Airports on artificial islands: A solution for noise and capacity problems of traditional contemporary airports?

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Summary:

During the past few decades air transport has known a spectacular growth. This article tries to discover the problems of the traditional contemporary airports that come with this increase of air transport. Moreover it seeks to analyze whether those problems can be solved by building airports on artificial islands, so called 'airport islands'. In the first part of the article the lack of capacity and aircraft noise pollution are identified as mayor problems of today's airports. Amsterdam Schiphol Airport and Brussels Airport are two cases that illustrate those problems. Looking at airports on artificial islands, some positive and negative aspects can be identified. First of all, airport islands can be expanded more easily but at a higher cost than traditional airports. Furthermore, the case of Hong Kong International Airport shows that aircraft noise disturbance can significantly be reduced by using flight paths over water. Nevertheless there are also disadvantages in moving airports to artificial islands. Kansai International Airport with its stability problems due to the sinking foundation of the island is an example. Other negative aspects mentioned are the acceptance of the airport islands by the population and the possible harmful ecological impact.

Keywords: Airports, land planning, capacity problems, airport islands, aircraft noise disturbance

1. Introduction

The time when airports were only built on the mainland, in the vicinity of cities, is over. Nowadays more and more concepts are developed to build airports in different environments. One of those concepts is the construction of an airport island[1] in the sea. There are various reasons for the construction of those islands and many go back to the problems of traditional contemporary airports.[2]

During the second half of the twentieth century a strong growth of air transport could be observed and in the last ten years the traffic continued to grow. Figure 1 shows for passenger-kilometer[3] as well as ton-kilometer[4] an average yearly growth of 5.2% between the year 1995 and 2005. The year 2001 is an exception to this trend. The terrorist attacks on 9/11 in the USA caused a negative growth. As can be seen in the figure, the air transport industry found it difficult to recover after the attacks. Because of higher insurance costs and stricter security measures the costs of all participants in the air transport business grew. (ICAO, 2002) The total amount of passenger-kilometer shows only a moderate growth between 2001 and 2003 and only after 2003 a strong growth could be realized again.

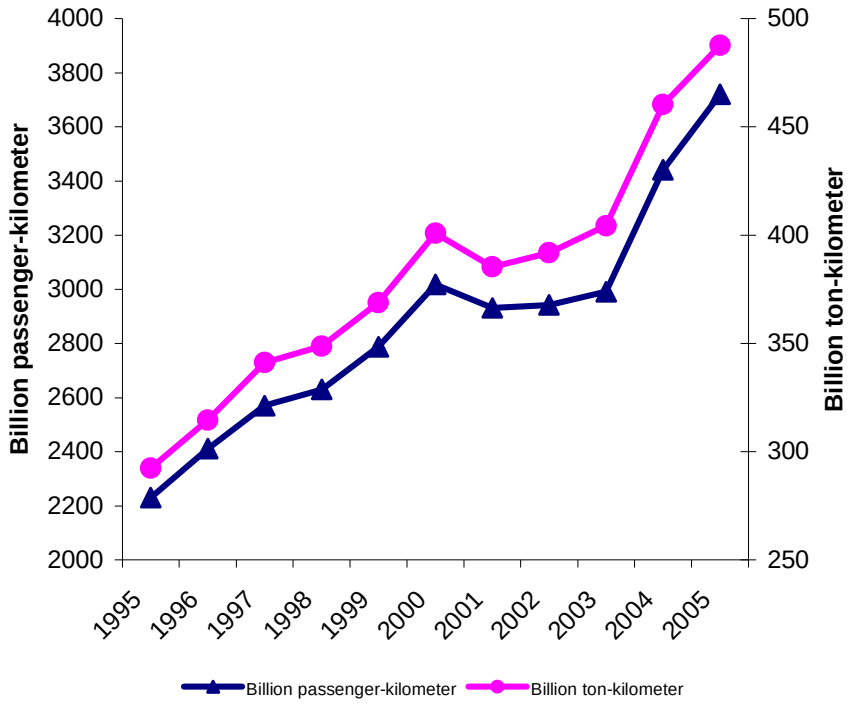
[1] In this article "airport islands" are defined as those airports which for the biggest part are built on artificial islands in the sea and which have no natural connection to the mainland.

[2] In this article "traditional contemporary airports" describes airports that are built on the mainland in the vicinity of cities.

[3] A passenger-kilometer takes into account the number of passengers and the flown distance.

[4] A ton-kilometer is a combined measure of the transport of passengers, freight and post, which also takes into account the covered distance. (ICAO, 2006a, p.7)

Figure 1 – Growth of air transport



Source: ICAO, 1995-2003; 2004a; 2005; 2006a

A positive growth of air transport is expected to continue in the following years, although rising fuel prices, an economic slowdown and other factors might slow down this growth. In its Global Market Forecast Airbus predicts a worldwide growth of revenue passenger kilometer of 4.9% per year up until 2026. The most promising markets for passenger air transport are the domestic markets of China and India where a growth of respectively 11.5% and 8.4% in revenue passenger kilometers is expected. For freight traffic, a worldwide annual average growth rate of 5.8% for the next 20 years is forecasted. This growth will be driven especially by the domestic Chinese market with an average annual growth of 10.5% and by the China-North America route with an average annual growth rate of 9.1%. (Airbus, 2008, p.46-47, p.114-115)

This strong growth also brings forth problems for the airports, which are often not able to deal with the extra traffic. This is why problems like congestion and aircraft noise annoyance will rise. Those problems will be dealt with in detail throughout this article. The aim of this study is to find out the problems of the traditional contemporary airports and to examine whether it is possible to solve the problems with the construction of airport islands.

First of all the problems of traditional contemporary airports are analyzed on the basis of a literature study. They will be illustrated by the cases of Brussels Airport and Amsterdam Schiphol Airport.

Following this analysis we will evaluate whether airport islands can solve the problems of traditional contemporary airports. Examples will illustrate the findings.

2. Literature study on the problems of traditional contemporary airports illustrated by cases

In the following part of this article the problems of traditional airports are treated. First the issue of capacity problems of traditional contemporary airports will be analyzed. Amsterdam Schiphol Airport will provide us with a clear example. Afterwards Brussels Airport will be examined as a classic case of an airport dealing with aircraft noise.

2.1. Capacity restrictions

Due to the growth of air transport, capacity restrictions become a more and more serious problem for the operation of airports.[5] Efficiency improvements are often only the first step to a solution, because efficiency can only be raised up until a certain point. In order to expand the capacity significantly, extensive investments in infrastructure such as new runways and buildings are necessary. As most of the airports are built in the vicinity of cities, there is not always sufficient space available for an expansion. Nowadays most of the airports have minor extra capacity but, according to a study of Eurocontrol, in 2010 there will be more than 20 airports struggling with capacity problems. In 2025 this figure will rise to 60 airports. (Eurocontrol, 2004, p. 35)

The capacity of an airport mainly depends on four elements: the airspace, the configuration and the equipment of the runways and taxiways, as well as the surface of the aprons, the airport building and the quality of the connections to and from the hinterland. (Van Berendoncks, 2006)

When the demand of air transport approaches the maximum capacity of an airport and especially of the runways, it will lead to departure and arrival delays. If the delays keep occurring, it can eventually result in a spread of congestion from peak hours to the formerly less congested hours because of a shift of airplane movements. (FAA, 1983, p.4)

[5] The FAA defines the capacity of an airport as a measure for the maximum number of airplane operations that can be processed in the airport as a whole or in a part of the airport. (FAA, 1983, p.3)

An airport which has had to cope with capacity problems for many years is **Amsterdam Schiphol Airport**. Since 1958 the airport is managed by the Schiphol Group. The Netherlands and the cities of Amsterdam and Rotterdam together have 100% of the shares. (Schiphol Group, 2006a, p.4; Schiphol Group, 2006b) As far back as the 1960's there were discussions about how to deal with the increase in air transport. Some suggested building an entirely new airport. Others proposed to add a fifth runway. An expansion of the capacity was among other things necessary to diminish the noise disturbance in the surrounding areas and to prevent possible new nuisance with growing traffic. (De Boer, 1993, p.28) When looking at the growth of Schiphol for the period of 1997 to 2007, in spite of the negative growth in 2002, 2003, 2005 and 2006, a growth of circa 2.24% in commercial aircraft movements can be noted (own calculations on the basis of Schiphol Group, 2007; Schiphol Group 2008)

To be able to cope with the growth of traffic and after a discussion and planning of over 30 years a fifth runway was finally opened on 13 February 2003. (De Volkskrant, 2003) The so-called "Polderbaan" cost about 320 million euro and was supposed to handle about 600,000 movements per year. (Veldhuijzen, 2005) The extra theoretical movements were necessary because the maximum capacity of the airport with 4 runways of 450,000 movements was almost reached during the year 2001. Moreover, with the new runway the government intended to reach a double objective. This plan implied that Schiphol could grow, but in a socially responsible way. (Schiphol Group, 2006a, p.7) However, with this the problems just began. Because of a shift in noise disturbance the claims did not diminish but increased enormously especially in the new affected regions. (Gedeputeerde Staten, 2005) Later in this article the issue of noise disturbance will be dealt with in depth. Due to erroneous calculations of the noise disturbance the Polderbaan could process about 30,000 movements less than expected. Furthermore it proved to be dangerous to have simultaneous operations on the Polderbaan and the Zwanenburgbaan, which is situated parallel to the Polderbaan. (Veldhuizen, 2005; Amsterdam Schiphol Airport, 2006)

In the end the airport with 5 runways and all the restrictions has only a capacity of about 450,000 movements per year, which closely resembles the capacity of the airport with only 4 runways. This capacity constraint led in 2006 to the start up of a report about the environmental effects of a further expansion of the airport because it was to be expected that in a few years time the capacity of Schiphol would not be enough to handle the demand. (Poot, 2006; BAS, 2008) The expectation is that around 2020/2025 about 80-85 million passenger will use the airport. In a study by the Netherlands Institute of Spatial Research published in 2007 seven possible future scenarios for Amsterdam Schiphol Airport are mentioned: Optimization of airport operations, expansion on the

ground surrounding the airport, reallocation of flights to partner airports, expansion of competitor airports, reallocation of the airport to another site, reduction of traffic and closure. (Nederlands Planbureau, 2007, p.8-9)

2.2. Noise Disturbance

New runways are often accompanied by the increase of complaints about noise disturbance by people who live close to the flight routes of the new runway. Noise disturbance is therefore the most important reason of interest groups to react against existing airports and their expansion. (Airport Council International, 2005, p.2) Furthermore, it seems that noise disturbance has, since the beginning of the 21st century, the most restricting influence on the capacity of airports.

What is now the difference between noise and noise pollution? As a matter of fact, noise pollution is unwanted noise. However, it depends on certain factors whether people think of noise as noise pollution or not. Those factors include the strength and frequency of noise, as well as the time and place where the noise is experienced. That is one reason why people experience aircraft noise as much more disturbing during the night as during the day. (Kamenický, 2000, p. 315) In 2001 the concept of "balance approach" was introduced by the ICAO to decrease the number of persons affected by aircraft noise. The intention of the concept is to prevent noise disturbance with five different measures in a cost efficient manner. The measures consist of technological improvements (reduction at source); land-use planning; noise abatement operational procedures like applying certain starting and landing procedures and aircraft operating restrictions, for example night curfews and noise charges.

Concerning the balanced approach, land-use planning and management are especially important. The population exposed to aircraft noise can be minimized with the introduction of zones around airports. Future claims and complaints can be prevented instead of having to be solved afterwards. (ICAO, 2006b; Kamenický, 2000, p.324) Countries like Norway, the United States, Austria and Great Britain have already approved laws in the past which introduced noise zones around airports. (Kamenický, 2000, p.324) A good example of land-use planning among others is the German "Gesetz zum Schutz gegen Fluglärm"[6] This law defines three noise zones around the airport with different land-use regulations for each one of them. (Bundesministerium der Justiz, 2001)

[6] Law for the protection against aircraft noise

Nevertheless it is not always easy to introduce zones around airports. The growth of airports often encouraged urban development in their vicinity. Industries that profit from the proximity of the airport set up their companies in the area and employees that work in those industries want to have their residence close to their work. As a consequence of this development the land prices around the airport rise, which can lead to political pressure to allow further growth. (Thomas and Lever, 2003, p.102)

The complaints of aircraft noise are one of the most significant problems of **Brussels Airport**. The situation grew into a dispute between the airport, the federal and regional governments, interest groups and local residents.

The future problems of the airport could already be suspected when after the Second World War the decision was made to expand the military airport in Melsbroek, close to Brussels. Because of the dominant west winds and the layout of the airfield in the east of Brussels, it was inevitable that ascending airplanes would fly over the city. (Airportmediation, 2006a)

At the moment Brussels Airport applies different measures to decrease the noise disturbance around the airport. First of all, the federal government introduced an individual and a general season-specific Quota Count (QC). The value of the Quota Count is a measurement of the noise profile of the airplane: The noisier the plane, the higher the value of the Quota Count. (Airportmediation, 2006b; Sleuwaegen et al, 2003, p.98) Since 1 January 2003 airplanes with an individual QC of 12 and more are not allowed to land or start at Brussels Airport during the nighttime between 23:00 and 6:00. In 2001 a Quota Count of maximum 20 was still allowed. Airplanes such as the DC 10-30, all Boeing 747 types and some models of the Airbus 300 belong to this category. (Airportmediation, 2006b) The MD-11, a plane often used by DHL, only just complies with the set norms. (Sleuwagen et al, 2003, p.98) On 31 October 2004 a ban for airplanes with a QC of 24 and more became effective in the “early hours” between 6:00 and 6:59. (Airportmediation, 2006b) Another mechanism to limit the noise nuisance is the new selection procedure regulating the use of the different runways.

However, the major problem of Brussels Airport is that not just one but *three* governments have the authority to introduce standards for noise pollution. The federal government, the Flemish government and the government of Brussels all issue different measures to protect their own interests. The measurements are also not always consistent. According to the regulations of the region of Brussels individual flights are not allowed to exceed a certain noise level. (Sleuwaegen et

al, 2003, p.98-100) If the airplanes nevertheless exceed the strict norms of Brussels, the region can ask an indemnification of 25,000 euro from the federal government. (Van Holen, 2005) However, the airport is obliged to spread all the flights, which indicates that sometimes also more noisy airplanes have to fly over Brussels. In March 2006 the noise restrictions of the region of Brussels were declared unconstitutional by the Court of Brussels. The Court of Appeal on the other hand announced this judgment as being not valid, so the application of spreading the flights evenly among the neighborhoods becomes more and more difficult. (De Tijd, 2008)

With the aim not to endanger the negotiations with the federal government, the government of Brussels has not yet claimed the compensation of the federal government. (Ysebaert, 2007a) Because the interest group Air Libre did not agree with this approach of Brussels, it went to court. (Belga, 2007a) The court of first instance decided on 8 February 2007 that the interest group and the inhabitants of Brussels are allowed to register the amount of decibel caused by airplanes with a noise meter and under the supervision of a bailiff. If the noise standards of Brussels were exceeded, the interest group could in addition ask an amount of 5000 Euro from the government of Brussels since 10 May 2007. (Ysebaert, 2007a; Belga, 2007b; Belga 2007c) To enforce the same noise standards as the ones in Brussels, the inhabitants of the surrounding Flemish municipalities likewise went to court after this decision. (Belga, 2007d) In the first half of 2008 different proposals were made by Belgian government officials to solve the question of noise disturbance around Brussels Airport. An example is the proposal of Yves Leterme, Minister of Mobility of Flanders, to introduce a “silent night” with no take-offs between midnight and 4:00. Up until now (5 June 2008) no agreement could be reached.

According to the information of government official Nagy, until 2007 around 1.16 million Euros were spent on lawyers, bailiffs and experts amongst others concerning the noise disturbance around Brussels Airport. (Ysebaert, 2007b)

The examples of Amsterdam Schiphol Airport and Brussels Airport show that capacity shortage and noise disturbance can be very problematic for the contemporary airport. Further analyses are necessary to determine whether airport islands could function as a solution to these problems.

3. Airport Islands - a solution?

In this article “airport islands” are defined as those airports which for most part are built on artificial islands and which do not have a natural connection to the mainland. Many of the airport islands that currently exist are not entirely man-made but also make use of already existing islands. In this article, airports that only use land creation for their expansion like Doha International Airport and Changi Singapore Airport are not considered because those airports still have a natural connection to the mainland.

At the end of 2007 four important airport islands existed: Kansai International Airport and Central Japan International Airport (Centrair) in Japan, Hong Kong International Airport in China and Incheon International Airport in South Korea. Other airport islands exist such as New Kitakyushu Airport and Kobe Airport, which are however internationally less important. (Lenhart, 2006, p.25)

3.1. Lack of expansion possibilities

Due to the limited capacity of traditional contemporary airports it is often not possible to realize the highest possible growth. (Humphreys, 2003, p.21) Especially for the construction of new runways a big surface area is needed which is seldom available. A lot of airports that were substituted by airport islands had very little area available for expansion. After all, most traditional airports were built in the vicinity of cities. In the course of time, with an increase of the population and the expansion of the cities, airports were surrounded by the city, so that an expansion was hardly possible. Because of a shortage of building space, houses were built closer and closer to the airport. This was especially the case with Itami Airport and Kai Tak Airport which were replaced by Kansai International Airport and Hong Kong International Airport respectively.

Airport islands on the other hand are easier to expand in the sea. However, the possibility for an easier expansion of the airport island also carries a high price tag. First of all because the construction of an airport island is more expensive in comparison with a traditional airport. Secondly because larger extensions such as runways necessitate the generation of land.

An example of a new airport built on the mainland is the airport of Munich. This airport was moved to a different location because of a capacity shortage and noise disturbance. It opened its doors on 17 May 1992. (Thomas, 1993, p.53; Flughafen München, 2005) The reasons for the

relocation of this airport are therefore the same as the arguments that are often mentioned for the construction of airport islands.

Table 1 shows the construction costs for the different airport islands, as well as for the new airport in Munich.

Table 1 – Construction costs of the airports and their total theoretical capacity

	Costs (billion US$)	**Number of passengers per year (millions)**	**Number of flight movements per year**	**Tons of freight per year (thousands)**
Kansai, Japan				
1994	11	30.7	160,000	370
2007	+ 14.6	n/a	230,000	n/a
Hong Kong, China				
1998	20	87	375,000	9,000
Incheon, South Korea				
2001	5,5	30	240,000	2,700
2008	+ 4.8	44	410,000	4,500
Centrair, Japan				
2005	6	20	130,000	510
2007	n/a	25	160,000	630
Munich, Germany (only first terminal)				
1992	5.4	20	473,000	n/a

Source: Procter, 1991; Kansai International Airport Land Development Company, 2005; Barnathan and Lindorff, 1994, p.52; Van Kooij, 2000; Civil Engineering, 2001, p.28; ICAO, 2004b, p.1-2; Incheon International Airport Corporation, 2006, p.23; Japanese Ministry of Foreign Affairs, 2005; Sekigawa, 2005; Flughafen München, 2005; Regionaler Planungsverband München, 2006; Kapur, 1995, p.66.

Based on industry estimates and the available information Kapur calculated that a new primary airport approximately costs seven billion dollar. (Kapur, 1995, p.66) Without taking into account the expansion, only Kansai and Hong Kong cost more. However, Hong Kong is a very big airport and Kansai had to deal with certain difficulties during construction (see also part 3.3.). Comparing the costs of the airport islands with the construction costs of the new airport in Munich, one can conclude that all airport islands were more expensive than this new airport. As to the amount of passengers, the airport of Munich can be compared with Centrair in its original layout (without extension). Nevertheless Centrair cost around 600,000 dollar more than the airport in Munich and

has moreover only a theoretical capacity of 130,000 aircraft movements. As for the movements, Hong Kong International Airport almost has the same theoretical capacity as Munich Airport. Moreover, its theoretical passenger capacity is more than four times as large, yet it cost only four times as much as Munich Airport.

If the costs of the islands are compared to each other, it can be observed that especially Kansai International Airport and Centrair have high building costs. The least expensive airport island is Incheon International Airport which in its original lay-out has a higher capacity than Centrair. The capacity of Kansai International Airport hardly differs from Incheon but former in its original lay-out cost twice as much. The difference in construction cost is due to the fact that Centrair and Kansai International Airport being entirely built on newly created land. When Hong Kong International Airport and Incheon were built, small islands were already present, which where integrated into the airport islands. As a consequence the construction costs of the island were lower.

The high costs of extending the airport islands are also notable. The cost of the expansion of Kansai International Airport is even higher than for the construction of the initial airport. It should be noted that in a time of 9/11 and SARS it was difficult for Kansai International Airport to finance a second island. The higher cost of the second island can be explained by the situation of the island: It lies further away from the mainland than the first one. At this location the sea was deeper resulting in higher costs for the creation of land than for the first island. (O'Farrell, 2004)

The high costs also have a negative impact on the financial statements and the returns on the airport. Kansai International Airport for example could only return a profit in the fiscal year of 2004, *ten* years after opening. The profit of 47.3 million dollar was considerably modest and in 2005 the airport booked again a loss of 151.4 million dollars. (Kansai International Airport Company, 2006, p.2; Kansai International Airport Company, 2005, p.3) The problem of Kansai International Airport lies in their finance structure: more than 60% is financed with debt. (Ishikura, Sugimura, and Ishii, 2005, p.526) This is why during the last years, the interest costs could not be covered by the operational returns, which worsened the financial position of Kansai International Airport. (Kansai International Airport Company, 2003, p.2; 2004, p.2; 2005, p.2; 2006, p.2) Kansai tries to diminish its financial losses by asking high landing fees. In 2005 Kansai International Airport had the second most expensive landing rights in the world for a Boeing 747 and an Airbus 320. (ATRS, 2007, p.36, 40) Naturally this has a negative effect on the traffic on Kansai International Airport as some airlines avoid the airport because of the high landing rights by flying to other airports such as Shanghai and Hong Kong. (O' Farrell, 2004)

Incheon International Airport could already book positive results in the fourth year, although this airport island too found it difficult in the first three years to cover the interest costs. (Incheon International Airport Corporation, 2006, p.21, 23; 2004, p.48; 2003, p.22) Hong Kong International Airport already returned a profit in the third financial year. After the fiscal year 2000, with the exception of 2003, the profits kept rising. (Hong Kong International Airport, 2005; Hong Kong International Airport, 2006, p.66) The landing rights at Hong Kong International Airport and Incheon International Airport are lower than those of Kansai. In 2005 the landing fees for a Boeing 747 at Hong Kong International Airport and at Incheon International Airport were even less than half of the rights at Kansai. (ATRS, 2007, p.35)

3.2. Noise reduction: The case of Hong Kong International Airport

In analyzing the problems of traditional contemporary airports and their solutions it is especially interesting to compare the noise disturbance around the airport of Kai Tak and the new Hong Kong International Airport.

The standard that represents the aircraft noise impact in Hong Kong is the Noise Exposure Forecast (NEF). This standard takes into account duration of the flyover, the maximum noise level, the frequency of the noise and the number of flights both during day and night. With the values of the estimates noise contours, which graphically represent the noise level around the airports, can be drawn up. (Civil Aviation Department of Hong Kong, 2007; Lau en Dao, 1998, p.15) An area with an NEF of less than 30 is suited for residential housing, whereas an area with more than 40 only qualifies for industrial sites. (Truax, 1999)

Due to its location the airport of Kai Tak had to deal with problems of noise disturbance before the opening of Hong Kong International Airport. During peak hours the airport had to handle between 30 and 33 aircraft movements per hour. For starting and landing the airplanes had two possibilities: The flight over water and the area of Lei Yue Mun or over the residential area of Kowloon. Even though most of the movements were carried out above water, the inhabitants of Kowloon were still exposed to a high noise pollution. (Lau en Dao, 1998, p.14)

In 1990 around 240,000 people lived in the NEF 30 contour. Moreover, it was expected that the number of people living in this noise contour would climb to 345,000 when the airport reached its

capacity. (Lau en Dao, 1998, p.15) At the beginning of the 1990's the airport already operated above its capacity. (Civil Aviation Department of Hong Kong, 2005) The result was that more than 6% of the inhabitants of Hong Kong were exposed to noise disturbance in the years before the closure of the airport in 1998. In contrast, in western countries only two percent of the population living around an airport is affected by aircraft noise. (Lau en Dao, 1998, p.15)

Especially in Kowloon City, noise disturbance was a serious problem. In this area of Hong Kong about 72% of all inhabitants lived within the NEF 40 noise contour. Moreover, about 488 schools were situated under the flight path. Around 70 of the schools were even situated in the NEF 30 or NEF 40 noise contours. It was expected that in the year before closing Kai Tak Airport, more than 100 schools were situated within those noise contours. (Lao and Dao, 1998, p.16)

Measures like the introduction of a night curfew for airplanes and special flight procedures could not decrease the noise disturbance around the airport. Because of the scarcity of land in Hong Kong an effective land planning could moreover not be realized. (Lau en Dao, 1998, p.17)

To prevent ineffective land use at the new airport, the plans of Hong Kong International Airport were drawn up from the beginning so that as little noise disturbance as possible would be produced. Among other things, agreements were made to decrease the target NEF 30 contour to NEF 25. According to an environmental impact analysis of the Civil Aviation Department of Hong Kong of 1991/92, updated in 1998, only 200 people still live in the NEF 25 contour. (Civil Aviation Department of Hong Kong, 2007)

Table 2 – Comparison noise disturbance Kai Tak – Hong Kong International Airport

	Kai Tak	**New Airport**
Population living within noise contour NEF 25	Around 760,000 people	Less than 200 people
Population living within noise contour NEF 30	Around 380,000 people	nil

Source: Civil Aviation Departement of Hong Kong (2007), *Aircraft Noise*, http://www.cad.gov.hk/english/ac_noise.html, 10.04.2007.

The new flight paths, which the Civil Aviation Department of Hong Kong aimed for, are meant to decrease the noise disturbance around the airport, especially during the night. In 2007 85.3% of the

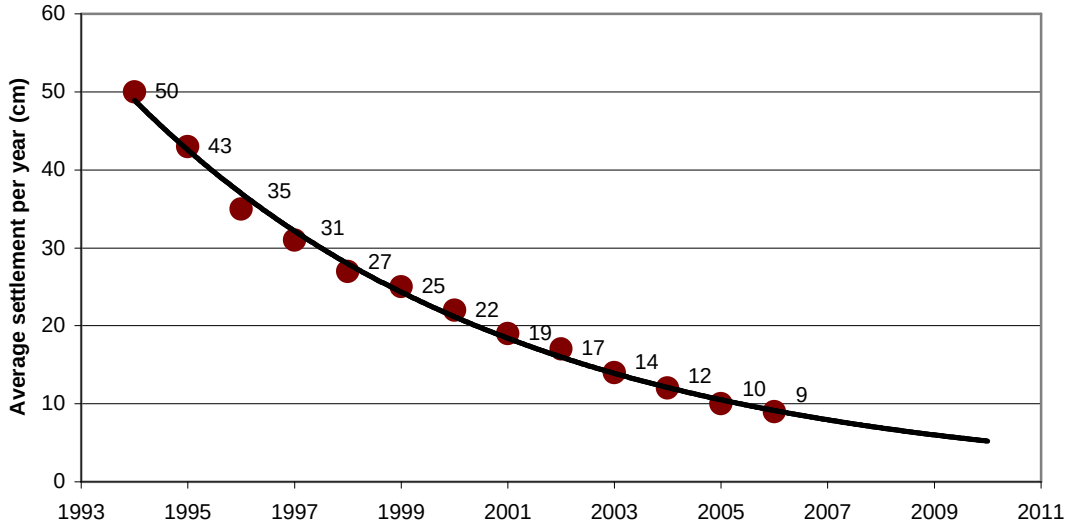
flights between 0:01 and 07:00 arrived from the southwest over the water. When departing between 23:00 and 07:00 about 99.3% of the flights were directed over the southbound route. In 2005 about 86.9% of the flights during the night landed over water and about 98.9% ascended above water. (Civil Aviation Department of Hong Kong, 2008)

3.3. Airport islands and their problems: The example of Kansai International Airport

Especially during the construction of the first airport island, Kansai International Airport, a lot of problems arose. Those problems mainly concerned the infrastructure and the stability of the island.

While constructing an airport island the upper clay layer of the seabed is compressed by the weight of the airport island. This causes an uncontrolled settlement. In order to prevent this, the water is artificially pressed out of the upper clay layer. This is also done so that no unforeseen settlement occurs after the construction of the airport island. (Kansai International Airport Company, 2007b) A few years after the opening of the airport it became clear that the calculated settlement occurred faster than expected. This can chiefly be attributed to the settlement of the deeper layers of the seabed. The deeper situated clay layer, the so called Pleistocene layer, is so deep under ground that it is impossible to reach to strengthen it artificially. Kansai International Airport was the first project that had an impact on the Pleistocene layer. (Kansai International Airport Company, 2001, p.3; Kansai International Airport Land Development Company, 2005) Up to 1994 no studies about the settlement of the ground existed, therefore experts had to estimate it. However, their estimates were not accurate enough and in the year 1999 it became clear that the island had already sunken 8 meters, only 5 years after the opening. A settlement of 8 meters was however forecasted after 40 years. (‘O Farrell, 2004) According to Kansai International Airport an average settlement of 12.49 meter was reached in 2006. (Kansai International Airport Company, 2007b) However, a settlement of only 12 meters was forecasted for the total settlement of the island from the beginning of the land creation. (Kansai International Airport Company, 2001, p.5) The island has thus already sunken almost half a meter more than the original estimate.

Figure 2 – Average settlement per year since the opening of Kansai International Airport



Based on: Kansai International Airport Company (2001), *Brief Summary of Settlement,* www.kiac.co.jp/english/land/land.htm, 27.09.2006; Kansai International Airport Company (2007b), *Technical Information,* http://www.kiac.co.jp/en/tech/index.html, 24.03.2007.

The trend line in figure 4.6. shows clearly that Kansai International Airport will continue to settle in the following years, although the settlement will slow down. It is to be expected that the airport island will be sinking around one centimeter less each year, beginning in 2006. In 2006 the island sank 9 centimeter on average. During its construction this was still 5 centimeters per month. (‘O Farrell, 2004)

Not only the settlement in general forms a problem but also its unevenness across the island. This is mainly the result of the unevenly distributed weight of the infrastructure on the island. The middle fraction of the passenger terminal is for example lighter than the adjoining structures. This causes the ground beneath the middle fraction to settle slower than the ground around it. Because of this uneven settlement, cracks in the walls of the building can appear. This is prevented by setting pillars under the passenger terminal that can be tilted up to compensate the uneven settlement. (Kansai International Airport Company, 2007a; ‘O Farrell, 2004)

Another problem arose with the construction of the second island. The second island was built further away from the mainland, in even deeper water. As the construction ground was softer than under the first island, the construction of the second island was even further complicated. This would lead to a higher settlement. (Airport-technology.com, 2007; ‘O Farrell, 2004) The Kansai International Airport Land Development Company expects that the second island would be settling

about 18 meters. (Kansai International Airport Land Development Company, 2005) The second island's effects on the first are also unclear. The second island could possibly speed up the settlement of the first island. If the two islands then settle at a different speed, problems at the connection of the two islands could arise. ('O Farrell, 2004)

4. Conclusion

In the course of this article a number of cases were analyzed to explain the problems of traditional contemporary airports and to find out whether airport islands can be considered a solution to these problems. The case of Hong Kong International Airport shows that an airport island can be a solution to noise disturbance. This is clearly shown by the fact that the number of people within the NEF 25 noise contour decreased from 760,000 tot 200 inhabitants in the case of Hong Kong International Airport. However, an important condition is, that the flight paths are situated over water, as is the case with Kansai International Airport and also another airport island in Japan: Centrair. If this is not the case, the risk is high that despite the construction of an airport island, the population around the airport is affected by aircraft noise. Here an airport island can not be considered as a solution for noise pollution.

As they are surrounded by cities many airports have limited expansion possibilities. Airport islands offer a way to get around these limitations. Because airport islands are situated in the sea, there are possibilities to enlarge the islands in the long run. However, the location of the islands can have disadvantages. For the construction one has to count on a higher cost than for the construction of a traditional airport. If technical problems occur with the construction of the island, as was the case with Kansai International Airport, the cost of the airport island can mostly increase in comparison with traditional airports. This is one of the reasons why some airport islands have problems to generate profits. One can therefore conclude that airport islands can form a solution to the capacity problems of traditional airports but that this solution comes at a high price.

Furthermore, the question has to be asked whether it would be possible to build an airport island in Europe. Up until now airport islands were only constructed in Asia. Japan is a pioneer in building these kinds of airports. There have been studies about the feasibility of building an airport islands in Europe. In the Netherlands plans existed to build an airport island in the North sea, named Flyland. Those plans were put on hold as a result of the bad economic circumstances following 9/11. When thinking about airport islands in Europe the question arises whether the construction of such islands

will be accepted by the population. Even in Japan, a country that is not known for protest actions, voices are starting to be heard against the construction of airport islands. There is also a safety concern; due to very busy seaways the safety in the vicinity of the islands can not be guaranteed. Moreover, the Asian airport islands were built in bays, while the proposed airport island in the Netherlands would have been situated in the open sea, where it would not been as protected against the wind and waves.

People will also ask questions about the ecological impact of airport islands. In studies such as the one for the aforementioned Flyland, potential negative effects on the environment became clear. (Flyland, 2003) Negative effects were already discovered with existing islands, especially Hong Kong International Airport. (see for example World Wide Fund For Nature Hong Kong, 1996) The question arises then whether new problems are created when solving the problems of traditional contemporary airports through the construction of airport islands. The long term affects are also not clear, as it concerns a relatively new concept.

Airport islands can form a solution for congestion and noise disturbance of traditional contemporary airports, if one takes the circumstances into account. When considering the problems of those airports, the question arises whether good land-use planning, which permits the airport to grow, cannot partly solve the problems of traditional contemporary airports.

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