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Expanding Rotterdam The Hague Airport as a solution to the Dutch aviation capacity problem

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Abstract

The Dutch aviation industry encounters a problem in the future in terms of capacity. This research investigates a possible solution for the future capacity problem, expanding Rotterdam The Hague Airport to 100 thousand commercial aircraft movements. The research will examine whether expanding this airport is a beneficial solution, using a cost-benefit analysis. We will test if it is beneficial by looking at available benefits and costs of expanding. We found that expanding Rotterdam The Hague Airport has one comparative advantage, due to travel time savings, and one comparative disadvantage, due to noise pollution, over expanding other regional airports. The conclusion is that expanding Rotterdam The Hague Airport is a beneficial solution for solving the future capacity problem in the Dutch aviation industry.

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1. Introduction

According to the ‘Luchtvaartnota’ of the Dutch government, by 2050, the Dutch aviation industry will have around 800 thousand commercial aircraft movements. (IenW, 2020). Currently, Schiphol provides more than threequarters of commercial aircraft movements in the Netherlands (CBS, 2020). Nevertheless, with the ongoing growth of the aviation industry, Schiphol is facing a major problem. The Dutch government has decided that Schiphol is only allowed to grow up to 500 thousand aircraft movements per year. This means that they are already over 99% of this capacity maximum. In the future, Schiphol might expand to eventually 540 thousand aircraft movements (NU.nl, 2019), but this still will not be enough to keep up with the growth of the aviation industry in the future.

The Dutch aviation industry struggles with a capacity problem in the future. Due to the coronavirus outbreak worldwide, the demand for the aviation industry has made a significant drop and is one of the hardest-hit industries (Robotti, 2020). The ‘luchtvaartnota’ of the Netherlands' government, in which they forecast the aviation industry until 2050, still expect to be fully operational again within a couple of years (IenW, 2020).

Thus, the Dutch government must look further to keep the Dutch aviation industry competitive with other countries, without expanding Schiphol any further in the upcoming years. The second and third airports in the Netherlands by size, are Eindhoven Airport, with just over 40 thousand commercial aircraft movements, and Rotterdam The Hague Airport, with 18,4 thousand commercial aircraft movements (CBS, 2020). In this data, only commercial aircraft movements are considered. The growth of the Dutch aviation industry could thus be created by expanding one of these two airports. The advantage these two airports have over an expansion of Lelystad Airport is that these two airports are already operational for a longer time.

The geographical placement of Rotterdam The Hague Airport could be an advantage over Eindhoven Airport because its placement is in the Randstad area in the Netherlands, where more people live, and more companies are settled, and maybe travel time savings for passengers could be achieved. It takes less time for more people to get to the airport from their homes or businesses. The placement next to Rotterdam, the second-largest city in the

Netherlands, could also be an advantage because Rotterdam has the largest Port in Europe. The port's presence could lead to a lot of extra investments, which could benefit the growth of the airport (Dooms et al., 2013). This research will examine the economic impact of an expansion of Rotterdam The Hague Airport as a solution for the capacity problem in the Dutch aviation industry. Therefore, the following research question will be examined:

Is an expansion of Rotterdam The Hague Airport a beneficial solution for the capacity problem of the Dutch aviation industry?

This research will forecast the expansion of Rotterdam The Hague Airport with 100 thousand commercial aircraft movements by 2050. To examine the effects of this expansion, we are going to look at what the costs and benefits of expansion are going to be and to what extent they impact the decision to expand the airport. Next to that, the paper will also look at social costs in the form of externalities. To look at the benefits of this expansion, we will examine what the expansion might mean for the Dutch aviation industry and what it might mean for Rotterdam and the employment in the region. The impact of extra employment will be compared to the population of Rotterdam. Employees of the airport will probably live in cities near Rotterdam as well. But because impact of employment of the airport on the city of Rotterdam will show us comparable results as of impact on larger geographical areas, and it is easier if it is just compared to Rotterdam, we just estimate impact of employment on the city of Rotterdam.

2. Capacity problem Dutch aviation industry

As earlier mentioned, Schiphol is only allowed to grow up to 540 thousand movements per year. However, this will not far be enough to cope with the growth of the aviation industry. Therefore, the Dutch government is already for a long time looking for possible solutions. The leading solution to this was seen in the North Sea by the government, by building a large airport at sea, like the ones in Osaka and Hong Kong. Nevertheless, the plan to move a part of Schiphol to the sea is now at hold, due to the high investment cost and the already very crowded North Sea (De Vrees, 2019). The solution for the capacity problem can also not be found in the opening of Lelystad Airport in 2021, because the maximum capacity of the airport is first 25.0000 thousand movements, and can later be extended to 45.000 movements, which cannot be expected until 2043 (IenW, 2020).

This research will forecast an allocation of 100 thousand commercial aircraft movements by 2050 at Rotterdam The Hague Airport, as a possible solution for the capacity problem. The research question will be answered by looking at the costs and benefits of expanding the airport to 100 thousand commercial aircraft movements by 2050. The research will look every five years in the future until 2050, whether it is beneficial to expand or not. The research question will be answered with a few hypotheses that will be tested in the research. The hypotheses are divided into benefit hypotheses, and costs hypotheses. The benefit hypotheses are the following:

- The expansion of Rotterdam The Hague Airport has a positive impact on the employment for the region of Rotterdam.
- Moving charter flights to Rotterdam will increase Schiphol's hub function.
- An expansion of Rotterdam airport will generate travel time savings caused by its location.

Next to that, the research will look at the costs of expanding Rotterdam The Hague Airport, with the following hypotheses being tested:

- An expansion of Rotterdam airport harms emissions.
- By expanding Rotterdam airport, the goals of the Paris Agreement cannot be achieved.

- An expansion of Rotterdam airport hurts the near housing market prices.

Based on testing these hypotheses, eventually, an answer to the research will be formed. As mentioned earlier, a possible solution for the Netherlands' capacity problem will be examined by expanding Rotterdam The Hague Airport to 100 thousand commercial aircraft movements by 2050. Our start year of calculating is 2019. In 2019, the airport had 18.406 commercial aircraft movements and handled over 2 million passengers (CBS, 2020). Our forecast will be based on 100 thousand commercial aircraft movements by 2050. As earlier mentioned, per 5 years will be looked at, whether it is beneficial to expand or not. To compute the commercial aircraft movements for the years between 2019 and 2050, a formula for an average annual growth will be used, because it is a usual way to forecast demand in the aviation industry (IATA, 2018) (Graham, 2000).

The formula of annual growth rate usually used when forecasting for a more extended period is the compound annual growth rate (CAGR) formula. This formula is usually used for investments, to grow from its beginning balance to its ending balance, but can also be used for other types of annual growth (Investopedia, 2020). Therefore, it is useful for us when forecasting growth because, as mentioned, we will assume that the demand for the airport will grow at an average growth rate. The formula to compute compound annual growth rate is the following (Investopedia, 2020):

$$CAGR = ((EV/BV)^{1/n} - 1$$

In this formula, EV is the ending value, and BV the beginning value of the commercial aircraft movements. Our research's end value is our end capacity of 100 thousand commercial aircraft movements by 2050, and the beginning value is 18.406 commercial aircraft movements in our the year 2019 (CBS, 2020). N is the number of years between the end year and the beginning year, which is 31 in our example. This will give us the following percentage for the average annual growth rate of Rotterdam The Hague Airport.

$$CAGR = ((100.000/18.406)^{1/31} - 1 = 5{,}6114\%$$

benefit analysis, it is remarkable how many passengers these commercial aircraft movements generate. In 2019, the airport had over 2 million passengers (CBS, 2020). The number of passengers per plane over the last years is around 100 at Rotterdam The Hauge Airport (Ecocrys, 2015). For the year 2019, we see that this is a little higher, but that fluctuates per year (Rotterdam The Hague Airport, 2020). For the ease of this experiment, we use 100 passengers per plane. We start forecasting from our first year 2020 and then start our forecast based on commercial aircraft movements' growth. Therefore, our first forecasted passengers are less in 2020 than the year before, because, in 2019, the occupation per plane was more in that year. Nevertheless, in our further forecast in analyzing costs and benefits, we will only look from 2020 until 2050. The results can be seen in table 1 below.

	2019	2020	2025	2030	2035	2040	2045	2050
Commercial aircraft movements	18.406	19.439	25.540	33.557	44.090	57.928	76.111	100.000
Passengers	2.094.798	1.943.900	2.554.000	3.355.700	4.409.000	5.792.800	7.611.100	10.000.000

Table 1. Commercial aircraft movements and passengers per 5 year

CAGR = 5,611%

The added value of this research is that it tries to solve the future capacity problem of the Dutch aviation industry and investigates whether expanding Rotterdam The Hague Airport is a beneficial solution. The research of Ecocrys (2015), already investigated possible expansions of the airport, but we will investigate a more extensive expansion of the airport, and investigate all costs and benefits until 2050. Another added value of this research is the impact of the airport on employment for the region of Rotterdam. It investigates the future until 2050.

3. Theoretical framework

3.1. Cost-benefit Analysis

In evaluating projects, the cost-benefit analysis is one of the most used methods because it is probably the most comprehensive method of economic evaluation available (Robinson, 1993). The reason cost-benefit analysis is a popular method is that by assessing monetary values to costs and benefits, therefore offers an excellent method for evaluating projects (Robinson, 1993) (Layard, 1994). In our research, not only standard costs and benefits will be considered, but also social costs for society, like noise pollution and emissions, and social benefits for society, travel time savings for passengers. Therefore, we will compose a social cost-benefit analysis.

In a cost-benefit analysis, a trade-off must be made between all costs and benefits, and whether it is a beneficial project or not. In our example, there must be examined whether it is beneficial for Rotterdam The Hague Airport to expand or not. In a cost-benefit analysis, we should only accept a project if the benefits outweigh the costs (Williams, 1974). In our research, social costs and benefits will be also be considered. Thus, a project is beneficial when its benefits (B) outweigh its costs (C).

To evaluate a project in a cost-benefit analysis, a final step must be made to determine whether a project is beneficial or not. Researchers must look at whether a project is beneficial now when costs and benefits are further into the future. This can be done by the net present value (NPV). That is the difference between total benefits and total costs, after taking into account the time value of money (Kingston, 2001). The time value of money is the interest on money. The term r expresses this interest. To value projects, all costs and benefits must thus be made present, performed by the following formula (Kingston, 2001):

$$NPV = \sum (B_t - C_t) / (1 + r)^t$$

This is the formula to value a project at present and examines whether benefits (B) of a project outweigh the costs (C) of a project. Our research tries to forecast whether it is beneficial for Rotterdam The Hague Airport to expand or not, considering possible social costs and benefits. In evaluating per 5 years whether the airport should expand, different

methods of costs and benefits will be applied, with some based on numbers of scientific articles. Some of the used values for costs and benefits are all calculated in different years. Thus, it would be wrong to value them at the same rate. Therefore, we use a base year to forecast from, to value all costs and benefits equally.

Our base year we use for calculations is 2015 because of many values for costs and benefits used in our experiment based on earlier research of Ecocrys (2015) in an expansion of Rotterdam The Hague Airport. Therefore, some of the values must be adjusted and indexed to the year 2015. An indexed rate is an interest rate tied to a specific benchmark with rate changes based on the benchmark (Investopedia, 2020). The index number can be seen as a way to value a change in aggregate prices for a particular commodity over a year (Diewert, 1998). The formula to calculate the index price of benefits and costs in our further research will be as follows:

Price 2015 = Price year X * (index rate year X/100)

The formula adjusts the prices in a year to the price it was in 2015, based on the price index of the benefit or cost in another year. As earlier mentioned, it is essential sometimes to use index prices to give a fairer view in the later cost-benefit analysis. Per benefit or cost will be explained whether to adjust for interest rates or not. This will be explained later in the research. As earlier mentioned, we will examine per 5 years, whether it is beneficial to expand or not. The reason we should interpret the results is that in for example 2030, the estimated costs and benefits apply to that specific year, and are not summed up from previous years.

3.2. Types of airports

In this section, we will discuss the different types of airports and their functions. It is essential to understand what type of airport Rotterdam The Hague Airport is and investigate the possible costs and benefits of expanding. In general, three types of passengers can be seen at airports. Persons living in the region served by the airport who visit other regions by plane, Passengers living elsewhere who travel to the region by plane, and transfer passengers who

do not coincide with the airport (Hakfoort et al., 2001). We will look at two types of airports, a hub-airport, and a regional airport.

3.2.1. Hub-airport

The function of a hub airport is usually seen as airports with a vast preponderance of flights operated as part of a radial network by one carrier. In a few rare cases, there is a general recognition that a hub has two leading carriers, but this only applies to a few major airports in China and the United Stated (Button & Lall, 1999). A hub airport is often seen as a connecting airport for passengers, thus for passengers who do not coincide with the airport. A hub function can serve many more destinations for passengers than a regional airport, due to its connectivity. Because all flights go to one central point, the hub airport, many new destinations can be developed, compared to a point to point structure. This can be seen in figure 6.5. Passengers who use this connectivity, are mostly passengers flying with larger domestic airlines, like KLM in the Netherlands.

Schiphol airport is a hub-airport because it serves many passengers who do not coincide with the Netherlands' region. This can be seen with the size of the airport, one of the largest in Europe, and the size of the Netherlands, one of the smallest countries in Europe. Schiphol has over 70 million passengers (Schiphol Royal Group, 2020), and that makes it the third-largest airport in Europe by passenger size. More than half of the Schiphol flights are executed by KLM, which has Schiphol as its main base (Decisio, 2015). Over 36% of passengers do not coincide with the Netherlands, making Schiphol a large hub-airport (Schiphol Royal Group, 2019). A hub airport's importance is that, with capacity keeping constant, business flights add more value for the economy than low-cost carrier flights (Nijdam & Otgaar, 2014). There are still a lot of low-cost carrier flights at Schiphol, with airlines as Transavia or Easyjet. If these flights can be transferred to regional airports, there will be more space for connecting passengers at Schiphol, which will increase its value.

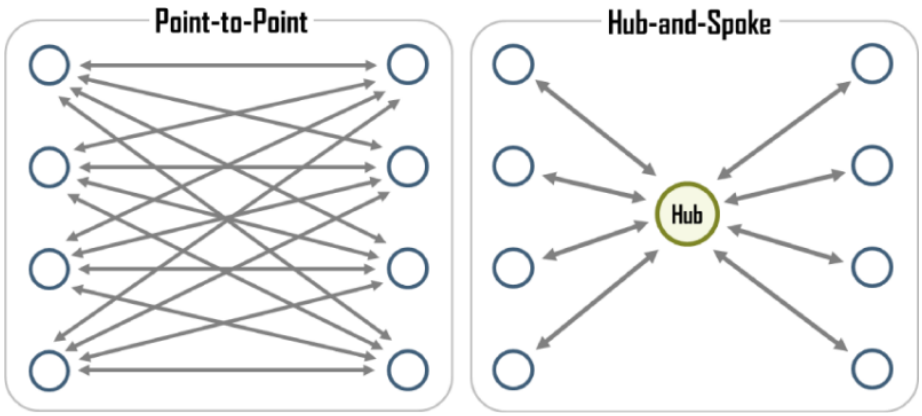


Figure 2. Different types of networks

3.2.2. Regional airport

A regional airport is an airport with a more point to point focus, like Rotterdam The Hague Airport. This is mostly for leisure passengers, who want to get to their destination as soon as possible, without any connecting flights. This is because leisure passengers tend to prefer one flight trip over an extra connecting trip. These airports are usually occupied by low-cost carrier airlines, because they choose regional airports and benefit substantially from low airport charges and station costs, compared to hub airports (Papatheodorou & Lei, 2006). Many passengers seem to enjoy low-cost carrier airlines, due to the similar levels of service quality and to their lower fares (Kim & Lee, 2011). The disadvantage a regional airport has is the amount of flight you should arrange to connect all origin-destination types. A hub airport needs a lot fewer flights to connect destinations, which can be beneficial for business travelers. This example can be seen in figure 2.

Rotterdam The Hague Airport is a regional airport because around 70% of travelers are leisure travelers (Ecocrys, 2015), and there are, even at the business travelers, almost none connecting passengers. The airport also does not have an airline that has Rotterdam The Hague Airport as its main base. Therefore, it can be concluded that it is a regional airport. Much extra value could be generated if low-cost carrier flight from Schiphol is being transferred to Rotterdam The Hague Airport because Schiphol is reaching its maximum of aviation movements. As earlier mentioned, a connecting traveler generates more value than a leisure traveler. Therefore, it could be beneficial for the Netherlands' aviation industry if the expansion of Rotterdam The Hague Airport is partly filled with low-cost carrier flights from

Schiphol. In this way, Schiphol can increase its hub function, which will add extra value to the Dutch economy.

3.2.3. Rotterdam The Hague Airport

Rotterdam The Hague Airport is mostly used by low-cost carrier airlines, with the largest being Transavia. Low-cost carrier airlines use point to point services as their strategic advantage and attract mostly leisure passengers by attracting passengers with low costs (Gillen & Lall, 2004). The number of leisure passengers for this research will be estimated at 70%, and the number of business travelers 30% (Ecocrys, 2015). This is important for our later research in costs and benefits because leisure passengers add less value to the economy through the aviation industry than business travelers (InterVistas, 2015). This will be explained further in the research to all costs and benefits. The airport has one operating runway taking care of all movements.

The airport currently provides 52.439 total air movements per year n 2019 (Rotterdam The Hague Airport, 2020). However, only 18,4 thousand of these movements are commercial aircraft movements, thus carried out by commercial airlines. The rest of the movements are mainly used for flight lessons or other types of traffic, which is mostly leisure flights of individuals (Ecocrys, 2015). The distribution of these flights can be seen in figure 3, where we can see that only less than half of the flights are commercial aircraft movements. In table 5 in the appendix, we see all other different types of movements. The small traffic movements are mostly learning flights or leisure flights. There are also some helicopter movements and general aviation movements, which are mostly used for police flights. The big traffic movements are mostly governmental flights (Ecocrys, 2015). Then, at last, the commercial aircraft movements. These are the regular flights executed by passenger airlines. This is also the category we will examine by forecasting commercial aircraft movement growth to 100 thousand movements by 2050.

As earlier mentioned, this research examines the possibility of an expansion of Rotterdam The Hague Airport to 100 thousand commercial aircraft movements by 2050. This will mean that there will be a lot more movements in total because all other types of movements will be kept constant. This is important in examining whether the airport must

expand or not, because the other types of movements will sometimes be considered in some analysis, and sometimes left out of consideration because only the commercial aircraft movements will then be necessary. This will be explained later in the research.

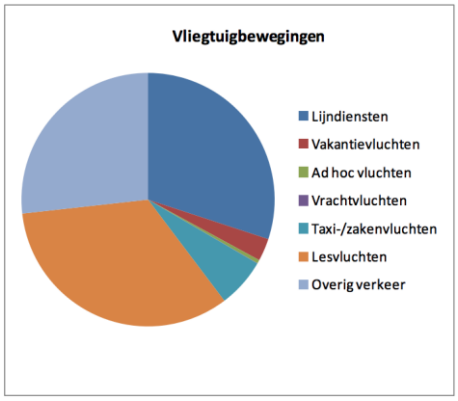


Figure 3. Type of aircraft movements at Rotterdam The Hague Airport

3.3. Population of Rotterdam

When we want to compare the growth of employment to the growth of population in Rotterdam, we first must look at the growth of the population of Rotterdam in general, and the percentage of the people that are working. Until around 2035, the number of people living in Rotterdam is based on a forecast of the Dutch central database (PBL & CBS, 2019). Therefore, we use this data to predict the total population of Rotterdam until 2035. To predict population growth from 2035 until 2050 is a little bit more difficult. But the expectation will use the same growth rate to predict the population of Rotterdam until 2050.

To predict what the impact of the expansion of the airport is on the employment of the city of Rotterdam, it is better to look at the working population of the Netherlands. The Netherlands will the upcoming years, get some trouble with an aging population (Garssen, 2011). The problem is that we will get a relatively smaller group of people working because more people are retiring in the upcoming years. This is since many people were born after the second world war, and they will all retire in the coming years. This generation is called the baby boomers (Knickmann & Snell, 2002). Therefore, the percentage of people over 65 will grow from 15% in 2020 until 19% in 2035 (PBL & CBS, 2019). From 2035 until 2050, the percentage of people over 65 in the city of Rotterdam is expected to grow from 19% in 2035 until 21% in 2050 (PBL & CBS, 2019), this is a slight decline in growth of the population over 65 years old in Rotterdam.

The percentage of people until 19 years old, a generation that will also not work, is around 21% of Rotterdam's population. This percentage will remain relatively the same from 2020 until 2050 (PBL & CBS, 2019). Therefore, we keep this percentage for all years constant at 21%. The calculations of the working percentages of the total population, as well as the total working population in the city of Rotterdam, is given in table 4 and will be used when comparing growing employment at the airport with the working population of Rotterdam.

	2020	2025	2030	2035	2040	2045	2050
Total population	652.100	686.200	712.800	723.300	734.215	745.295	756.541
Percentage 20-65 years old	64%	62,67%	61,33%	60%	59,33%	58,67%	58%
Working population	417.344	430.042	437.160	433.980	435.610	437.265	438.794

Table 4. Future population of Rotterdam

4. Costs

In this section, we will discuss the costs externalities generated by the expansion of Rotterdam The Hague Airport to 100.000 commercial aircraft movements per year by 2050. The main externalities that will be discussed are negative externalities due to noise and emissions. The costs of these externalities will also be calculated and considered when forecasting whether the airport should expand or not. First, an explanation of the costs of some emissions generated by the aviation industry will be given. The growth of emissions will also be compared to the Netherlands' environmental goals, to look at whether it is feasible to meet the requirements of the Paris Agreement when the airport expands. After that, a more in-depth look will be taken into the effect an expansion has on the houses near the airport due to noise pollution. There will also be looked at what the effect of this will be on the housing prices of the houses near the airport. In the end, some other negative externalities will also be discussed, like congestion and security.

4.1 Investment costs

The expansion of Rotterdam The Hague Airport will also have investment costs, which must be considered when looking at whether it is feasible to expand or not. At the current time, the maximum capacity of commercial aircraft movements without any further construction is 23.254 (Ecocrys, 2015). This means that this will be enough for 2020, but not for the years after that anymore. To calculate the investment costs, only commercial aircraft movements are expected to increase to 100 thousand aircraft movements, and the other type of aircraft movements will be held constant.

The advantage the airport currently has is the fact that there is already an operational runway. It is unnecessary to add another runway in our experiment because one runway will be enough for our number of aircraft movements between 07.00 and 23.00. Two London airports with similar time restrictions, Gatwick and Stansted, whom both have around 200 thousand aircraft movements per year with only one runway (Londen Stansted Airport, 2017) (IVY HOLDCO LIMITED, 2019). Therefore, we can assume that one runway will be enough for our expansion of Rotterdam The Hague Airport and that we do not need to construct a second runway for our expansion to 100 thousand commercial aircraft movements.

Investment costs are necessary for an expansion of the airport, types of investment costs include construction costs, land and property costs and compensation, preparation and administration costs, and on-site supervision and testing (CE Delft, 2013). The construction costs are mainly based on the construction of terminal buildings, ground transportation links and other infrastructure, and parking garages, airport office buildings, and airfield pavements (Douglas & Lawson, 2003). These investment costs will be estimated for the complete analysis of whether the airport should expand or not.

4.2. Emissions

In 2016, almost all countries in the world signed the Paris agreement. The Paris agreement is a promise between countries of the United Nations, in which they agree on a couple of commitments for a better future in terms of climate change. The main goal of the Paris agreement is the hold the increase of global temperature well below two degrees Celsius above pre-industrial levels, with an actual goal of 1,5-degree increase (United Nations, 2015). This means that all the countries of the United Nations must act, that the global average temperature will not increase to well below two degrees Celsius compared to the temperature before the industrial revolution. Other underlying goals that the Paris agreement had were in terms of emissions. The first one was that the amount of CO2 emissions needed to be reduced by approximately 20 percent. The other was that the amount of market share of energy produced by renewable energy sources had to grow to around 20 percent of all energy produced in the world. The goal is to achieve these commitments around the start of the second half of the 21st century. If we want to look at the exact effect of an expansion of Rotterdam The Hague Airport will mean for the goals of the Paris agreement for the Netherlands, we must first investigate what these requirements are for the Netherlands, and to what extent the aviation industry will take part.

The main goal of the international policy on CO2 emissions is that by 2050, the amount of CO2 emissions is less than half as they were in 2005 (United Nations, 2015). For the outgoing and incoming flights, the Dutch government meets the same goals for the Paris agreement by 2050 as all other countries. Nevertheless, besides this goal for 2050, the Dutch government sets two other targets. The first one is that the amount of CO2 emissions is the same in 2030 as in 2005. The second one is that by 2070, the Dutch government wants that the CO2 emissions generated by the aviation industry are zero (IenW, 2020).

For the aviation industry, the Dutch government only must meet environmental goals for the emissions of domestic activities, such as domestic flights or ground activities at airports. The reason that emissions generated by the aviation industry are not separated per country is due to the cross-border character of the industry (De Rijksoverheid, 2019).
The Dutch government wants that by 2050, the amount of CO2 emissions of Dutch airports and domestic flights are zero (IenW, 2020). This includes all ground activities at airports.

Also, the Dutch government wants to have all flights within the 500-kilometer range to be fully electric.

Some other emissions play a role in global warming as well, emitted by the aviation industry. The ones that will be considered in this research next to CO2 are NOx and particulates. There is still much uncertainty for these emissions to what extent they play a role in the aviation industry. Therefore, the Dutch government does not set goals for these emissions in their environmental policy for the upcoming years (IenW, 2020). There will almost certainly be goals set for the amounts of these emissions, but the Dutch government first wants more investigation into these emissions. The European Commission will come in 2020 with an investigation in these emissions. After that, the Dutch government will adjust its policy on the possible requirements. Some measures could already be taken on the emission of nitrogen. NOx-emissions could be reduced by, for example, efficiency improvements in planes or fuel use, or by flying shorter distances (CE, Delft, 2017). Nevertheless, to take actual measures to reduce all the above emissions, further research must first take place. Therefore, they will not be considered in the discussion whether the requirements of the Paris agreement can be met or not, but the costs for the society for some of them will be discussed.

4.3 Noise Pollution

Noise pollution is an essential externality of the aviation industry. The airport will generate much extra noise when it increases its number of commercial aircraft movements. The reason why noise is such an essential externality of the aviation industry is that noise is often cited as the most undesirable feature of life in the urban community (Smith, 2004). The main reason people find noise very harmful is because people will have trouble sleeping due to noise pollution, which will lead to health problems (Lu & Morell, 2006). Because of these sleep problems, people find it very harmful to live close to airports, how closer people live to airports, and how more substantial the impact of noise is on their subjective mental well-being (Lawton & Fujiwara, 2016). The problem with measuring noise pollution on people's mental well-being is that it is often different between persons; thus, aviation noise is subjective. The reason behind this is that each person has a different tolerance level for noise (Smith, 2004), but one thing is sure, noise is an unwanted sound for everyone. The best way

to measure the social costs of noise is to look at the prices of houses close to airports, and to what extent to houses further away from the airport differ from the houses close to airports.

The loudness of a sound is measured in decibel (dB). The name of this is an honor to the founder of this system, Alexander Graham Bell. A decibel is one-tenth of a bel. The amount of decibel of a sound is increases on a logarithmic ratio. The amount of decibel can be calculated by using a logarithmic ratio of the actual sound pressure to a nominal value (Smith, 2004). Using this type of scale to calculate sound is that a doubling of sound will lead to an increase in the amount of decibel of 3. For example, if we look at the difference in decibel (dB) using the logarithmic scale between a sound X1, that is twice as large as a sound X2. This gives us the following formula:

L = Sound in dB

$L = 10 \text{ Log}_{10} (X1/X2) = 10 \text{ Log}_{10} (2/1) = 3.01 \text{ dB}$

We can conclude out of the logarithmic ratio of the calculation of differences in sound, that a sound that is twice as loud will lead to an increase of 3.01 in dB. For many people, this could be a strange scale to calculate an increase in sound, because it is not the doubling of a number most people are used to. To explain, a doubling of a sound of 70 dB will be equal to a sound of 73 dB. This will be the scale used in our research to investigate the social costs of expansion due to noise pollution. Noise pollution starts at a threshold because there is always surround sound, even when there are no planes yet. A generally accepted method to measure aviation noise is in Lden (L-day-evening-night). This variable represents the impact of noise on people during the entire day. This research starts to look at sounds over 40 decibels because sounds under 40 decibels are generally seen as background sounds (Chepesiuk, 2005). In estimating later social costs, this minimum of noise level is named N0.

As earlier mentioned, to investigate the number of social costs, we will look at the change in housing prices near the airport. However, to know to what extent noise the prices of houses impact, we must know how much an increase in decibel decreases the price of a house. We will look at the percentage decrease in houses near the airport per extra decibel. There are different percentage decreases used in similar experiments, varying from 0,5% to 1%, but the one we use in our research is a decrease of 0,8% (CPB, 2006). We use

this percentage because this is based on research done by the Dutch government on the impact of Schiphol on noise pollution for residents near Schiphol. Thus, an increase of 1 decibel will decrease the value of houses by 0,8%.

In the calculation of the decrease in house value of houses near the airport, the hedonic price method will be used. The hedonic price method is a method for pricing a value determined by its characteristics and determined by external factors affecting the price of the value (Lucas, 1975). Because in our research, the social costs of noise are determined by the value of houses, as well as by the presence of aviation noise, it is reasonable to use this pricing method. The calculations and further explanation of the social costs of noise will be given further.

5. Benefits

5.1. Added value Economy

When weighing the added value of the aviation industry in our cost-benefit analysis, it is crucial to understand what value is created and how it is measured. The definition of added value in economics is that it contributes to the Gross Domestic Product (GDP) made by an individual producer, industry, or sector (OECD, 2001). The GDP is a measure to sum all the gross value added in a country's economy in a year. It is a method to measure all economic activity in a country. In our research, we will thus investigate the impact of the aviation industry as a share of all economic activity in The Netherlands. The elements that will have an impact on the GDP will be discussed in the section below. To summarize, if the added value of the aviation industry is mentioned in this research, the share of the aviation industry on the GDP of The Netherlands is meant.

Some benefits will be considered because of the expansion of the Dutch economy, and some benefits are for the people in the area because of the presence of the airport. The aviation industry's economic impacts are usually divided into four types of impact: direct impact, indirect impact, induced impact, and catalytic impact (Oxford Economics, 2014). A benefit that travelers could have at Rotterdam The Hague Airport is a shorter processing time (Jorge & de Rus, 2004), which could be time-saving compared to larger airports. A benefit

that people living in the area near the airport could have is the travel time effect. Shorter travel time to an airport is precious for some people (Mackie et al., 2001). All these possible positive economic impacts of the aviation industry will be explained and discussed whether they will be considered in the cost-benefit analysis of an expansion of Rotterdam The Hague Airport.

5.2. Direct impact

The first impact that will be discussed is the direct impact of the aviation industry. The direct impact is most easily deduce from aviation activities. The direct impact of the industry is the direct employment and economic activity generated by the aviation industry. This consists mainly of airline and airport operations, aircraft maintenance, air traffic management, head offices, and activities directly serving air passengers. Direct impacts also include civil aerospace manufacturers' activities selling aircraft and components to airlines and related businesses (Oxford Economics, 2014) (InterVistas, 2015). The direct impact is directly deductible from aviation activities and can be fully assigned to the presence of the aviation industry. The direct impact is thus generated by employment and economic activities directly related to an airport's presence.

To estimate the direct impact of an airport, we will look at the employment directly associated with the operation and management of activities at the airports (InterVistas, 2015). Thus, in the rest of the research, we will specifically look at the jobs directly generated because of the activities of an airport. To calculate the final added value of the direct impact of Rotterdam The Hague Airport's expansion, we will look at the number of direct jobs that will be created and the average value that a direct job adds to the economy. In this way, we can look at the direct impact of an expansion on the economy. Exact calculations of the direct impact will be given further in the research.

5.3. Indirect impact

The next impact that will be discussed is the indirect impact of the aviation industry. Indirect impacts include employment and activities of suppliers to the air transport industry (Oxford Economics, 2014). It consists of all the employment, income, and GDP generated by

down-stream industries that supply and support the activities at the airport (InterVistas, 2015). Examples of these support activities are aviation fuel suppliers, construction companies that build airport facilities, a wide variety of activities in the business services sector, and wholesalers providing food for inflight catering or catering at airports (InterVistas, 2015) (Oxford Economics, 2014). As for the direct impact, we will look specifically at the indirect jobs generated by indirect activities to calculate the added value of expansion.

The indirect impact of the aviation industry comes thus as support of direct activities at airports. Therefore, in most researches in the indirect impact of airports, a multiplier is used to calculate the number of indirect jobs based on the present direct jobs. To calculate the number of indirect jobs created by an expansion of the airport, we will thus use a multiplier on the number of direct jobs, to estimate the total indirect impact on the economy. Further calculations on the multiplier of indirect jobs and calculations on the added value due to the indirect impact will be given further in the research.

5.4 Induced impact

The aviation industry's induced impact consists mainly of spending of people directly or indirectly employed in the air transport sector that supports jobs in industries (Oxford Economics, 2014). The impact is based on people employed in the aviation industry, spending their income in the national economy (InterVistas, 2015). For example, employees of airports doing their groceries with their income, or spending their income on a personal fitness trainer. In this way, they generate employment in other sectors of the economy with their incomed earned in the aviation industry.

It is very debatable whether to consider the presence of induced impact or not. In the paper of Oxford Economics (2014), the induced impact is estimated for the whole aviation industry. The induced impact of the industry is almost as significant as the direct and indirect impact together. Nevertheless, many studies overestimate the value of aviation growth, because they tend not to take account of the growth that would occur in the absence of an expansion of the airport (Hakfoort et al., 2001). Besides, a study on the economic importance

of Schiphol of Decisio (2015), left the induced impacts out of consideration, because they were not directly related to the activities at Schiphol.

On top of that, it is questionable whether the induced impacts where non-existing without the aviation industry because it is assumable that these people would have other jobs if there were no spending of direct and indirect aviation employees (InterVistas, 2015). This research investigates the impact of choice to expand Rotterdam The Hague Airport, not the whole aviation industry. The extra commercial flights now allocated to Rotterdam The Hague Airport could also be allocated elsewhere. Because we do not want to overestimate the benefits of expanding Rotterdam The Hague Airport, we will leave the induced impacts out of our final cost-benefit analysis.

5.5. Catalytic impact

The last impact that will be discussed is the catalytic impact of the aviation industry. Catalytic impacts, also known as Wider Economic Benefits, capture how the airport facilitates other sectors of the economy (InterVistas, 2015). Catalytic impacts are often divided into different types of mechanisms: Trade, investments, tourism, and productivity. The impact is thus a spin-off for economic activities of other industries whose developments and growth depend on the aviation industry (Wittmer & Vespermann, 2011). The catalytic impact of the aviation industry adds the most value, and creates the most jobs compared to direct, indirect and induced impact ((Oxford Economics, 2014). Researches to broader economic benefits due to the aviation industry must always consider the presence of catalytic impacts. However, because our research looks at the expansion of Rotterdam The Hague Airport, it is more difficult to decide whether to consider the catalytic impacts due to the expansion.

Tourism is the sector that is most dependent on the aviation industry. More than half of the tourists in the world arrived at their destination by plane (UNWTO, 2011). Moreover, this percentage keeps on growing, due to the growing mobility of people, meaning that they desire to travel further and discover more places (D'Ambrosio et al., 2012). However, the impact of tourism due to the aviation industry is mainly caused by incoming passengers, spending money in our economy. Therefore, we must distinguish outgoing and incoming

passengers (Decisio, 2015). At Rotterdam The Hague Airport, there are more outgoing tourists than incoming tourists. Furthermore, outgoing tourists decrease spending in the Netherlands because they are spending their money in other countries. For these reasons, the impact of tourism on Rotterdam The Hague Airport will not be considered in our cost-benefit analysis.

The presence of productivity benefits will be considered, in terms of travel time savings people or companies could have, due to the placement of Rotterdam The Hague Airport. Companies can lower their costs and higher their productivity due to travel time savings. Travel time savings will be explained later in the travel time savings section.

Another mechanism of Catalytic impacts is the investment impact of the aviation industry. The relatively fast growth of air transport usage has boosted business investment by around 0.7% per year in the EU over the last decade, equivalent to just under one-third of the growth in European business investment over this period (Britton et al., 2006). Airports can attract many other businesses because of their better connectivity and investment climate, and more companies might locate their firms near an airport (InterVistas, 2015). This is further explained in Bel and Fageda's (2008) research, who found a 4 percent increase in the number of large firms located near airports caused by a ten percent increase in air supply. Nevertheless, this mainly applies to intercontinental flights and business travelers.

In research of IATA (2005) was found that 25% of sales depend on the presence of useful airport links. This can be defined as trade activities. However, this is mainly focused on airports with many business travelers. As mentioned earlier, we assume that most of our travelers are leisure travelers who travel with low-cost carriers. This might change in the future, but because that is very uncertain, and because we do not investigate broader economic impacts, we will not consider catalytic impacts in our final cost-benefit analysis.

5.6. Travel time savings

We will now discuss two types of benefits for travelers of Rotterdam The Hague Airport. The first one is the travel time effect of travelers. Travel time is the time it takes citizens on average to get to a place. In our research, this place is Rotterdam The Hague

Airport. Travel time savings could also increase productivity because companies can lower their costs and, in this way, increase productivity (Nijdam & Otgaar, 2014). Ecocrys (2015) claims that both citizens of the Rotterdam region and citizens of other parts of the Netherlands achieve travel time benefits due to the expansion of Rotterdam The Hague Airport. The paper estimated that all travelers of the Netherlands benefit from an expansion of the airport. A research to the travel time effects savings conclusions of Ecocrys (2015), stated that the findings of travel time savings due to the expansion of the airport were somewhat correct, but the value of time used by Ecocrys (2015) was too low compared to other researches in value of time (TU Delft, 2016).

Because of the airport placement, it is very assumable that there is indeed a travel time effect. The placement of Rotterdam The Hague Airport is an advantage compared to Eindhoven Airport or Lelystad Airport. Therefore, this effect will be considered in the cost-benefit analysis of whether the airport should expand. This will be performed by using the value of time of travelers, which will be explained later. The airport's expansion will have an increasing number of travelers who could benefit because the province that the airport is in, Zuid-Holland, is the highest density area in the Netherlands (CBS, 2020). Calculations of travel time effects will be further in the research.

5.7. Processing time

The second benefit that travels could experience at Rotterdam The Hague Airport is a faster processing time compared to other airports. The processing time is the time it takes a passenger on an airport to enter an airplane or to leave one. Processes of outgoing passengers include baggage charts, check-in, passport control, security, and boarding of the airplane. Processes of incoming passengers include baggage delivery, passport control, and border security (ACI, 2015). If the processing time at an airport is shorter, this could be beneficial for travelers due to their value of time.

In the research of Ecocrys (2015) to the expansion of Rotterdam The Hague Airport, an average processing time of 40 minutes was estimated for regional airports in the Netherlands, and average processing time of 135 minutes was estimated for Schiphol. Because they only compared to Schiphol's processing time, the extra value of time of

passengers due to the shorter processing time had a massive impact on their final cost-benefit analysis. This is hugely overestimated because the difference in processing time between regional and national airports should not be 95 minutes but 15 minutes, and then still, the effects would be overrated (Manshanden & Bus, 2018). Our research investigates the expansion of Rotterdam The Hague Airport, with charter flights that would otherwise be allocated at other regional airports. For these reasons, the impact of processing time savings on expanding Rotterdam The Hague Airport is not considered in this research.

6. Methodology

6.1. Costs

6.1.1. Investment costs

In this section, we will explain the investment costs of an expansion of Rotterdam The Hague Airport. Estimation of investment costs for Rotterdam The Hague Airport has already been made until a certain amount of commercial aircraft movements by Ecocrys (2015). Different investment costs are calculated for all these different scenarios by an analysis of the airport itself (Ecocrys, 2015). The number of commercial movements for all the different scenarios of Ecocrys (2015) for an expansion of Rotterdam The Hague Airport can be found in table 22 in the appendix, as well as the corresponding years of our experiment in table 23.

Table 25 in the appendix shows the different types of investment costs for different scenarios, calculated by the airport itself. We can use these different types of investments for some of our scenarios per 5 years forecast. However, scenario 3d of Ecocrys (2015), will approximately be reached by 2035, so for years until 2050, estimation must be made to calculate the investment costs of an expansion of the airport. Until the years 2035, we use the investment costs based on the numbers used by Ecocrys (2015), but with a slight adjustment for the difference of commercial aircraft movements in our research, this can be found in table 23. The research of Ecocrys (2015) added 10% additional costs of the actual investment to account for maintenance on buildings, based on Berenschot's (2011) norm for more massive investments.

To forecast investment costs after 2035 is very difficult because investment costs are challenging to further far away in the future. After all, it is difficult to estimate the cost

parameters for investments of airport expansions far in the future (Smit, 2003). Nevertheless, because we will not have to build an extra runway for our estimation of an expansion of Rotterdam The Hague Airport to 100 thousand commercial aircraft movements, we can try to estimate the investment costs until 2050 based on our other investment scenarios. It is still difficult to forecast far away in the future, but investments of expansion are expected to return to scale at larger airports (Martin & Voltes-Dorta, 2010). After around 2,5 million passengers per year, there are expected to be no economies of scale anymore for investment costs of expansion of airports (Jeong, 2005). Estimation of investment costs after 2035 will still be with reservation, because of all the parameters that could change, but we will try to calculate them, to consider the final cost-benefit analysis.

Because we expect that there are no economies of scale in investment costs when expanding, we can assume that investment costs are linear when capacity increases. If we look at table 1, we see that there are in 2025 already over 25 thousand commercial aircraft movements. Because we assumed that there are approximately 100 people per aircraft, we can conclude that we have over 2,5 million passengers at that time, meaning there is a constant return to scale of investment costs. To forecast the investment costs from 2035 until 2050, we will use a high-low method to calculate the extra cost per commercial aircraft movement. This calculation will be done by dividing the difference in investment costs from 2025 to 2035 by the difference in commercial aircraft movements from 2025 to 2035. We will calculate the investment costs per commercial aircraft movement, to estimate the investment costs with increasing commercial aircraft movements after 2035.

We will make the difference in investments from 2025 to 2035 because it is above the norm of 2,5 million passengers of Jeong (2005), and looking at the most considerable difference in costs will give the most realistic view of extra investment per commercial aircraft movement. We will only look at the difference in commercial aircraft movements because the number of other movements stay constant, so considering them will give a wrong estimation of extra investment costs per movement. Therefore, to estimate the investment costs for the years 2040, 2045 and 2050, we will use the following formula according to the high-low method:

Investment costs per extra commercial aircraft movement:

C.a. = commercial aircraft

$$= \frac{\text{Investment costs 2035} - \text{investment costs 2025}}{\text{C.a. movements 2035} - \text{c.a. movements 2025}} = € 2.370$$

Thus, it will cost 2.370 euros to expand with an extra commercial aircraft movement on average. This number will be used to forecast from 2035 onward because, until 2035, we used numbers based on a calculation of the airport itself (Ecocrys, 2015). From 2035, the estimated extra costs per commercial aircraft movement will be used to forecast from 2035 until 2050. The final investment costs can be found in table 12 in the result section and used in the final cost-benefit analysis.

6.1.2. Emissions

First, we will calculate individual prices for all the emissions that are being investigated. Then, we will calculate the total cost of emissions due to the aviation industry. We will try to calculate the total costs of these emissions to evaluate whether the airport should expand. The emissions with the most significant environmental impacts that are due to the aviation industry are Carbon dioxide (CO2), Particulate matter (PMx), and nitrogen (NOx) (Environmental and Energy Study Institute, 2019). Therefore, we will try to calculate what the costs are for these emissions when the airport expands.

For the pricing of these emissions, a calculation of the social costs of emissions has been performed by CE Delft (2017), commissioned by the Dutch government. These calculations will be used for Particulate matter and nitrogen. For the pricing of CO2, we will use an average of the price given by CE Delft (2017), and we do not use the market price of CO2. We want to calculate the social costs of CO2 emissions, and not the price countries pay to each other to emit CO2. Therefore, the average price calculated by CE Delft (2017), was 57 euros per tons, this is 0,057 euro per kilogram. This is the price we will use in the experiment because we want to look specifically at the social costs of emission.

Particulate matters come mainly in two kinds of types, and these are PM10 and PM2,5. To calculate the price of particulate matter, we will use the average price of these two

different types. Which is (44,6+79,5)/2 = 62.05. The average social cost of nitrogen (NOx) is 34,7 (CE DELFT, 2017). All these prices are given in Euro/kg of emission. Therefore, if we want to use the social cost per kilogram of emission, we will get the following table:

Type	Price per Kg
CO2	€ 0,057
NOx	€ 34,7
PM2,5/10	€ 62,05

Table 5. Social costs per emission by CE Delft (2017)

As the prices are per 2017, we must adjust them for aggregate price changes. Using the price of emissions in cost-benefit analysis in other years, it is accepted to use the consumer price index (CPI) to adjust for price differences in different years (CE Delft, 2017). Because we use the base year of 2015, we will use the consumer price index's index rates to calculate the cost of emissions for society with prices of 2015. The consumer price index in 2017, compared to 2015, is 101,70 (CBS, 2020). This rate will thus adjust emission prices. The adjusted social costs for the year 2015 can be found in table 28 in the appendix. This will be used in calculating the social costs of emissions in the result section.

Because it is challenging to investigate the exact emissions of PM10/2,5, NOx, and CO2, we will use the different scenarios of Ecocrys (2015), calculating the social costs of emissions expansion of Rotterdam The Hague Airport until 2035. The emissions for different scenarios of Ecocrys (2015) can be found in table 25 in the appendix. The actual emissions we use will be adjusted for our number of movements compared to the movements of Ecocrys (2015), which we can find in tables 24 and 26 in the appendix. As shown in Table 4 in the appendix, particulate matter, and nitrogen are in tons, and carbon dioxide is measured in kilotons. One ton is equal to a thousand kilos, and a kiloton is equal to a thousand tons. Because our expansion exceeds the giant scenario of Ecocrys (2015) in 2030, we should estimate emissions from 2035 until 2050. We will try to forecast different emissions for CO2, NOx, and particulate matter per extra commercial aircraft movement. This will give us a better look at the social costs of pollution when Rotterdam The Hague Airport will expand to 100.000 commercial aircraft movements by 2050.

To calculate what the amount of kilogram per movement will be per type of emission, we will try to calculate what an extra commercial flight movement will emit per type of emission. The cost per emission type per commercial aircraft movement will be executed by looking at the increase in emission from scenario 2 to 3d. The number of other flight movements stays constant in these scenarios, as we see in table 26 in the appendix, we can calculate the amount of emission per extra commercial flight. In our research, the number of other movements is also held constant. Thus, we can calculate the extra emissions per commercial aircraft movement. The change between these two specific scenarios is chosen because it is the highest amount of change in commercial aircraft movements, thus the best reproduction of emission per increase of commercial aircraft movement. Therefore, the following calculations for each type of emission will be used:

Emission per extra commercial aircraft movement

$$\Rightarrow \frac{\text{Emission scenario 3d} - \text{Emission scenario 2}}{\text{Extra commercial flights from scenario 2 to 3d}}$$

This will be done for all three types of emissions. This will give us the following emissions per extra commercial aircraft movement.

PM10/2,5 = 0,117 kg per movement
NOx = 3,8938 kg per movement
CO2 = 998,41 kg per movement

If we look at table 6, we see a high increase in emissions after 2035. We can conclude that commercial aircraft movements generate a lot more emissions than the other types of aircraft movements. In the result section, we will look at the social costs of expanding Rotterdam The Hague Airport in terms of emissions. To calculate the extra costs of emissions from the years 2035 until 2050. We will use the amount of 2035 as a start and calculate the extra costs of expanding by using the number of emissions per commercial aircraft movement, as calculated above. This will give us a more transparent look at what the social costs of emissions will be when the airport expands.

Type	2020	2025	2030	2035	2040	2045	2050
PM10/2,5 emissions (ton)	5,57	6,78	7,62	8,93	10,55	12,68	15,47
NOx emissions (ton)	158,93	192,06	222,67	262,74	316,62	387,42	480,44
CO2 emissions (kton)	33,24	39,77	47,723	57,72	71,54	89,69	113,54

Table 6. Emissions of an expansion of Rotterdam The Hague Airport

The calculations we use in our research are based on the current type of airplanes. Nowadays, already a lot of Boeing 737's and Airbus A320's, the most common planes to operate at Rotterdam The Hague Airport, are being replaced by new generations. These new generations of airplanes are a lot more fuel-efficient and generate fewer emissions. Almost half of the commercial aircraft movements are conducted by different types of the Boeing 737 (201). The new generation of the Boeing 737, the Boeing 737-max, is already for a long time grounded, and not returning to the sky anytime soon (NPR, 2020), because of accidents due to system failure of the Boeing 737-max. The planes in the future are going to be a lot more fuel-efficient, but it is not yet sure what the exact percentages of improvements are for our invested emissions. Therefore, we still use numbers based on the types of aircraft currently operating at Rotterdam The Hague Airport.

6.1.3. Noise Pollution

As earlier mentioned, the social costs of noise will be calculated by looking at the impact of an extra decibel on the percentage change of housing in the region of Rotterdam. The municipalities or areas of Rotterdam that are most affected by the noise pollution of Rotterdam The Hague Airport are the ones that are in line with the runway of the airport. The housing prices of these areas will be considered when calculating the impact of expanding the airport. In this research, the municipalities that are considered when looking at the highest noise pollution, in combination with the placement of the runway, are Overschie, Schiedam, Vlaardingen, Hillegersberg-Schiebroek, and Lansingerland (GGD, 2017) (To70, 2014).

In these municipalities, the percentage of people that complain because of aviation noise is more significant than 7%, whereas all other parts in the region of Rotterdam that

complain because of aviation noise are below 3% (GGD, 2017). These areas are expected to be most impacted by an expansion of Rotterdam The Hague Airport, and therefore will be used. To calculate the house price, that we will use in our further research on social costs due to noise, an average of these five areas' average house price will be made. The average house price of these five areas combined is €194.400 (CBS, 2015), as shown in table 22 in the appendix. We looked at the house prices of 2015 because that is our base year.

The average house value can be used in our research to the social costs due to noise pollution because we will look at the decrease in value caused by an increase in noise. As mentioned in the theoretical framework, an increase in 1 decibel will lead to a percentage change of 0,8%. As earlier mentioned, everyone has a different tolerance level to noise, but this is difficult to consider when estimating social costs of noise (Lawton & Fujiwara, 2016). Therefore, to estimate the effect of noise pollution on people, it is essential to assume that every one individual has the same utility function for externalities (Pearce & Edwards 1979). We will use a hedonic price method to estimate the social costs of aviation noise. The following formula for social costs Cn has been estimated by Lu and Morell (2006) research:

$$C_n = \sum I_{ndi} * P_v * (N_{ai} - N_0) * H_i$$

This formula to calculate the social costs Cn is based on a couple of variables. Indi is the average percentage decrease in a house per decibel, which is in our research 0,8%. The Nai−N0 term is the difference of noise between the measured Lden and the minimum N0, which we estimated at 40 decibels. The Hi is a term for the number of houses within a specific range of Nai−N0. There are multiple ranges to state different noise pollution levels, with all a certain number of houses within that range. The sum singe is, to sum up, all these ranges to estimate the total social costs due to noise pollution. The Pv is the average price per year of houses in the affected areas. The average price of houses in the affected areas P was estimated at €194.400, which can be found in Appendix A.

To calculate the average price per year of a house, we will use the formula of the capital recovery factor of an asset. With the calculation of the capital recovery factor, we can calculate the average price of houses per year, based on the average price. The variables that will be considered in the calculations of the capital recovery factor are the length of the

lifetime of an asset, as well as an interest rate. The standard formula to calculate the capital recovery factor is the following:

$$A = P * (i *(1+i)^{n} / (1+i)^{n}-1))$$

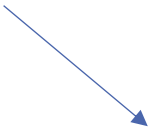
In our research, the average calculated price of an asset per year will be the average price of a house per year, Pv. The interest rate (i) will be the mortgage interest on houses (r), and the length of life of an asset will be the lifetime of an average house in years (N). The average mortgage interest on houses was 2,98% over 2015 (PBK, 2019). The average lifetime of a house is set at 47 years (Van Nunen, 2017) (CBS, 2020). This will give us the following average price per year Pv (capital recovery factor): €7.740. This value will be used to calculate social costs due to noise pollution (Cn).

We will thus look at the number of houses that will be affected by noise pollution due to the airport. There will be a different type of sound contours because people living closer experience more nuisance than people living further away. The different types of sound contours will be based on earlier research on noise pollution of an expansion of Rotterdam The Hague Airport (Rotterdam The Hague Airport, 2015), which can be found in table 27 in the appendix.

The different types of sound contours will be based on a research of Rotterdam The Hague airport (2015) on noise pollution for the different scenarios of expansion of Ecocrys (2015), which can be found in table 29 in the appendix. For the ease of the experiment, we will use the same sound contours for different scenario types, but adjusted for our number of aircraft movements, which can be found in table 26 in the appendix. Sounds above 70 decibels are experienced as very disturbing, but they are 0 in every scenario because only at the runway is this sound audible (Rotterdam The Hague Airport, 2015). If some houses that won't fall, for example, in sound contour 48 dB anymore, because of the adjusted aircraft movements compared to the scenario of Ecocrys (2015), they will be added to a sound contour lower. The research of the airport differs houses from existing and planned buildings of new houses, we will consider both due to the far forecast of our research.

As earlier explained, the comparable scenarios of the expansion experiment of Eccorys (2015) are reached in 2035. If we want to forecast after that, we will use the high-low method again, to calculate the extra houses per extra commercial aircraft movement, because the other types of movements stay constant after 2025. If we look at the different sound contours in table 29 in the appendix, we see different percentages of increased houses per sound contour for different scenarios. Therefore, we will calculate the extra affected houses for all three different sound contours per extra commercial aircraft movement from 2035 until 2050. Rotterdam The Hague Airport (2015) tells us that we can assume that the number of houses per sound contour increases proportional, based on similar researches on Schiphol. Therefore, the high low method is approved. We will calculate the extra affected houses for all three sound contours per extra commercial aircraft movement based on the following formula:

Extra affected houses sound contour per extra commercial aircraft movement =



$$\frac{\text{Number of houses in 2035} - \text{Number of houses in 2025}}{\text{C.A. movements 2035} - \text{C.A. movements 2025}}$$

We will use this formula to calculate the number of houses in different sound contours from 2035 until 2050. With the extra affected houses per commercial aircraft movement, the number of affected houses will be estimated from 2035 until 2050. This will give us the following table of affected houses.

Lden	2020	2025	2030	2035	2040	2045	2050
+40 dB	92.736	111.793	138.317	166.337	206.378	258.992	328.116
+45 dB	40.604	43.426	48.482	49.882	54.622	60.850	69.032
+50 dB	13.182	16.140	17.634	21.038	24.634	29.358	35.565
+55 dB	2.233	3.219	4.234	5.324	6.869	8.898	11.565
+60 dB	29	33	91	137	213	313	445
+65 dB	0	2	3	5	7	10	14
+70 dB	0	0	0	0	0	0	0

Table 7. Houses affected by noise pollution per different sound contour

In the table above, the number of affected houses per different sound contour is displayed per 5 years when Rotterdam The Hague Airport will expand. The houses in different sound contours are not cumulative. Thus houses in sound contour 48 dB are not in sound contour 40 dB. This is because it would otherwise give a wrong view of the total social costs due to noise pollution. After all, some houses would be considered multiple times. We assumed a proportional increase in affected houses per sound contour. The social costs due to noise pollution will be estimated by the expected decrease in housing prices in the surrounding areas. Total social costs due to noise pollution can be found in the result section.

6.2. Benefits

6.2.1. Employment

In this section, the impact of an expansion of Rotterdam The Hague Airport on the employment on the region of Rotterdam will be tested. Because Rotterdam The Hague Airport will be expanded to 100.000 aircraft movements in 2050, this will generate a lot of extra jobs. The growth increase in jobs will be compared to the growth of people that live in the region of Rotterdam, to see what the impact of an expansion of Rotterdam The Hague Airport will have on the share of employment for the region of Rotterdam.

We will estimate the growth of direct and indirect employment for the Netherlands' GDP, or more specifically for the economy of Rotterdam. To calculate the direct and indirect impact one person has on the economy, we use the data of InterVistas (2015), and especially the scenario of the 28 countries in Europe, which countries these are can be found in table 27 in the appendix. In the annual salary of an employee, the paper uses data of all European airports, which lead up to less than if we calculate the annual salary of an employee in our 28 European countries (InterVistas, 2015). This research will calculate the annual salary of direct and indirect employees based on the 28 European countries because this will be more assumable if we are going to forecast an expansion of Rotterdam The Hague Airport, and what the impact of it will be to the economy.

The annual salary per employee will be calculated by dividing the total income by the number of jobs for both direct and indirect jobs, which we can found in table 8. The added value per both direct and indirect jobs will be calculated in the same way, by dividing the total added value of GDP by the number of jobs. Therefore, if we want to calculate the added value of the growing employment at Rotterdam The Hague Airport, we will use the following numbers of InterVistas (2015).

- Added value per direct job: € 65.600
- Added value per indirect job: € 59.000

The impact of an expansion of Rotterdam The Hague Airport on employment in the region of Rotterdam will be tested. Because Rotterdam The Hague Airport will be expanded to 100 thousand commercial aircraft movements in 2050, this will generate a lot of extra jobs. The growth increase in jobs will also be compared to the growth of people that live in the region of Rotterdam, to see what the impact of an expansion of Rotterdam The Hague Airport will have on the share of employment for the region of Rotterdam.

	Impact	Jobs	Income (€ Billions)	GDP (€ Billions)	% of National GDP
EU 28	Direct	1,276,200	€ 55.4	€ 83.7	0.6%
	Indirect	945,800	€ 32.6	€ 55.8	0.4%
	Induced	1,036,600	€ 32.7	€ 64.0	0.5%
	Total	**3,258,600**	**€ 120.7**	**€ 203.4**	**1.6%**

Table 8. Employment aviation industry (InterVistas, 2015)

6.2.2. Direct impact

Employment data was gathered from 125 airports representing 71% of European passenger traffic (InterVistas, 2015). According to this research, low-cost Carrier passengers generate 20% less direct jobs than non-Low-cost Carrier passengers. Employment in this research changes when the capacity of an airport increases. The current ratio of passengers at Rotterdam The Hague Airport consists of 30% of business passengers, and 70% leisure passengers, which we can see in table 9 (Ecocrys, 2015). This paper assumes that 70% of these passengers use low-cost carrier airlines, and 30% of them do not. With Rotterdam The Hague Airport continually growing, the amount of jobs that are generated changes by the passenger changes due to economies of scale (InterVistas, 2015). Therefore, the number of jobs per 5 years is also changing due to the airport's change of scale. According to InterVistas (2015), a connecting passenger generates 3% less direct jobs than origin/destination passengers. However, since Rotterdam The Hague Airport is mainly used for origin/destination passengers, the proportion of transfer passengers is not considered, because it is very low (Rotterdam The Hague Airport, 2020).

Airport Size / Traffic Type	Comment
Less than 1 million traffic units	Each increase of 1000 traffic units increases employment by 1.2 Jobs
1 million - 10 million traffic units	Each increase of 1000 traffic units increases employment by 0.95 Jobs
Over 10 million traffic units	Each increase of 1000 traffic units increases employment by 0.85 Jobs
Connecting passengers	Connecting passengers generate 3% less direct jobs than origin/destination passengers
LCC passengers	LCC passengers generate 20% less direct jobs than non-LCC passengers

Table 9. Employment increases per airport size (InterVistas, 2015)

For the research, one FTE counts for an average of 1,2 jobs at Rotterdam The Hague Airport. Therefore, the conversion factor to go from FTE to total jobs is to multiply by 1,2 (Ecocrys, 2015). This research looks in general at jobs to compare it later with the growth of Rotterdam's population until 2050.

If we look at Rotterdam The Hague Airport, they are already above one million passengers at the start of our research, and we never reach the amount of over 10 million passenger units. That is because we intended to reach 100 thousand aircraft movements in the year 2050, and as earlier mentioned, we use the average of 100 passengers per plane for Rotterdam The Hague Airport (Ecocrys, 2015). The research will thus look at the airport size of one million passengers until 10 million passengers.

The table of InterVistas shows an average job increase in all airports in Europe, but that might be different for every country. Therefore, it might not be easy to forecast the number of created jobs because of an expansion of Rotterdam The Hague Airport. In the research of Ecocrys (2015), the number of jobs created per 1 million passengers was 752 fte. With the conversion factor of 1,2, this meant the number of jobs was around 0,902 jobs per thousand traffic units. This number is very close, but slightly a little bit under the amount of InterVistas (2015) of 0,95, but that could be due to the presence of more low-cost carrier airlines, or the fact that aviation industry in The Netherlands, in general, generates fewer jobs than in other countries.

To calculate future jobs with a growing number of commercial aircraft movements of Rotterdam The Hague Airport, this research will use an average of these two numbers for two reasons. The reason the number of Ecocrys (2015) is considered, is because this is a forecast of Rotterdam The Hague Airport, thus it is based on the right case, but it is still a forecast, and not a research of current data. Therefore, the calculation of InterVistas (2015) is also being used, because it is based on actual data of almost all European airports. However, the number of 0.95 jobs per thousand traffic units, will be slightly changed, since low-cost carrier passengers will generate 20% less direct jobs (InterVistas, 2015). Since passengers of Rotterdam The Hague Airport comprise 70% of leisure passengers, the following calculation is being used to calculate the number of jobs created per thousand traffic units:

Total direct job increases per thousand passengers = 0,95 * (100% - (20% * 70%)) = 0,817

As earlier stated, the research will use an average of this calculated number based on the research of InterVistas (2015) and the forecasted number calculated for an expansion of Rotterdam The Hague Airport by Ecocrys (2015). Therefore, the number used in this experiment to calculate an increase in direct jobs per thousand extra passengers will be as follows: (0.817 + 0,902) / 2 = 0,86

If we look at all British airports' data, the number of direct jobs per thousand passengers was around 0,865 (Oxford Economic Forecasting, 2006). Therefore, because this country is similar to the Netherlands, this is an acceptable multiplier to calculate increases indirect jobs when the airport will expand. Thus, we will assume that 0,86 direct jobs will be created per thousand extra passengers for the rest of the research. Direct employment generated by the expansion of the airport can be found in table 10.

6.2.3. Indirect impact

If we want to forecast what will happen to the indirect employment because of the direct employment at the airport, it is a tricky thing to forecast. With indirect employment, InterVistas (2015) might not be a suitable measurement method to use, because indirect employment will be, more than direct employment, be further away from airports, or be more linked to the aviation industry in general rather than a specific airport. It is more difficult to

choose between the two methods than direct employment because indirect employment is always more challenging to measure. The indirect employment will be forecasted by using a multiplier on direct employment. To calculate the multiplier of indirect jobs created by the direct jobs at an expansion of Rotterdam The Hague Airport, we look at two papers that use a relatively similar multiplier. There will be made an average between both papers to forecast the number of indirect jobs that will be generated.

For calculating the multiplier of indirect jobs created by direct jobs, we will thus not look at InterVistas (2015), due to the difficulty of assigning indirect employment to a specific airport. The paper also gives a very high multiplier of indirect jobs created, which can overestimate the benefits of expanding. We will use the multiplier to forecast the number of indirect jobs generated by direct jobs for the expansion of Lelystad Airport is 0,2 (Strategem, 2014). The multiplier used to calculate the number of indirect jobs for the expansion of Eindhoven Airport is 0,25 (Strategem, 2014). The average multiplier to calculate the number of indirect jobs based on the direct jobs will thus be: (0,25+0,30) / 2 = 0,225
This means that in our forecast for indirect employment, every thousand direct jobs will generate around 225 indirect jobs. Generated indirect employment due to the expansion of the airport can be found in table 10.

In conclusion, the following methods will be used to calculate the employment growth when Rotterdam The Hague Airport will expand. These methods will also be used when looking at the added value the created employment will generate for the Dutch aviation industry or the added value for Rotterdam's employment.

- Direct jobs per thousand passengers = 0,86
- Multiplier indirect job per direct job created = 0,225

In table 10, we can see the direct and indirect employment when based on the number of passengers. In table 10, we also calculate the total employment, to use in a later analysis on the impact of an expansion of the airport on the working population of Rotterdam. The added value of the direct and indirect impact will be shown in the result section.

	2020	2025	2030	2035	2040	2045	2050
Passengers	1.943.900	2.554.000	3.355.700	4.409.000	5.792.800	7.611.100	10.000.000
Direct employment	1.372	2.196	2.886	3.792	4.982	6.546	8.600
Indirect employment	309	494	650	853	1.120	1.473	1935
Total employment	1.681	2.690	3.536	4.645	6.102	8.019	10.535

Table 10. Total employment due to expansion of Rotterdam The Hague Airport

6.2.4. Travel time savings

In this section, we will give calculations on the value of travel time savings travelers of Rotterdam The Hague Airport will benefit. In the research of Ecocrys (2015), a valuation was given for travelers' travel time savings using Rotterdam The Hague Airport. However, as earlier mentioned, this valuation was too low. They used the value of time for regular commuters in the Netherlands based on KIM (2013). The valuation of Ecocrys (2015) was too low because the value of time for air travelers is higher than the value for commuters (Koster et al., 2010) (Furuichi and Koppelman, 1993) (Pels et al., 2003) (Hess and Polak 2006). Ecocrys (2015) also expects a low value of passengers coming with other types of transport than public transport or car, but the value of time for passengers with these types of transport has a similar value as passengers coming by car (Decisio, 2017).

The average profit of time a traveler has by the expansion of Rotterdam The Hague Airport is estimated at 3 minutes for travelers all over the country, and 29 minutes for travelers within the region of Rotterdam (Ecocrys, 2015). The numbers are based on every origin municipality in the Netherlands, with a weigh on the proportion of citizens of that municipality, and the alternative airport that otherwise would have been used. About 45% of the travelers come out the metropolitan region of Rotterdam-The Hague (SEO, 2015), therefore, we use this percentage for the people that gain a 29-minute profit due to the expansion of the airport, and 55% percent of the people gain a 3-minute profit compared to other airports.

The distribution of type of passengers is currently around 70% of leisure passengers, and 30% of business travelers (Ecocrys, 2015). The percentage of business travelers might be a little bit overestimated by a few percents (Manshanden & Bus, 2018), but due to the minimal difference, this distribution is acceptable, and we will use the same percentages as Ecocrys (2015). The reason that the value of time for air travelers is higher than for commuters is that the cost of missing is too high (Koster et al., 2010). The value of time for air travelers found by Koster et., al (2010) was estimated on 35 euros for leisure passengers and 71 euros for business travelers, which is in line with earlier findings (Furuichi and Koppelman, 1993) (Hess and Polak 2006). This research is performed on travelers of Schiphol. Thus, findings can be used in our research because it concerns Dutch travelers.

The values of the travel time savings in minutes, the distribution of leisure and business travelers, and the value of time for different air travelers will all be considered in estimating the total benefits of travel time savings when the airport expands. Because we analyze the benefits and costs of expansion every five years until 2050, we will look at the number of passengers per 5 years, to value the benefits of travel time savings. We will look at the average value time saving per passenger and use this to forecast travel time savings based on the number of passengers until 2050. Considering all values of variables, the following value of travel time saving per passenger will be calculated.

Travel time saving per passenger per hour:

VoT = Value of time

(%leisure passenger * VoT leisure passenger) + (%business passenger * VoT business passenger) = €45,80 per hour per passenger

To estimate the total travel time savings, the proportion of travelers that benefit from the savings within the region of Rotterdam-Den Haag, as well as the proportion of the rest of the Netherlands that benefits, must be considered realistic view of travel time savings. As earlier mentioned, the 45% travelers within the region of Rotterdam- Den Haag gain a 29-minute profit in travel time, and the 55% travelers coming from the rest of the country gain a

3-minute profit in travel time. Because the calculations of travel time savings per passenger are based on the research of Koster et al., (2010), the value for travel time savings must be adjusted by the index figure of 2015, to give a realistic view in our final cost-benefit analysis. The index figure for passenger transport over land is 106 in 2015, compared to the base year 2010 (CBS, 2018). To estimate the travel time saving per passenger, we can use it in our further forecast of expansion, the following valuation should be used:

3 minutes = 1/20 hour
29 minutes = 29/60 hour

Travel time saving per passenger:

((% regional passengers * 29/60) + (%national passengers * 1/20)) * Travel time saving per passenger per hour * index figure 2015 = €11,89 travel time saving per passenger

This value will be used further in the experiment, for travel time savings per passenger, and will be used in the final cost-benefit analysis forecast on whether Rotterdam The Hague Airport should expand or not.

6.2.5. Impact on employment Rotterdam

In this section, we will compare increased employment, due to the expansion of the airport, with a population of Rotterdam until 2050. In table 11, the forecast of the growing employment of the city of Rotterdam is represented, as well as the forecasted employment until 2050. As discussed earlier, the only direct and indirect impact is considered in calculating the airport's total employment. The percentage of people that work in the total population is also displayed to give a better view of the impact of the airport on the employment of the city.

	2020	2025	2030	2035	2040	2045	2050
Total population	652.100	686.200	712.800	723.300	734.215	745.295	756.541
Percentage 20-65 years old	64%	62,67%	61,33%	60%	59,33%	58,67%	58%
Working population Rotterdam	417.344	430.042	437.160	433.980	435.610	437.265	438.794
Employment airport	1.681	2.690	3.536	4.645	6.102	8.019	10.535
Share of working population	0,4%	0,6%	0,8%	1,1%	1,4%	1,8%	2,4%

Table 11. Future employment Rotterdam

We see an increasing share of the working population of Rotterdam works at the airport. In the conclusion, we will dive deeper into the exact extra value for Rotterdam's employment, due to an expansion of the airport.

7. Results

7.1. Costs

7.1.1. Investment costs

In table 12, we can see the different investment costs of expansion per 5 years. We assume that the airport will grow at a constant rate. Thus, we expect that the investment costs after 2035 will also grow at a constant rate because, after four million passengers at airports, constant scale to returns could be expected for expansions of airports (Main et al., 2003) (Jeong, 2005). There are no investments in an extra runway because one runway will be enough to provide for the number of commercial aircraft movements by 2050.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Commercial aircraft movements	19.439	25.540	33.557	44.090	57.928	76.111	100.000
Other aircraft movements	45.303	46.288	46.288	46.288	46.288	46.288	46.288
Total aircraft movements	64.742	71.828	79.845	90.378	104.216	122.399	146.288
Investment costs (In thousand euros)	0	€9.770	€38.350	€53.730	€86.530	€129.620	€186.240

Table 12. Investment costs of expansion

If we look at the total investment costs by 2050, we estimated that expansion costs around 186 million euros to provide approximately 80 thousand extra commercial aircraft movements. We will compare our results with two other expansions of European airports to see whether our estimated investment costs are assumable. The expansion of London Gatwick cost 110 million pounds in 2005 (Gatwick Airport, 2019), which was about 160 million euros (XE Currency, 2020). This expansion generated fewer movements than our expansion but is relatively similar. However, changing for price differences, this would be very close to our estimation. Due to the relatively similar expansion of London Gatwick, we can assume that our estimation of investment costs will be somewhat correct and will be considered in the final cost-benefit analysis on whether the airport should expand or not

7.1.2. Emission

Table 13 shows the total emission costs for particulate matter, nitrogen, and carbon dioxide when expanding the airport. The social costs of emissions are the value of environmental damage caused by the airport (CE Delft, 2017). We can see that the social costs due to the emission of nitrogen are the highest of all three. This can be very assumable because, in 2008, in the Netherlands, the social costs due to the emission of nitrogen were estimated between 0,4% and 2,1% of the GDP of the Netherlands (PBL, 2012). Nowadays, the Netherlands is an urgent nitrogen problem, causing the government to lower maximum speed at runways to 100 kilometers per hour (Rijkswaterstaat, 2019). The social costs of particulate matter are relatively low, due to the low emitted amount. The amount of carbon dioxide emissions is very high, but due to the low social cost of an extra emitted kilo of carbon dioxide, the total social costs of carbon dioxide emissions are lower than the impact of nitrogen emissions. The total emission costs will be considered later in the complete cost-benefit analysis on whether the airport should expand or not.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Costs PM10/2,5 emissions (thousand EUR)	€340	€410	€460	€540	€640	€770	€940
Costs NOx emissions (thousand EUR)	€5.420	€6.550	€7.600	€8.960	€10.800	€13.220	€16.390
Costs CO2 emissions (thousand EUR)	€1.860	€2.230	€2.670	€3.230	€4.010	€5.020	€6.360
Total emission costs (thousand EUR)	€7.620	€9.190	€10.730	€12.730	€15.450	€19.010	€23.690

Table 13. Emission costs of expanding Rotterdam The Hague Airport

7.1.3. Noise pollution

In table 14, the affected houses are displayed for three different sound contours. Because the 40+ dB sound contour is not very different from the 40 dB threshold, it will not be considered in estimating social costs due to noise pollution. The social costs due to noise pollution are calculated by the decrease in housing prices of the surrounding places, as earlier explained.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Social costs noise pollution (thousand EUR)	22.840	26.500	30.020	33.660	38.920	45.830	54.910

Table 14. Social costs noise pollution

Because we calculated the social costs due to noise pollution as a function of the average price per year of houses in the Netherlands, the social costs, as displayed in table 11, are costs per year. Thus, the costs in, for example, 2022, will be between the costs of 2020 and 2025. We see that the social costs of noise pollution, do not increase from 2020 until 2050 compared to other forecasts of costs and benefits. This could be, due to the relatively low increase in houses that experience more than 45 dB Lden, from 2020 until 2050. They increase a lot, but not as excessively as other costs or benefits.

7.1.4. Total costs

In calculating the total costs of expanding Rotterdam The Hague Airport, we distinguished two types of costs. Investment costs of the airport, and social costs due to externalities. The social costs of expanding the airport consist of emission costs and noise pollution. All total costs of expanding the airport are shown in table 15 below and will be considered in deciding whether the airport should expand.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Investment costs	€ 0	€ 9.770	€ 38.350	€ 53.730	€ 86.530	€ 129.620	€ 186.240
Emission costs	€ 7.620	€ 9.190	€ 10.730	€ 12.730	€ 15.450	€ 19.010	€ 23.690
Noise pollution	€ 22.840	€ 26.500	€ 30.020	€ 33.660	€ 38.920	€ 45.830	€ 54.910
Total costs	€ 30.460	€ 45.460	€ 79.100	€ 100.120	€ 140.900	€ 194.460	€ 264.840

Table 15. Total costs of expanding Rotterdam The Hague Airport (in thousands)

7.2. Benefits

7.2.1. Direct impact

The direct impact on the economy is the impact of added value by direct employment at the airport. Table 10 in the methodology section shows that the growth of direct employment is displayed when the airport expands until 2050. The number of direct jobs at the airport is calculated by using the number of passengers. The number of direct jobs per thousand passengers is estimated at 0,86. As earlier mentioned, the added value to the economy of a direct job is €65.600 per year (InterVistas, 2015). In table 16 below, this will be used in calculating the added value for the economy of direct employment per 5 years until 2050.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Direct employment	1.372	2.196	2.886	3.792	4.982	6.546	8.600
Added value direct employment (thousands EUR)	€90.000	€144.060	€189.320	€248.760	€326.820	€429.420	€564.160

Table 16. Added value economy of direct employment

7.2.2. Indirect impact

The indirect impact on the economy is the added value of indirect employment at the airport. In table 16 in the methodology section, the growth of indirect employment is shown as a function of direct employment. As explained in the methodology section, the number of indirect jobs at the airport is estimated by using a multiplier of the number of direct jobs. Our estimated multiplier of indirect jobs generated by direct jobs is 0,225. An indirect job adds less value to the economy than a direct job, € 59.000 per year (InterVistas, 2015). Table 17 shows that the added value for the economy due to indirect employment is displayed per 5 years until 2050.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Indirect employment	309	494	650	853	1.120	1.473	1935
Added value indirect employment (thousands EUR)	€18.230	€29.450	€38.350	€50.330	€66.080	€86.910	€114.170

Table 17. Added value economy of indirect employment

7.2.3 Travel time savings

As mention in the methodology section, the average travel time saving per passenger is €11,89. This number will be multiplied by the number of passengers per 5 years, to forecast the possible benefits of an expansion of Rotterdam The Hague Airport until 2050 due to travel time savings. The results can be seen in table 18.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Passengers	1.943.900	2.554.000	3.355.700	4.409.000	5.792.800	7.611.100	10.000.000
Travel time savings (thousands EUR)	€23.110	€30.380	€39.900	€52.420	€68.880	€90.500	€118.900

Table 18. Total travel time savings

The total travel time savings can be seen in the table above. We calculated the travel time savings per passenger. The total travel time savings are calculated by multiplying the average travel time saving by the number of passengers. The benefits due to travel time savings will thus grow with the same growth rate as the number of passengers because the travel time saving per passenger is held constant. A possible misinterpretation could be that we held the percentage of passenger type constant until 2050, which might change in the future. The reason we have done so is that we expect that the airport will keep its function as a regional airport, with mostly leisure passengers.

We see that by 2050, the benefits due to travel time savings are over a hundred million dollars. This is not a benefit that other airports would have when they expand so that the savings can be entirely related to the placement of Rotterdam The Hague Airport. With the airport located in the highest density province of the Netherlands, this is most certainly a benefit compared to the expansion of other airports.

7.2.4. Total benefits

In calculating the total benefits of expanding Rotterdam The Hague Airport, we took direct impact, indirect impact, and travel time savings due to the airport's placement into consideration. As mentioned earlier, benefits are probably underestimated, because induced and catalytic are not considered, since it is not clear whether they are directly related to the airport. Benefits are thus probably higher than shown in table 19 below.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Direct impact	€ 90.000	€ 144.060	€ 189.320	€ 248.760	€ 326.820	€ 429.420	€ 564.160
Indirect impact	€ 18.230	€ 29.450	€ 38.350	€ 50.330	€ 66.080	€ 86.910	€ 114.170
Travel time savings	€ 23.110	€ 30.380	€ 39.900	€ 52.420	€ 68.880	€ 90.500	€ 118.900
Total benefits	€ 131.340	€ 203.890	€ 267.570	€ 351.510	€ 461.780	€ 606.830	€ 797.230

Table 19. Total benefits of expanding Rotterdam The Hague Airport (in thousands)

8. Conclusion

In this section, we will look at all the costs and benefits, and dive deeper into whether Rotterdam The Hague Airport should expand or not to 100 thousand commercial aircraft movements by 2050. We will also look into whether it is beneficial for the Dutch aviation industry to allocate this number of flights to the airport, or that it would be the same, or even better, to expand, for example, Eindhoven Lelystad Airport. All hypotheses will be answered, which will end up in answering the research question. The way the results should be interpreted is somewhat complicated. If we look at a year, for example, in 2030, the benefits and costs are present in that specific year, they are not cumulative from earlier years. We did not add all years between 2020 and 2050, because it would get too complicated. However, the cost-benefit ratio for years between 2030 and 2035 would lie somewhere in between those two. We just looked at five years to get a view of the distribution of the profitability of the project from 2020 until 2050. The results in 2050 are not the benefits and costs of the expansion of the airport, but the total benefits and costs of Rotterdam The Hague Airport, including the benefits and costs that already where present at the start.

In table 20, all costs and benefits are displayed, as well as the difference in benefits and costs, and the benefit-cost ratio. A project is seen as acceptable if the benefits outweigh its costs (Williams, 1974). The results show that the project of expanding the airport is beneficial in every year, thus the benefits of expanding always outweighs the costs until 2050. However, we see that further in the future, the benefits cost ratio decreases; this means costs will increase harder than the benefits. In the end year of our research, the project's value will be €532.390.000 for the year 2050.

Index 2015=100	2020	2025	2030	2035	2040	2045	2050
Commercial aircraft movements	19.439	25.540	33.557	44.090	57.928	76.111	100.000
Passengers	1.943.900	2.554.000	3.355.700	4.409.000	5.792.800	7.611.100	10.000.000
Total costs	€ 30.460	€ 45.460	€ 79.100	€ 100.120	€ 140.900	€ 194.460	€ 264.840
Total benefits	€ 131.340	€ 203.890	€ 267.570	€ 351.510	€ 461.780	€ 606.830	€ 797.230
Benefits costs	€ 100.880	€ 158.430	€ 188.470	€ 251.390	€ 320.880	€ 412.370	€ 532.390
Benefits costs ratio	4,31	4,49	3,38	3,51	3,28	3,12	3,01

Table 20. Total cost benefit analysis of an expansion of Rotterdam The Hague Airport (in thousands EUR)

The added value of Rotterdam The Hague Airport due to direct and indirect impact is a considerable part of total benefits if we look at table 19. However, it is very assumable that the impact would be similar if other airports in the Netherlands expand by this proportion. Direct and indirect impacts are undoubtedly significant in analyzing whether the airport should expand or not, but it is not a comparative advantage the airport has over other airports. However, the benefits of travel time savings are a major comparative of Rotterdam The Hague Airport over other regional airports in The Netherlands, due to its placement in the most density province of the Netherlands. Expanding Rotterdam The Hague Airport will thus have extra value over other regional airports in the Netherlands because the most people can save time by using this airport.

If we look at increased employment in the city of Rotterdam in table 11, we see an increasing share of Rotterdam's working population at the airport. The share of working population by 2050 is six times larger than in 2020. In figure 21, the growth of working population is compared to the growth of employment at the airport. The growth of employment is visualized on the right y axis, and the growth of working population of Rotterdam is visualized on the left y axis. We see that in 2035, there is a slight decline in the working population of the city, but this might be since more people are retiring, due to the aging of the Dutch population, because of the post-war baby boom, as earlier explained.

It is noticeable that, if we look at figure 21, the growth of employment at the airport is growing faster than the proportion of Rotterdam's working population. It is a wrong assumption only to consider the working population of Rotterdam, because the people working at Rotterdam The Hague Airport, are not only living in Rotterdam, but might also live in other parts in the province of South Holland, or maybe even in other provinces. Nevertheless, population near cities or in cities will grow faster in the future until 2050 than in other smaller towns (PBL & CBS, 2019). Thus, if we consider the population of a more substantial part, the number of people on the left axis would be more significant, but the comparison against the employment at the airport would look relatively the same, if not even more positive. Therefore, the graph gives us a clear view of the impact of the increased employment at the airport on the working population of Rotterdam, or even the region of Rotterdam. We can thus conclude, by looking at figure 21, that an expansion of Rotterdam The Hague Airport is very beneficial for employment of Rotterdam, and an expansion is, if we look at employment, very desirable for the city.

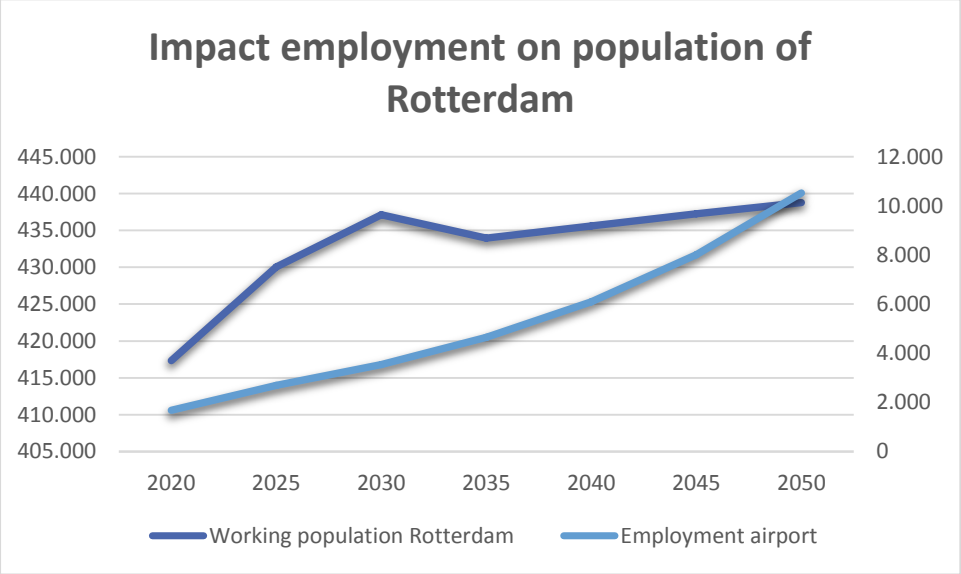


Figure 21. Impact employment on population of Rotterdam

The hub-function of Schiphol can be increased by moving charter flights to Rotterdam The Hague Airport. As we earlier saw, the importance of a hub airport is that, with capacity keeping constant, business flights add more value for the economy, than low-cost carrier flights (Nijdam & Otgaar, 2014). At Schiphol, there are still plenty of flights carried out by low-cost carrier airlines. If those flights could be transferred to Rotterdam Airport, it would increase Schiphol's hub-function, which will add a lot more value to the economy. However,

as we earlier saw, leisure passengers do not create as many jobs as indirect jobs (InterVistas, 2015), and might decrease employment at Rotterdam The Hague Airport. Moving charter flights from Schiphol to Rotterdam The Hague Airport will increase Schiphol's hub-function but might decrease employment at the airport, which will decrease the benefits of the expansion.

If we look at the social costs due to externalities of noise pollution and emissions in table 15, we see that they do not play as big of a part as the investment costs. Investment costs would probably be relatively similar at expanding other regional airports. This is thus, not a comparative disadvantage. For the social costs of emissions, the same is true. It would be similar to expanding other regional airports. The social costs due to noise pollution are probably larger at Rotterdam The Hague Airport than other regional airports, due to its close placement next to the second-largest city in the Netherlands.

The main goal of the international policy on CO2 emissions is that by 2050, the amount of CO2 emissions is less than half as they were in 2005 (United Nations, 2015). The Dutch government wants its emissions of domestic flight emissions or ground activities to be zero by 2050 (IenW, 2020). Since 2008, the Netherlands does not have any domestic scheduled flights anymore (Trouw, 2008). All emissions of ground activities must be zero by 2050, but it is hard to conclude whether this is achieved by 2050 because we did not investigate deep into ground activities. Looking at the leading international goal of CO2 emissions, it seems like expanding Rotterdam The Hague Airport is wrong, considering the increasing emission of carbon dioxides. However, aviation is responsible for 12% of CO2 emissions from all transport sources, compared to 74% of road transport.

On top of that, the global aviation industry produces around 2% of all human-induced carbon dioxide CO2 emissions (ATAG, 2020) (Modak, 2018). Besides, our research assumed the same aircraft in 2050 as in 2020, whereas the aircraft in 2050 is probably a lot more fuel-efficient. It is thus unclear whether an expansion of Rotterdam The Hague Airport leads to a case where the Dutch government can not meet the Paris agreement requirements in terms of CO2 emissions. There are other sectors way more critical in decreasing CO2 emissions, and it is not undesirable to expand Rotterdam The Hague Airport in terms of CO2 emissions.

To conclude, an expansion of Rotterdam The Hague Airport is a very beneficial project in terms of value. The comparative advantage the airport has over other regional airports is the travel time savings for passengers. The comparative disadvantage the expansion has is the extra noise pollution for residents living near the airport. But the comparative advantages are a lot higher than the comparative disadvantages. Thus, an expansion of Rotterdam The Hague Airport is all in all a beneficial solution for the future capacity problem of the Dutch aviation industry.

9. Discussion

In this research, we looked into the solution of expanding Rotterdam The Hague Airport to 100 thousand commercial aircraft movements by 2050. We concluded that expanding the airport had a comparative advantage in travel time savings, and a comparative disadvantage in social costs due to noise pollution, compared to other regional airports. Because the total benefits outweigh total costs, the analysis confirms that an expansion of the airport was a beneficial solution for the future capacity problem of the Dutch aviation industry. We also saw that the expansion of the airport positively impacted the employment for the city of Rotterdam.

The largest downfall of this research is the fact of only investigating the option of expanding Rotterdam The Hague Airport, and not looking at other options, like expanding Eindhoven Airport, or expanding Lelystad Airport further than now planned by the government. If the government wants to solve the capacity problem in the Dutch aviation industry in the upcoming years, they must always look at all the possible options, instead of just one. Further research in solving the capacity problem in the Dutch aviation could thus be done by comparing all solutions that solves the capacity problem.

Our research assumed that Rotterdam The Hague Airport only has two options, expanding or not. However, another possible option the government has, is shutting down the airport, and use the land for other purposes. The area could then be used for example for housing, or as an industrial area. This research did not look at these possibilities, when they could possibly be more beneficial than an expansion of the airport. This is something future research could implement, which could be used in deciding whether Rotterdam The Hague Airport should expand or not.

Our analysis's positive implications are the search for a possible solution for the Dutch aviation capacity problem in the future. We did not consider the induced impact and catalytic impact, to try not to overestimate benefits. However, there are some limitations this research has, which will be explained. The first one is that, due to the lack of available data, researches performed on benefits and costs is based on earlier researches in the aviation industry or based on earlier researches in expanding airports. One of the hypotheses was concerning the Paris agreement. It is beyond the scope of this research in deciding whether the environmental goals can be met or not due to the lack of information on future emissions of the aviation industry, and therefore a correct conclusion whether the Paris agreement goals can be met cannot be drawn. Our research assumed that the airport was free in deciding to expand or not. Nevertheless, research in expansions of airports should always consider policy issues (Humphreys & Francis, 2002), which our research did not.

The travel time savings in my research are based on findings of Ecocrys (2015). But in the future, travel time savings may differ every 5 years due to infrastructure changes. Therefore, the calculations of travel time savings until 2050 might be a little bit overestimated, because there might be faster train connections in the future, which decrease travel time savings. Future research must always look, for example, every 5 years at changes in infrastructure, and look whether the travel time savings for passengers using Rotterdam The Airport are still the same.

Future studies in solving the Dutch aviation industry's capacity problem in 2050 could look at multiple options of expanding airports instead of just one. Besides, if another research looked at solving the total capacity problem in the Netherlands, broader economic benefits, like induced and the catalytic impact, could be investigated. If the entire aviation industry is investigated, there could be better looked at the environmental goals of the Dutch government and the environmental goals of the world (United Nations, 2015).

Another limitation of this research is the fact that only impact of employment on the city of Rotterdam is considered, and not the impact on larger geographical areas. As earlier mentioned, this is done because calculating larger geographical impact would probably show comparable figures. But still, further research could be done into the impact on larger

geographical areas, because it would give a more specific view of the impact of increased employment on some areas near the city of Rotterdam, and thus the calculated impact would be more precise.

In our discussion, we mentioned that expanding Rotterdam The Hague Airport would increase the hub-function of Schiphol Airport. We showed that increasing the hub-function of Schiphol Airport would add more value to the economy, because normal passengers add more value than leisure passengers. However, the extra value created by increasing the hub-function of Schiphol Airport is not calculated. This would mean that the benefits in our final cost benefit analysis are underestimated. In making a more precise cost benefit analysis, the extra created value by increasing the hub-function of Schiphol Airport should be added. There are opportunities here for further research.

The research only investigated costs and benefits that have a numerous value, but of course, there are other things that should be weighted as well when deciding whether the airport should expand or not. These are for example the appearance effects of an airport next to a large city, the drop in utility people experience by looking at the airport, or the increase in utility people experience by aircraft spotting.

There are some unavoidable limitations to this research. Nevertheless, this research still gives a clear solution to the Netherlands' capacity problem and shows that expanding Rotterdam The Hague Airport is a beneficial option. The research also shows that expansion would have a positive effect on employment for the city or even the region of Rotterdam. It is interesting to see what the future will hold to solve the Dutch aviation capacity problem.

Appendix

Area	Average value of house in 2015
Hillegersberg - Schiebroek	241.000
Lanslingerland	256.000
Overschie	170.000
Vlaardingen	159.000
Schiedam	146.000
Average of 5	194.400

Table 22. Housing prices in surrounding areas (CBS, 2015)

Type of movements	1	2	3a	3b	3c	3d
Small traffic	40.000	40.000	40.000	40.000	40.000	40.000
Helicopter flights	870	870	870	870	870	870
General aviation	4.543	5.428	5.428	5.428	5.428	5.428
Big traffic	580	580	580	580	580	580
Commercial aircraft movements	22.674	25.198	29.423	33.775	38.000	42.225
Total fligths	68.557	72.066	76.291	80.463	84.868	89.093

Table 23. Different scenarios of expansion of Rotterdam The Hague Airport (Ecocrys, 2015)

	2020	2025	2030	2035	2040	2045	2050
Commercial aircraft movements	19.439	25.540	33.557	44.090	57.928	76.111	100.000
Other aircraft movements	45.303	46.288	46.288	46.288	46.288	46.288	46.288
Total aircraft movements	64.742	71.828	79.845	90.378	104.216	122.399	146.288
Scenario Ecocrys (2015)	1	2	3b	3d	n.a.	n.a.	n.a.

Table 24. Number of movements compared with scenarios of Ecocrys (2015)

Scenario	Pm2,5/10 (tons)	NO_x (tons)	CO_2 (kilotons)
1	5,9	168,3	35,2
2	6,8	192,7	39,9
3a	7,2	208	43,9
3b	7,7	224,9	48,2
3c	8,2	241,4	52,5
3d	8,8	259	56,9

Table 25. Emissions for different types of scenarios (Ecocrys, 2015)

Index 2015=100	1	2	3a	3b	3c	3d
Investment costs (Thousand EUR)	€ 0	€9.800	€20.433	€38.748	€46.683	€52.971

Table 26. Investment costs different scenarios of expansion Ecocrys (2015)

The EU 28 consists of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Figure 27. EU 28 countries of InterVistas (2015)

Type	Price per Kg
CO2	€ 0,056
NOx	€ 34,12
PM2,5/10	€ 61,01

Table 28. Social costs per emission by 2015

Lden	1	2	3a	3b	3c	3d
+40 dB	154.960	175.037	193.268	210.317	225.712	240.053
+45 dB	58.552	62.975	66.830	70.969	73.375	75.599
+50 dB	16.221	19.448	20.548	22.138	23.849	26.202
+55 dB	2.395	3.265	3.826	4.370	4.850	5.390
+60 dB	31	35	71	95	117	140
+65 dB	0	2	2	3	5	5
+70 dB	0	0	0	0	0	0

Table 29. Affected houses due to noise pollution for different scenarios (Rotterdam The Hague Airport, 2015)

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