the journey is important. Therefore, this characteristic is included as transmission characteristic for all PoE.

3.2.4. Vaccination status of travelers

‘Vaccination status of travelers’ is removed from the list of characteristics. The panel suggested that there is overlap with other characteristics and the

connectivity with endemic countries is an important factor for this characteristic. Also, it is very difficult to know the vaccination status of travelers. Most of the time a vaccination is also not required, but suggested.

3.2.5. Trade via point of entry

The panel suggested to adjust the levels of the 'trade via PoE' characteristic. Life stock, animals and biological products were mentioned by most pilots as a risk. Besides, the pilots also mentioned that importation is risk for the PoE, but not export. Export is a risk for the receiver. Some pilots mentioned that this characteristic is more relevant to vectors. However, literature showed the importance of food- and waterborne and livestock diseases. Furthermore, some suggestions were made regarding vectors or preparedness (e.g. hospitals nearby airport). These suggestions are not relevant for the current study.

3.2.6. Different conveyances at point of entry

Based on the suggestions made in the pilots and the literature the type of conveyance is a relevant characteristic for the questionnaire regarding ports and ground crossings. It is in relation to the density of the travelers at the PoE and the amount of travelers. This poses overlap with the amount of travelers and density at the port. However, ports and ground crossings can receive a lot of daily traffic or recreational ships that don't pose a high risk of international spread of infectious diseases, but do receive a lot of visitors. Literature also showed that cruises and ferries could pose a higher risk.

Furthermore, the characteristic is removed for the questionnaire regarding airports, because it is irrelevant. There are not many recreational flights and most of the flights have a clear defined start and end point of their journey. Besides, the type of conveyance is not related to the model, but to the maintenance and changing of HEPA filters. This can be checked before arriving at the airport.

3.2.7. Climate

Climate has been removed based on suggestions from the panel. The climate is relevant for vectors, but not so much for infectious diseases.

3.2.8 Other suggestions

Moreover, suggestions were made to separate transit passengers from passengers entering the country. A layover is a risk. When spending more time at a PoE, the case can develop symptoms and transmit the disease to others. This characteristic is added for airport and ground crossing. For ports the transit time is less relevant, because transit don't occur much at ports. Besides, the suggestion was made to add the density of travelers. Most pilots pointed out that besides volume of travelers and time spend at the airport, the density of the population can also increase the risk of transmission. This is in line with previous found literature. Furthermore, the

panel suggested to add the possibility for local community to use the facilities of the airport. Contact between travelers and local community can increase the risk of the disease spreading at the PoE.

Appendix H: Respondents

Respondent	PoE	Expert/control	Competent (>8)	Include?
1	Airport	Expert	Yes	No, consistency
2	Airport	Expert	Yes	Yes
3	Airport	Expert	No	Yes
4	Airport	Control	No	Yes
5	Airport	Expert	No	Yes
6	Airport	Expert	Yes	Yes
7	Airport	Expert	No	Yes
8	Airport	Expert	No	Yes
9	Airport	Control	No	No, consistency
10	Airport	Expert	No	No, time
11	Port	Expert	No	Yes
12	Port	Expert	Yes	Yes
13	Port	Expert	Yes	Yes
14	Port	Control	No	Yes
15	Port	Control	No	No, consistency
16	Port	Control	No	Yes
17	Port	Expert	No	No, no trade-offs
18	Port	Expert	No	Yes
19	Port	Expert	No	No, consistency
20	Ground	Expert	No	No, no trade-offs
21	Ground	Expert	No	No, no trade-offs
22	Ground	Expert	No	Yes
23	Ground	Expert	No	Yes
24	Ground	Expert	Yes	Yes
25	Ground	Expert	Yes	Yes

Appendix I: Final characteristics and levels

Airport	Port	Ground crossing
Number of travelers entering the country (excl transit passengers) • < 1 million per month • 1-2 million per month • > 2 million per month	Number of travelers entering the country (excl transit passengers) • < 300 thousand per month • 300-800 thousand per month • > 800 thousand per month	Number of travelers entering the country (excl transit passengers) • < 300 thousand per month • 300-900 thousand per month • > 900 thousand per month
Travelers from risk areas • No direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country • Direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country	Travelers from risk areas • Not many ships from geographic areas where other infectious diseases are endemic or epidemic than the ones in your country • Many ships from geographic areas where other infectious diseases are endemic or epidemic than the ones in your country	Travelers from risk areas • No direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country • Direct connections with geographic areas where other infectious diseases are endemic or epidemic than the ones in your country
Duration of the journey • Most travel < 3 hours • Most travel between 3-8 hours • Most travel > 8 hours	Duration of the journey • Most travel < 5 days • Most travel between 5 - 21 days • Most travel > 21 days	Duration of the journey • Most travel < 3 hours • Most travel between 3 - 24 hours • Most travel > 24 hours

Type of imported cargo • non-biological goods • biological goods (possibly in combination with non-biological goods) • livestock (possibly in combination with biological goods and non-biological goods)	Type of imported cargo • non-biological goods • biological goods (possibly in combination with non-biological goods) • livestock (possibly in combination with biological goods and non-biological goods)	Type of imported cargo • non-biological goods • biological goods (possibly in combination with non-biological goods) • livestock (possibly in combination with biological goods and non-biological goods)
Transit passengers • < 3 million transit hours • 3-6 million transit hours • > 6 million transit hours		Transit passengers • < 900 thousand transit hours • 900-2400 thousand transit hours • > 2400 thousand transit hours
Density of population at PoE • There are not many places where travelers are in close contact to other travelers • There are many places where travelers are in close contact to other travelers	Density of population at PoE • There are not many places where travelers are in close contact to other travelers • There are many places where travelers are in close contact to other travelers	Density of population at PoE • There are not many places where travelers are in close contact to other travelers • There are many places where travelers are in close contact to other travelers
Contact between local communicty and travelers at PoE • The local community can not use facilities	Contact between local communicty and travelers at PoE • The local community can not use facilities	Contact between local communicty and travelers at PoE • The local community can not use facilities

at the ground crossing • The local community can use facilities at the ground crossing	at the ground crossing • The local community can use facilities at the ground crossing	at the ground crossing • The local community can use facilities at the ground crossing
	Type of conveyances at PoE • The majority of the ships are recreational ships (e.g. yachts, sailboats) • The majority of the ships are cargo ships • The majority of the ships are ferries • The majority of the ships are cruise ships	Type of conveyances at PoE • The majority of the transportation vehicles are small busses and cars • The majority of the transportation vehicles are large busses and trains