Modeling the Effect of Night Time Penalties on Commercial and Business Flights for Regional Airport Noise and Economics: Rotterdam Airport Case Study

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Noise is one of the main concerns of airports around the world. Several measures have been taken by regulators to reduce noise at airports. Some of these measures are meant to control noise at major or busy airports; however, certain operational restrictions (quota, curfew, and budget) are also implemented throughout the whole country regardless of the role and the size of the airports. An empirical example, using the Rotterdam Airport, a regional airport in the Netherlands, illustrates how regional airport should determine its night surcharges policies, especially with different type of aircraft categories. In this research, the night surcharges received from Business Jet category and Commercial aircraft category are being compared. The results indicate that the night surcharges did not compensate for the number of day time flight movements and potential revenues losses. Regional airport may need to be more selective in setting the night surcharges in order to maximise its revenues.

Nomenclature and Abbreviation

$Ł_{DEN}$	Day, Evening and Night noise level
$Ł_{DN}$	Day and Night noise level
Ke	Kosten Metrics
IFR	Instrument Flight Rules
INM	Integrated Noise Model
AOR	Airport Operations Ruling
$SACN$	Stitching Airport Coordination Netherlands
KLM	Royal Dutch Airlines
GA	General Aviation
IVW	Inspectie Verkeer en Waterstraat (Transport and Water Management Inspectorate)
$ADECS$	Advanced Decision Systems
FAA	Federal Aviation Administration
$Ł_{EQ}$	Equivalent noise level
$RANOMOS$	Rotterdam Airport Noise Monitoring System
$CMLR$	Committee of Environment for Rotterdam Aerodrome
NMT	Noise Monitoring Terminal
$MTOW$	Maximum Take-off Weight
$Ł_{max}$	Single event maximum noise level

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I. Introduction

Although aircraft has become quieter, the community is still complaining about aircraft noise. There are several debates about this phenomena, some claimed that as a community becomes wealthier, they are more likely to complain about noises which disturb their quality of life, and some reported that the number of planes rather than the noise of individual aircraft has become the real problem.[1]

A range of mitigating measures has been implemented, not only by airports but also by State governments and regulatory bodies reducing the impact of aircraft noise on surrounding areas. Some of these rigid policies or rules have not been fairly implemented and has created severe setback for some airports, especially for regional and/or small airports. Most common short term measures that have been enforced by some European governments and regulators are the 'noise quota' and the 'night curfew' on airports. Such constraints may be relevant to large and busy international airports. On the contrary, for regional and/or small airports this constraint might lead to limitations of welfare enhancing capacity extensions and expanding operations.

It is difficult regional airports to be selective and demanding, since they have limited infrastructure and high competition amongst themselves. In addition of having 'noise quota' and 'night-time penalties' imposed by the Government, would definitely create more challenging situation for regional airports to attract airlines and to expand its capacity.

For this research, Rotterdam Airport was chosen as a case study because of its challenging situation. Rotterdam Airport has strict noise restrictions and regulations imposed on them by the Dutch Government. One of the restriction is the '35 Kosten metrics' noise contour which they have to adhere to, and one of the regulation is the 'night-time penalties' for flights that take-off or land during the curfew hours. Officially, the airport is close from 23.00 - 7.00 hours for scheduled flights such as commercial and business flights. Any of these scheduled flights that land or depart between the curfew hours required permission from Rotterdam Airport. However, for medical, military or government flights this condition is exempted.

Looking at the community's complaints records, although higher number of flight movements has direct influence on the number of complaints, but, the night flights seem to generate higher ratio of complaints per flight movement than day flights. Therefore, it would be interesting to analyse the possible impact of noise constraints and night-time noise penalties on regional airport's economy.

These night penalties are established to deter flights from flying during the night, in order to protect the environment and reduce annoyance to the communities living near the airport. Nevertheless, the effectiveness of these night penalties were never been measured in term of its impact on the airport economics. The research presented in this paper aims to develop a better understanding of the effects of night-time penalties of different aircraft category on regional airport noise management relative to airport economics. In this case, only the Commercial and the Business aircraft type were analysed because they are the main source of revenues for Rotterdam Airport.

This paper firstly provides an overview of the current noise measures undertaken by Rotterdam Airport. With the present infrastructure, Rotterdam Airport can cater up to 4.5 million passengers annually, but unfortunately the airport is only allowed to handle 1.5 million passengers per year due to the current limitation on the number of aircraft operations and the 35 Kosten noise contour. In relation to the noise contour, the number of complaints received per year is analysed to understand the effectiveness of noise measures implemented at Rotterdam Airport. Evidence from the complaints data, community complaints' trends are being formulated in Section 3. In Section 4, the impact of night penalties on Rotterdam Airport economics, are investigated. The night surcharges of Commercial aircraft and Business Jet categories are being calculated and compared. In section 5, the modeling of noise footprints for different type of aircraft are being carried out, thus finding the value of noise based on night-time surcharges. Section 6 discussed the results and finally, concluding remarks are presented in Section 7.

II. Noise restrictions at Rotterdam Airport

Noise is one of the most significant areas of environmental impact of aviation,[2] especially when noise can be immediately identified by the community that is being affected by it. Noise at airports is primarily generated by arriving and departing aircrafts. However, since an airport is the land-side medium that accommodates the airlines, airports have been made accountable as the problem owners of this issue.[3]

Rotterdam Airport (formerly known as Zestienhoven), is located north of Rotterdam city, in the Netherlands. Rotterdam Airport is a regional airport, situated in a highly dense catchment area which covers The

Hague, Rotterdam and Utrecht region. It even has greater market potential than Schiphol Airport, especially in attracting business passengers. The existence and the location of Rotterdam Airport have been frequently debated. The current regulation and volume of air traffic of Rotterdam Airport are the outcome of a political process. Rotterdam Airport is required by law to operate within a certain noise zone. Currently, the noise legislation that applies to Rotterdam Airport uses the Kosten noise metric. The noise regulations are based on the Airport Operations Ruling (AOR) 2001.

Rotterdam Airport's situation becomes more complicated because the airlines slots awarded at Rotterdam Airport are determined in advance by an independent party, the Stitching Airport Coordination Netherlands (SACN), and Rotterdam Airport has no direct influence on the slots. Therefore, it is difficult for Rotterdam Airport to attract airlines from popular destinations with a mix fleet to fly to/from Rotterdam Airport, and to encourage these airlines to use quieter aircrafts, because the slots are limited.

Rotterdam Airport is 100% owned by the Schiphol Group. However, the growth and development of Rotterdam Airport is also under the control of other stakeholders such as the City of Rotterdam, the Dutch Government, airlines indirectly under KLM, the passengers and also the communities. As a privately owned airport, Rotterdam Airport B.V has to make a profit to sustain its operation and business, but on the other hand, Rotterdam Airport also wishes to value itself as an airport that serves the community by providing accessibility and employment to the region.

Rotterdam Airport has to fulfill various stakeholders' requirements, such as the vision of the City of Rotterdam, who wishes to develop Rotterdam Airport into a "Business Airport" that offers scheduled services, general aviation (GA) services and limited leisure services. In contrast, the airline KLM wants to eliminate any competition from low cost carriers and reinforcing the hub-and-spoke services at Schiphol airport. KLM has proposed that Rotterdam Airport should only offer GA services but no scheduled services and leisure passenger services and also non mainpoint traffics. Since Rotterdam Airport is located strategically in between the business centre and government offices of Rotterdam and The Hague, the passengers want Rotterdam Airport to offer frequent scheduled of business services and also leisure services. The Dutch government also sees the potential of Rotterdam Airport as a "Business Airport".

Currently, business at Rotterdam Airport consists of 30% high yield passengers and 70% low yield passengers, and Rotterdam Airport views itself as an airport that offers a mix of all kinds of traffic.

Rotterdam Airport needs to evaluate its role carefully in terms of the types of services that it wishes to offer that will allow it to sustain its operations and fit within the noise constraints that have been imposed by the Dutch Government.

A. Impact of noise restrictions on flight movements

Boeing has undertaken a special study about noise for a sample of 590 airports around the world,[4] to highlight and report about airport noise restrictions and government regulations to airlines. Table 1 on the following page illustrates the noise measures taken by Rotterdam Airport. By comparing with other regional airports of the same size and operations in Europe, the noise mitigation measures enforced on Rotterdam Airport are quite stringent. Very few regional airports in the world have the noise quota regulation, which limits the number of flight movements per year at its airports.

However, the biggest constraint to Rotterdam Airport's growth is the introduction of 35 Kosten noise contour. This restriction is strictly regulated and controlled by the Dutch Government. The enforcement of the current noise contour is done by the Transport and Water Management Inspectorate (IVW). Each year, an operational plan is made with a prediction of the type of flights that would be flying through Rotterdam Airport. A corresponding noise contour is calculated using the Kosten (Ke) metrics and the plan will only be approved if the noise limit does not exceed the specified grid. Every three months, the actual flights at Rotterdam Airport and the expected flights for the rest of the year are combined and a new noise contour is recalculated. If possible violations are detected; the plan for the rest of the year will be readjusted. If by the end of the year, the actual noise contour exceeds the regulated noise contour, the airport will be charged a penalty by the Government.

The 35 Ke contour covers about $6.54km^2$ over Rotterdam city (refer Fig 1 on the next page) and every year the Dutch government will revise the noise quota.

The contour is related to the distribution of the total of aircraft footprint calculated for the whole with the geographic boundary set at 35Ke. The boundary of 35Ke is been defined by the 67 grid points around Rotterdam Airport, with specific Kosten values allocated at each point.

Table 1. Measures taken to reduce noise at Rotterdam Airport

Measures	Description	Measures at Rotterdam Airport
Curfews	Take-off and landing operations are prohibited for certain periods of time	Airport closed between 2300 and 0700 hours Between 2300 and 0700 hours, airport only open for police, rescue, ambulance, government flights.
Engine run-up	Engine run ups are restricted	No engine run-up between 1800-0800 hours unless authorised by Airport Authorities.
Noise abatement	A set of procedure aimed to reduce noise	Incorporated in Standard Arrivals and Standard Instrument Departures
Noise surcharge	Implementation of noise charges	For Chapter 2 and noisy Chapter 3 aircraft the noise surcharge is 400% of the landing charge
Operating quota	Restriction number of operations	Calculated noise zone based on approximately 27,500 movements

Source: Boeing - Airport Noise Regulations[5]

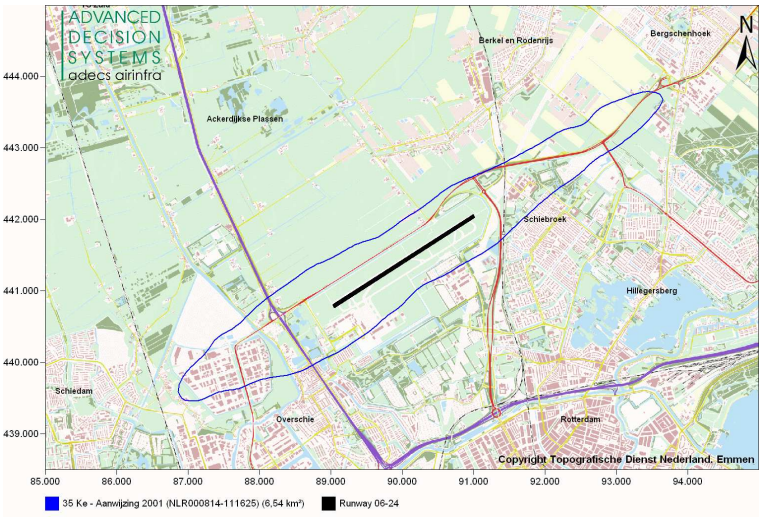


Figure 1. The official 35Ke contour for Rotterdam Airport (2008)

It is a challenging task for Rotterdam Airport to predict and plan its operations to fit within the regulated noise contour especially when it also has to accommodate ad-hoc aircraft movements from the police, rescue, ambulance, government and also business flights. Rotterdam Airport also has to cater for small and light aircraft movements for flight training and recreational flying, and this contradict with the vision of Rotterdam Airport and City of Rotterdam of a Business Airport.

The 35 Ke noise restriction is for large aircraft above 6,000kg, jet aircraft, helicopters and other aircraft flying with instrument landings and departure (IFR). The Ke metrics was introduced by prof. dr. ir. C.W. Kosten, who was the Dutch noise expert in 1968, who was commissioned by the Dutch government to devise a calculation method for land planning purposes. The limit of 35 Ke was introduced to prohibit residential development to be built within this specified boundary.

Yearly noise contour at Rotterdam Airport are being calculated using ADECS software, and this software is in line with the official regulations and has been utilised to produce the legally mandatory reports presented to the Dutch Ministry of Transport. But for this research, INM version 7.0 was selected to conduct the noise footprint modeling in Section V, on the basis that INM is one of the most widely used tools in the world to compute noise contour. INM was developed by the US Federal Aviation Administration (FAA) to calculate the noise contour for United States airports.

In the Kosten noise model, the noise exposure B, generated in one year, is calculated as follows:

$$Ke = 20 * log(\sum g(i) * 10^{L_{Amax}/15}) - 157 \quad (1)$$

- L_{Amax} is the maximum sound level, due to the passing of one aircraft, expressed in dB. Aircraft with a level of L_{Amax} smaller than 65 dB are not taken into account (threshold value)
- $g(i)$ is the penalty factor, according to time of day (refer Table 2)

Table 2 shows various weighting or penalty factor given for different time. For flight movement between 08.00-18.00 hours there is no penalty, and the penalty increase gradually. The highest penalty is between 23.00-06.00 hours where the weighting factor is 10. The latest night curfew hours at Rotterdam Airport is from 23.00-07.00 hours, there but the penalty for 06.00-07.00 is 8, and this is a slight difference compared with other penalty factor uses by other metrics such as L_{DEN} or L_{DN}, where the penalty is still 10 during 06.00-07.00 hours.

Table 2. Penalty factors in the Kosten system

From	0:00	6:00	7:00	8:00	18:00	19:00	20:00	21:00	22:00	23:00
to	6:00	7:00	8:00	18:00	19:00	20:00	21:00	22:00	23:00	0:00
Weight factor	10	8	4	1	2	3	4	6	8	10

For various penalty factors tabulated in Table 2, the following Fig. 2 shows the impact on Kosten level given by Eq. 1. It can be seen that it is not linear relation between penalty level and Kosten units.

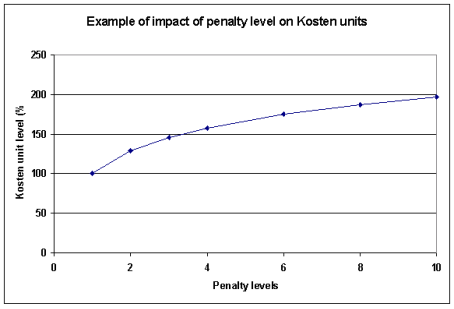


Figure 2. Impact of penalty level on Kosten units

However, we can decrease the number of flights at the higher penalty level in order to maintain the same Ke as the penalty factor of 1. This is shown in Fig. 3 on the next page, where the number of flights and penalty level are inversely related in maintaining a constant level of Kosten.

III. Noise complaints at Rotterdam Airport

When it comes to quantifying the value on noise around airports, most researches that were carried out are on the social costs of airport noise, its impact on the price of the houses in the vicinity and the cost of compensation for the total noise nuisance experienced by the residents.[6–8] Another interesting finding from Hsu and Lin[8] is that the noise level created by a single flight has a higher impact on social costs than flight frequency. When the frequency is reduced, the corresponding reduction in social cost does not compensate for the increase of noise caused by introducing larger, noisier aircraft. In contrast, Stewart[1] indicates that the number of planes is the real cause of aircraft noise, and the result from L_{EQ} or L_{DEN} metrics does reflect the actual experience of people living close to the airport.

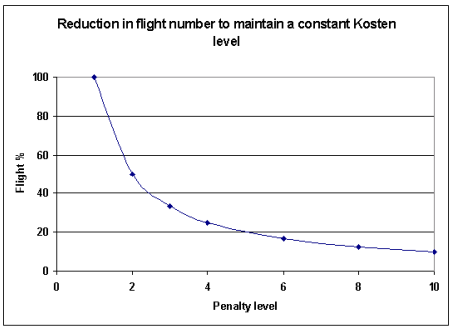


Figure 3. Reduction in flight number in maintaining a constant Kosten level

Carlsson et. al[9] conclude that people are sensitive to noise and the time of day matters to the communities. Some residents in the Bromma area in Sweden show a significant willingness-to-pay for a decrease in the number of aircraft movements in the morning and evening throughout the week.

As for Rotterdam Airport, the communities' complaints are been monitored by an organisation known as DCMR Milieudienst Rijnmond or Environmental Protection Agency in Schiedam utilizing the RANOMOS (Rotterdam Airport Noise Monitoring System) aircraft monitoring system, where the Noise Monitoring Terminal (NMT) are located at 6 different locations around the Rotterdam region. The quarterly and yearly report of noise complaints are published and can be accessed by the public on the DCMR website[10] and these reports are also given to the Dutch government.

Residents can complain at any time, either via internet, writing or by telephone, about aircraft noise and their complaints will be automatically recorded. The centre will record the location of their addresses and will be linked to the system based on the date and time the complaints are filed. The complaints will then be matched to the type of aircraft flying at that particular time.

The number of complaints recorded around Rotterdam Airport for the year 2008 is shown in Fig. 4.

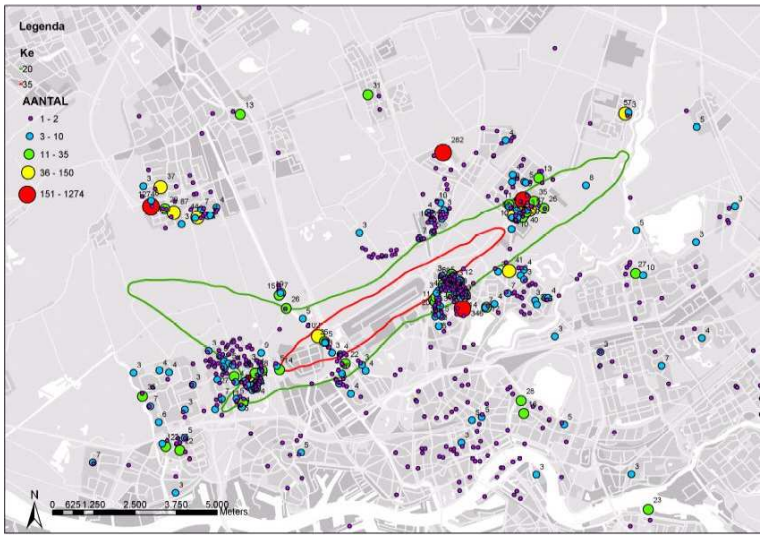


Figure 4. Communities complaints at Rotterdam Airport

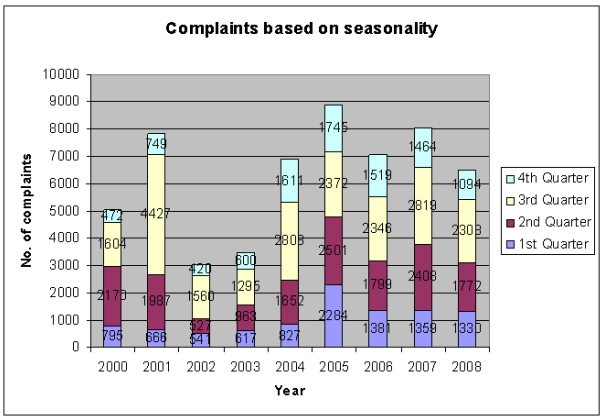
From the noise complaints chart (refer Fig 4), most of the complaints came from outside the 35 Ke contour (red contour). The green contour is for small aircraft below 6,000 kg and it is known as the 47 BKL noise contour. However, this research is more focus on the 35 Ke contour, therefore, the 47BKL contour is not been taken into consideration.

The dots and numbers indicate the number of complaints per address in one year, and the red dot

indicates a single complainant, filing complaints between 151 and 1274 times per year and these and these are called "veel-klager" or frequent-complainants. Although the percentage of the frequent-complainants is only 0.6% but the percentage of the complaints is about 49.4% out of the total complaints.

Due to the high contribution of frequent-complainants, it causes some distortion in understanding the type of problems caused by aircraft nuisance. Therefore, in this research, the frequent-complainants are disregarded in order to validate the actual complaints regarding aircraft nuisance around Rotterdam Airport. Looking at Fig 4 on the preceding page, it is noted that most complaints arise from residents who are under the aircraft flight path, which is unavoidable since their houses are situated nearby the airport.

It is important to understand the behaviour of complainants, and to find the reasons why do they complaint. Fig 5 shows a consistent trend from 2000-2008. It is noticeable that total number of complaints seem to increase during the 2nd and 3rd quarter of the year, which represents the spring and summer season.



(a) Total number of complaints based on seasonality

(b) Total number of flights vs. Total number of complaints in 2008

Figure 5. Seasonality complaints

A. Complaints based on night flights

Although higher frequency in flight movements increases the number of complaints, the time of day seems to have higher influence on the ratio of complaints.[11] In 2001, Rotterdam Airport introduced the night curfew regulation at its airport. The night curfew lasts from 23.00 - 07.00 hours. Officially, Rotterdam Airport is closed after 23.00 hours, and any scheduled or business flights that land or depart between the curfew hours required special permission and authorisation from Rotterdam Airport. However, for medical, military or government flights this condition is exempted.

To discourage airlines from flying during the curfew hours, high penalty charges are also imposed. Nevertheless, there is still a higher number of night flights and Fig. 6 on the following page shows the number of complaints recorded against the number of night flights.

It is noted that from Fig. 6 on the next page, the number of complaints was high in year 2001. However, when the night curfew regulation was introduced at the end of year 2001, the number of night flights and the number of complaints dropped drastically, only to rise again slowly as the number of night flights increased. Psychologically, the residents would expect that there will no longer be any night flights once the night curfew regulation is established. The ratio of the number of complaints versus the number of night flights was high from year 2004-2005. The last few years has seen the level of complaints stabilised despite the reduction of aircraft movements due to the recession.

Consistent with the finding by Carlsson et. al,[9] for Rotterdam Airport Rotterdam, most complaints arise between 07.00-08.00 hours in the morning and 22.00-01.00 hours at night (refer Fig. 7 on the following pagea). This due to the perception of curfew hours where the residents expect aircraft should not be flying at that particular time and also during the night; the aircraft noise is more audible as compared to daytime especially during late hours in the evening.

Looking at the movements' time at Rotterdam Airport in 2008 (refer Fig. 7 on the next pageb), the highest flight movements are between 14.00 - 18.00 hours, but, the number of complaints is slightly less

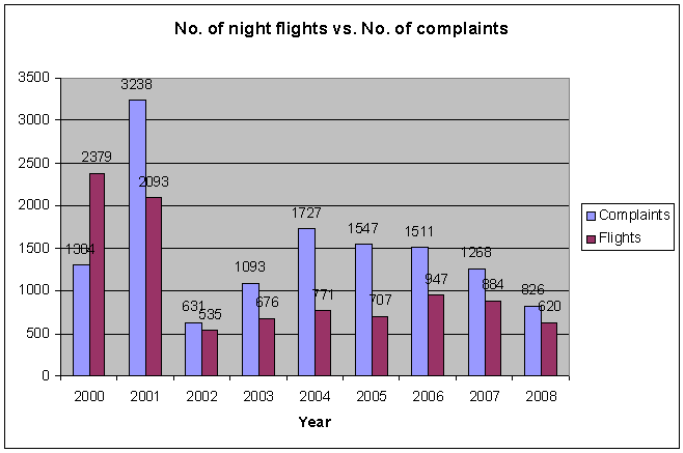
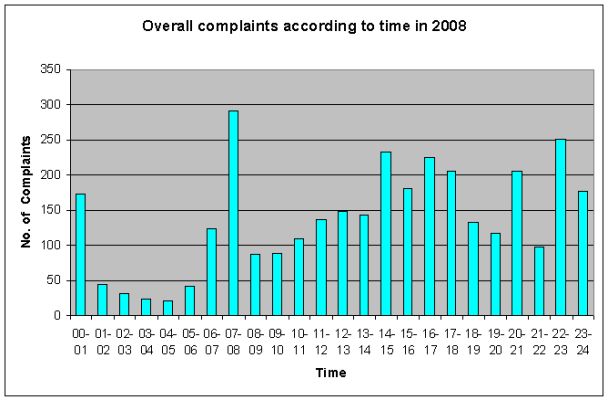
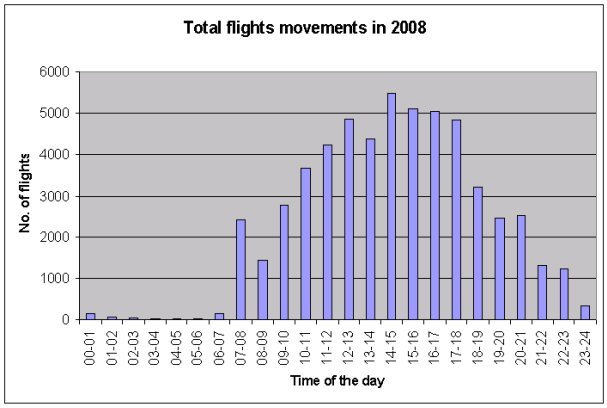


Figure 6. Number of complaints vs. number of flights for night time



(a) Complaints distributed over the day



(b) Total flight movements distributed over the day

Figure 7. Number of complaints vs Total flight movements throughout the day in 2008

compared to the number of complaint received for flight movements during 07.00-08.00 hours. The curfew hours (23.00-07.00 hours) produce higher ratio of complaints per aircraft movement compared to the day time ratio. Fig. 7 indicates that time-of-the-day has different effects on the number of complaints and the flight frequency.

This finding also seems to be consistent with number of complaints recorded by Manchester Airport in 2001,[12] where complainants are more sensitive during the first half of the night and early morning. However, high frequency during the afternoon did not create as many complaints, probably due to the fact that most residents are not at home during that hour. Detailed research needs to be carried out in the future to prove this hypothesis and to find out other factors that influence the residents' complaints regarding flight frequency based on the time of the day.

B. Complaints based on aircraft type

Table 3 on the next page provides an overview of the aircraft types that received the most complaints in relation to the number of flights for the year 2008. The Boeing 737-700 receives the highest number of complaints, followed by the Fokker 50 and the Boeing 737-800. Most regular traffic operations are performed with these types of aircraft. For business operations, the Piaggio Avanti has the most complaints, due to its pusher type engine characteristic which produces a very high pitch that annoys the residents.

A Boeing 737-200 flight is a one-off case for the year 2008. It has the highest rate of complaints because

it was a Chapter 2 aircraft, and it was landing at Rotterdam Airport during late evening. However, since it belongs to the Brazilian Air Force, carrying the Brazilian's President to the Netherlands, it was given permission by the Ministry of Transport and Water to land at Rotterdam Airport. The timing of the flight determined the numbers of complaints since late at night people are more sensitive to disturbance than during the middle of the day.

Table 3. Complaints based on aircraft type for 2008

Type of	Flights		Complaints		Ratio Day	Ratio for Night
Aircraft	Day	Night	Day	Night	Complaints/Flight	Complaints/Flight
Boeing 737-700	1003	146	1278	250	1.3	1.7
Fokker 50	916	35	1173	58	1.3	1.7
Boeing 737-800	372	10	496	19	1.3	1.9
Boeing 737-200	3	0	129	0	43.0	
Piaggio Avanti	38	6	52	22	1.4	3.7
Falcon 900	24	19	34	29	1.4	1.5
Gulfstream 5	17	19	24	34	1.4	1.8
Cessna 550	28	7	32	18	1.1	2.6
Beechcraft Beechjet	21	6	27	23	1.3	3.8
Dornier 328	32	1	44	1	1.4	1.0
Cessna 560	26	9	30	13	1.2	1.4
Airbus 320	32	1	38	1	1.2	1.0
Boeing 737-400	27	0	34	0	1.3	
Fokker 70	24	2	29	2	1.2	1.0
Fokker 100	28	2	28	2	1.0	1.0
British Aeropsace 146	23	0	28	0	1.2	
Piper 28	26	0	27	0	1.0	
Airbus 319	22	0	27	0	1.2	
Gulfstream 4	8	8	11	14	1.4	1.8
Boeing 737-300	16	1	24	1	1.5	1.0
Others	392	59	496	81	1.3	1.4
Total	3078	331	4061	568	1.3	1.7

By observing the number of flights made during the day and at night by different types of aircraft, an obvious trend was noted. Table 3 shows that most business type aircraft such as Piaggo Avanti, Falcon 900, Gulfstream V, Cessna 550 and Beechcraft Beechjet has a high ratio of night flights compared to commercial flights e.g. B737-700, B737-800 or Fokker 50. The ratio of complaints per movement is also higher for Business type aircraft in comparison with Commercial type aircraft.

C. List of top 10 noisiest aircraft at night in 2008

The previous section showed considerable variation in sensitivity to aircraft noise at different times of the day and night in terms of number of complaints recorded. Complaints tend to peak in the late evening, early night and in the early morning hours. In this section, the level of noise measured during the night produced by individual aircrafts was investigated to determine whether different noise levels at different hours of the night have any significant influence on the number of complaints.

Table 4 on the next page summarises the highest noise levels measured in a single event (L_{max}) by the NMT at different station, for individual flights movements during the night.

Table 4 on the following page illustrates the correlation between the measured noise level and the number of complaints received. The business aircraft category such as the Beechjet 400 and Falcon 900 taking-off early in the morning seems to receive more complaints as compared to a Boeing 737-700 that produces higher noise level during take-off at almost the same hour of the day.

The Piaggio Avanti showed a noticeable trend of landing at an extremely early hour in the morning and seems to have a higher number of complaints as compared to B737-700 which produces a slightly higher noise level

The noise characteristics and landing procedure of the Piaggio Avanti requires further exploration in the future to understand the reason why it creates a higher number of complaints from the community.

It can be concluded that noise characteristics rather than maximum noise level produced and different time of the day has higher impact on the community complaints.

Table 4. Summary of top 10 noisiest flight movements in the night (2008)

Date	Time	Aircraft type	Noise measuring terminal	Noise level (Lmax)	Landing Departure	No. of complaints
26-04-2008	06:59	Boeing 737-700	Schiebroek (5)	86.5 dB	Departure	1
02-11-2008	06:06	Falcon 900	Schiebroek (5)	86.4 dB	Departure	1
28-07-2008	23:09	Boeing 737-800	Schiebroek (5)	86.3 dB	Departure	1
10-03-2008	23:15	Boeing 737-800	Overschie (3)	85.9 dB	Departure	3
07-02-2008	06:41	Gulfstream IV	Schiebroek (5)	85.6 dB	Departure	0
25-04-2008	06:38	Beechjet 400	Overschie (3)	84.4 dB	Departure	4
06-05-2008	06:57	Falcon 900	Schiebroek (5)	84.4 dB	Departure	4
10-03-2008	03:10	Piaggio Avanti	Schiebroek (5)	84.3 dB	Landing	3
29-02-2008	23:01	Boeing 737-700	Schiebroek (5)	84.1 dB	Landing	1
11-03-2008	03:17	Piaggio Avanti	Schiebroek (5)	84.1 dB	Landing	1

IV. Analysis of Commercial and Business flights on noise restrictions and airport economics

Table 3 on the previous page, shows that day flight is about 9 times the number of night flights, yet the complaints ratio for day flights is only 1.3 as compared to the night flights ratio of approximately 1.7. Even though an increase in flights frequency induces complaints,[1] apparently, the time-of-the-day and the type of aircraft actually trigger more complaints.

If just by observing on total number of complaints, the Boeing 737-700 received the highest number of complaints, followed by Fokker 50 and Boeing 737-800. These are commercial aircraft for scheduled services operated at Rotterdam Airport daily. B737-200 complaints are omitted because they were considered as a one-off case.

The Piaggio P180 Avanti, Dassault Falcon 900, Gulfstream V, Cessna 550 Citation and Beechjet 400 are being grouped as Business Jet aircraft which operate at Rotterdam Airport either to serve as private Business jet or aircraft used for government services. Analysing the ratio of number of complaints per day-flights per year for both categories, a consistent ratio of 1.1 - 1.4 can be observed.

A different trend appeared from the ratio on the number of complaints for night flights. For the commercial category, the ratio is only between 1.7 and 1.9, however, for business aircraft category the ratio for Piaggio Avanti is about 3.7 and Beechjet 400 is 3.8, and both have only 6 night flights per year but obtained the highest complaints. Although for these aircraft, the recorded single event maximum noise level (L_{max}) are equivalent or lower than B737-700 or B737-800, the number of complaints is higher due to the distinctive annoying noise perceived by the community.

Another apparent observation is that certain business type aircraft have a higher frequency of night movements in comparison to day movements, such as Gulfstream V. To discourage flights movements during the night, Rotterdam Airport imposes night penalty fees on every aircraft that lands or takes-off during the curfew hours. In the following sections, the value of noise is evaluated in terms of the night penalty that Commercial and Business aircraft have to pay to Rotterdam Airport.

A. Rotterdam Airport flights operational quota

Fig. 8 on the following page shows that in 2000, the movements at Rotterdam Airport were as high as 28,541 flight movements per year. However, when the Dutch Government introduced the operational quota of 27,500 per year and the 35 Ke contour in 2001, the number of movements starts to decrease and the number of movements seems to stabilise between 21,000-22,00 movements per year since 2005 till 2008.

This happens because the flights movements at Rotterdam Airport are being constraints mainly by the 35 Ke contour (refer to Fig. 1 on page 4). Rotterdam Airport has to ensure that they do not violate the 35 Ke boundary, and since the past few years as larger and heavier aircraft type starts flying into Rotterdam

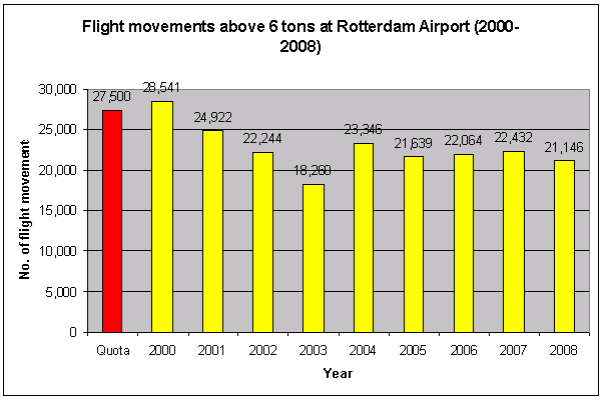


Figure 8. operating quota vs Annual flight movements (2000-2008)

Airport, they tend to produce larger noise footprints which used up the allocated area faster. Therefore, in order to maintain the accumulated noise footprints within the 35 Ke boundary, annual flight movements have been reduced and this has created losses of potential revenues between 20% -25% per year.

B. Landing fee and night surcharge tariff at Rotterdam Airport

The night surcharged tariff is dependent on the landing fees of an aircraft, and the aircraft landing fees are calculated based on the aircraft maximum take-off weight (MTOW). For the year 2008, the landing fees for different MTOW are listed in Table 5:

Table 5. Landing fees as of November 2008

Aircraft Weight	Minimum Charge	Fixed Charge	+ Rate per tonne
up to 6 tonnes	€17.50	-	€11.00 per tonne
6 - 20 tonnes	€50.90	€42.40	€6.70 per tonne
over 20 tonnes	-	€134.30	€9.40 per tonne

Rotterdam Airport takes high pride in ensuring residents quality of life are preserved, and one of the measures taken to guarantee better environment for its neighbouring residents is by imposing high night penalty charges. The following are the night surcharge tariffs of Rotterdam Airport as of November 2008:

Table 6. Night surcharge penalty at Rotterdam Airport

Night surcharge	Landing and subsequent take-off 00.00-06.00 lt	Landing and subsequent take-off 23.00 -07.00 lt	Landing or subsequent take-off 23.00-07.00 lt
Night Surcharge	150% of landing fee	75% of landing fee	50% of landing fee
Min landing fee incl. night surcharge	€323.75	€226.60	€194.25

To discourage aircraft flying at night, the night surcharge tariffs has been increased 25% in April 2009.[13] According to Rotterdam Airport, most aircraft usually land in the night period and take-off during day time or vice versa, which fall under the third category of Table 6. This means that the aircraft lands or takes-off during the day (08.00-22.00) and returns or departs within the curfew hours. Therefore, in this research the surcharge of 50% of the landing charges is used for the calculations. Based on this assumption, in the

following section, the revenues received from night surcharges based on different aircraft type are calculated to evaluate the effectiveness of the penalty charges per aircraft type.[14]

C. Night surcharges obtained from Commercial aircraft flight

Referring to Table 3 on page 9, the type of aircraft that fly to and from Rotterdam Airport can be categorised into two major groups. The first group is the Commercial aircraft category, which comprises of Boeing 737-700, 737-800 and Fokker 50. The following indicates the total night surcharges received based on the total number of movements for the year of 2008.

Table 7. Landing fee including night surcharge for Commercial type aircraft (2008)

Aircraft type	MTOW (kg) (50%)	Landing fees per aircraft	Night surcharge	Ldg fees incl night surcharge
B737-700	70,000	€792.30	€369.15	€1,188.45
Fokker 50	21,000	€331.70	€165.85	€497.55
B737-800	79,000	€876.90	€438.45	€1,315.35

Since the night surcharge is calculated based on the MTOW, and B737-800 has the heaviest weight, therefore, B737-800 generates the highest night surcharge cost. But looking from the Kosten night penalty calculation, if an aircraft fly lands or takes-off during curfew hours it will be given a penalty weight of factor 10 (refer Table 2 on page 5). Hypotheoretically, This means Qty 1 night-flight footprint is equivalent to Qty 10 day-flight footprints. It also indicates if there are more night flights, it will fill up the noise contour area faster and reduce the total annual movements at Rotterdam Airport.

Table 8. Loss of potential revenues due to night penalty factor for Commercial type aircraft(2008)

Aircraft type	Total landing fees and night surcharge for Qty 1 aircraft	Total landing fees for Qty 10 aircraft during day time	Loss of potential revenues	Ratio of day vs. night revenues
B737-700	€1,188.45	€7,923.00	€6,734.55	6.67
Fokker 50	€497.55	€3,317.00	€2,819.45	6.67
B737-800	€1,315.35	€8,769.00	€7,453.65	6.67

Table 7 shows that Qty 10 day-flight contributes 6.67 times more aeronautical revenues for Rotterdam Airport compared to Qty 1 night-flight. The night surcharge has an inverse relations between night-time penalty charges and the number of flights movements. The amount received from night-time penalty does not compensate the reduction in the number of day-flights and the potential revenues loss. The night-time penalties only subsidise 50% only of the landing fees of one aircraft , but does not compensate for the loss from 8.5 day-flight potential revenues. If there are high number of Commercial night-flights, it will fill up the 35Ke contour faster and subsequently, will also reduce the number of potential flight movements faster too.

D. Night surcharge obtained from Business aircraft flights

As for the Business aircraft category, this study only includes the Piaggio 180 Avanti, Falcon 900, Gulfstream V, Cessna 550 and Beechjet 400 into this observation.

The Piaggio P180 Avanti, Cessna 550 and Beechjet 400 have the lowest MTOW, and therefore, the landing fees including the night surcharge are lower than the stipulated minimum charges. In this case, the calculation of the landing fees including night surcharges for the Piaggio P180 Avanti, Cessna 550 and Beechjet 400 are based on the minimum charge of €194.25 as stated in the Summary of Airport Charges Regulation, November 2008 (refer Table 6 on the previous page). These aircraft pay the lowest night surcharges and landing fees to Rotterdam Airport.

Table 9. Landing fee including night surcharge for Business type aircraft (2008)

Aircraft type	MTOW (kg) (50%)	Landing fees per aircraft	Night surcharge	Ldg fees incl night surcharge
P180 Avanti	5,239	€55.00	€27.50	€194.25
Falcon 900	20,640	€322.30	€161.15	€483.45
Gulfstream V	41,136	€519.70	€259.85	€779.55
Cessna 550	6,850	€82.60	€41.30	€194.25
Beechjet 400	7,394	€89.30	€44.65	€194.25

Table 10. Loss of potential revenues due to night penalty factor for Business type aircraft(2008)

Aircraft type	Total landing fees for Qty 1 aircraft during day time	Total landing fees and night surcharge for Qty 10 aircraft	Loss of potential revenues	Ratio of day vs. night revenues
P180 Avanti	€194.25	€550.00	€355.75	2.83
Falcon 900	€483.45	€3,223.00	€2,739.55	6.67
Gulfstream V	€779.55	€5,197.00	€4,417.45	6.67
Cessna 550	€194.25	€826.00	€631.75	4.25
Beechjet 400	€194.25	€893.00	€698.75	4.60

Since Piaggio Avanti has the lowest MTOW and has to pay the minimum night surcharge rate as stipulated in Table 6 on page 11, therefore, the revenue ratio obtained from the day flights is the lowest, followed by Cessna 550 and Beechjet 400 respectively. It seems, heavy aircraft contributes more revenues for Rotterdam Airport, where else the noise produced by light weight aircraft such s Piaggio can still produce high L_{max} and received high number of complaints.

Rotterdam Airport has to be selective in accepting night flights, because it will reduce potential revenue generations for its airport. As for Business Jet, the profits generate from the passengers are also unattractive due to its low load factor of only 20%-30%.[15]

E. Value of noise based on night-time surcharges relative to maximum noise level

From the above section, the results indicate that operators of small and light Business aircraft such as Piaggio Avanti, Cessna 550 and Beechjet 400 have to pay minimal night surcharge, and contribute minimal additional aeronautical revenues to Rotterdam Airport. In contrast, Commercial aircraft category such as B737-700 or Fokker 50 have to pay hefty night penalty charges to Rotterdam Airport, and indirectly these surcharges will increase the aeronautical revenues for Rotterdam Airport.

Therefore, in order to evaluate whether the night surcharges have been fairly implemented on each type of aircraft, the value of noise is been calculated based on the maximum noise level produced by different type of aircraft as of from Table 4 on page 10. The value of noise from the passenger's perspective is also been calculated as comparison with the value obtained from night surcharge per noise level (dB).

Table 11 on the following page includes two different values. From the night surcharge per noise level perspective, for large and heavy aircraft like B737-700 and B737-800, the penalty cost per noise level is between €15.31 - €14.13 per dB and for small and light aircraft such as Piaggio Avanti and Beechjet 400, the penalty cost per noise level is about €2.30per dB.

From the perspective of maximum noise level (L_{max}), the landing fee including the night surcharge imposed on small and light aircraft is considered as unjustifiable since the small and light weight aircraft produces a high level of noise comparable to large and heavy weight aircraft during landing and departure. These type of aircraft also evoke a higher number of complaints from the surrounding community, and yet

Table 11. Value of noise based on landing fee and night surcharges per dB and per passenger for 2008

Aircraft type	Measured (Lmax (dB)	Ldg fee and night surcharge (€)	Night surcharge per dB (€/dB)	No. of pax	Night surcharge per pax (€/pax)
B737-700	86.5	1188.45	13.74	112	10.61
Falcon 900	86.4	483.45	5.60	6	80.58
B737-800	86.3	1315.35	15.24	142	9.26
B737-800	85.9	1315.35	15.31	142	9.26
Beechjet 40	84.4	194.25	2.30	3	64.75
Falcon 900	84.4	483.45	5.73	6	80.58
B737-700	84.4	1188.45	14.08	112	10.61
Piaggio Avanti	84.3	194.25	2.30	3	64.75
B737-700	84.1	1188.45	14.13	112	10.61
Piaggio Avanti	84.1	194.25	2.31	3	64.75

need only to pay a very minimal penalty.

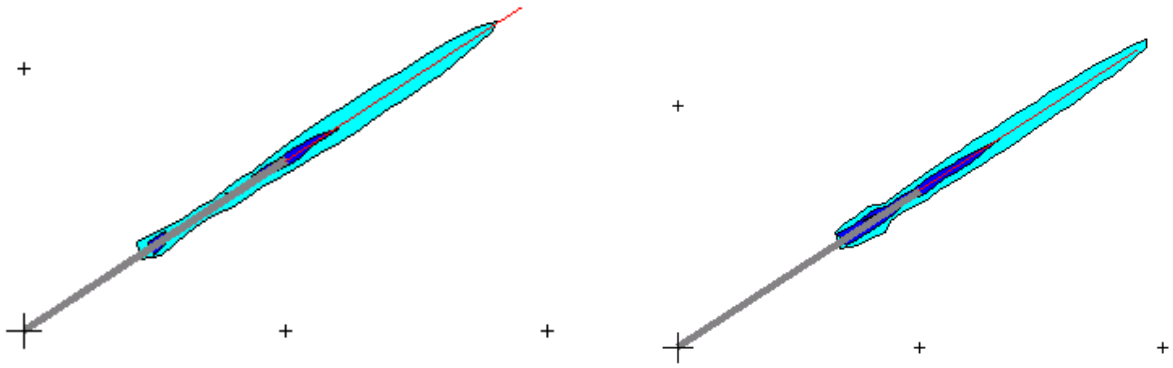
For the airlines, night surcharge is having greater impact on the profitability on the ticket of the airlines since Business passengers have to pay a high amount of penalty fees, between €80.58-€64.75 per passenger to the airlines if they depart or arrive during the curfew hours.

V. Value of noise based on night-time surcharges relative to Ke footprint modeling

Whereas, the previous section focused on the maximum L_{max} noise levels, ultimately the restrictions are enforced relative to the noise footprint. With reference to the Ke formulation shown in Eq. 1 on page 5, the values are calculated in terms of their distance from the sound source. All of the flight footprints are then superimposed to show the amalgamated levels for a full year so that the contours can be compared with the agreed noise limit, e.g. the 35Ke footprint for Rotterdam shown in Fig. 1 on page 4. Consequently, one finds that as the annual number of flights increase, the Ke noise contours also seem to spread outwards to show increased experience of noise levels at any given distance from the source of noise. Therefore, although it may seem from Table 11 that the Business Jets create just as much noise as the larger commercial flights, we must also consider that the Business Jets tend to climb out at a faster rate and therefore they do actually have a smaller noise footprint. Consequently, taking the B737-700 as the base line commercial flight (the most frequent at Rotterdam) it can be shown by modeling the footprint in INM that it would take Qty 5.5 Gulfstream V to achieve the same cumulative footprint as the B737-700 and Qty 10 Cessna 550.

Therefore, with the airport capacity being limited by noise we need to consider whether the multiple Business Jet flights will bring in more revenue for the airport as this may effect the operational strategy of the airport. Taking this one step further, the B737-700 night time flight actually uses up the same quota of noise in the footprint as Qty 55 Gulfstream V and Qty 100 Cessna, with an enormous impact on the revenue generation capabilities of the airport. It is not just noise and the cost of penalties, one of the main underlying research themes of this paper is the need to consider revenue management in conjunction with noise management so that the airports revenue is maximized within the set of constrains imposed on them, whether noise or flight number quotas.

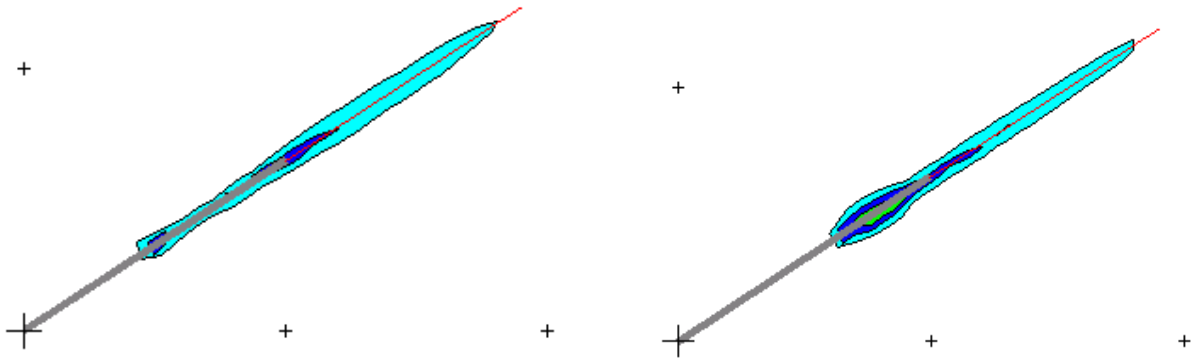
The potential impact on revenue maximization is illustrated through the results for the cases mentioned earlier. The B737-700 is taken as the datum as it is the most frequent commercial flight and night time offender while the Gulfstream V and Cessna 550 are used to represent the Business Jets. Another reason why Gulfstream V is chosen as an example is because Gulfstream V seem to have more night flights than day flights (refer Table 3 on page 9). Cessna 550 is chosen because it represents small and light weight Business Jet that has an average flights at Rotterdam Airport. This is to illustrate the economic trade-offs that must be considered if we want to maximize revenue while staying with the noise legislated boundaries.



(a) Qty 1 B737-700 footprint at night

(b) Qty 55 Gulfstream V footprint during the day

Figure 9. Qy 1 B737-700 night footprint vs Qty 5.5 Gulfstream V night footprint or Qty 55 day footprint



(a) Qty 1 B737-700 footprint at night

(b) Qty 100 Cessna 550 footprint during the day

Figure 10. Qy 1 B737-700 night footprint vs Qty 10 Cessna 550 night footprint or Qty 100 day footprint

It can be seen from Table 12 and Table 13 on the following page that the revenue from the night time B737-700 (including landing fee and the surcharge) flight is only €1,188.45 while alternatively 5.5 night time or 55 day time Gulfstream V could have been accommodated to bring in revenue of either €4,827.53 or €28,583.50 respectively.

Similarly, 10 night time or 100 day time Cessna 550 could have been accommodated to bring in revenue of either €1,942.50 or €8,260 respectively. Finally, it is also shown that the single B737-700 night flight essentially used up the noise quota of 10 equivalent B737-700 day flights with the potential loss of revenue being €6,734.55.

Table 12. Loss of Potential revenues from Qty1 B737 night flight(2008) vs. Gulfstream and Cessna night flights

Aircraft type	Landing fee and night surcharge Qty 1 B737-700	No. of night flights equivalent to Qty 1 B737-700 night flight	Total landing fees and night surcharge	Loss of potential revenues
B737-700	€1,188.45	1	€1,188.45	€0.0
Gulfstream 5	-	5.5	€4,827.53	€3,099.08
Cessna 550	-	10	€1,942.50	€754.05

Table 13. Loss of Potential revenues from Qty1 B737 night flight(2008)vs. Gulstream and Cessna day flights

Aircraft type	Landing fee and night surcharge Qty 1 B737-700	No. of day flights equivalent to Qty 1 B737-700 night flight	Total landing fees and night surcharge	Loss of potential revenues
B737-700	€1,188.45	10	€7,923.00	€6,734.55
Gulfstream 5	-	55	€28,583.50	€27,395.05
Cessna 550	-	100	€8,260	€7,071.55

The results highlight the huge impact that the night time noise penalties make on restricting day time capacity and influencing an airport's potential for revenue generation. However, many night time are a necessary 'evil' due to delays outside the control of either the airport or the airline. Nonetheless, many of the night time flights accommodated by Rotterdam for example can not be 'managed' in this way. However, the work will now continue to look at the optimal revenue model in the future.

VI. Discussion

Rotterdam Airport is a regional airport in the Netherlands, with higher inclination of being a City Airport since its vision is to accommodate high yield passengers such as business people. Unfortunately, due to its controversial location, it is facing high pressure from the Dutch Government and the surrounding communities. For such a small airport it has one of the most stringent noise measures introduced at its airport (refer Table 1 on page 4) and this makes Rotterdam Airport less attractive to low cost airlines.

The Dutch Government has introduced noise quota which restrict the number of traffic movements per year at Rotterdam Airport and Rotterdam Airport is only able to accommodate limited number of scheduled services since the allocation of slots for scheduled services has been predetermined independently by party, Airport Coordination Netherlands (SACN),[16] and Rotterdam Airport has no direct influence on offering more attractive slots to airlines.

The slots allocation for commercial airlines is being controlled in order to reserve slot space for 'ad-hoc' and emergency services from Government, military and medical flights. Every year Rotterdam Airport has to produce a report and present to the Ministry of Transport and Water Management, to prove that the 35 Ke noise contour grid has not been violated.

The calculation used in mapping the 35Ke contour area is purely based on the noise footprint made by different aircraft type. Therefore, by increasing the number of night flights, it will definitely increase the yearly noise level due to the night penalty weighting factor, and will reduce the number of annual movement at Rotterdam Airport.

Nonetheless, if we look from the complainants' perspective, it could be concluded that noise annoyance does not only derived from the loudness or the measured noise level from an individual aircraft but also from various factors such as; flight frequency, population distribution, seasonality, time of the day, aircraft type, aircraft pitch noise, take-off and landing procedure, flight routes and quality of life of the community.

It is found that night flights have great influence on Rotterdam Airport noise regulations and economics. Table 3 on page 9 shows about 10% out of total flights movements are night flights. Business Jets seem to have higher ratio of night flights compared to Commercial aircraft category. Analysis on the night penalty surcharges are being carried out , and they indicate that night flights surcharge penalizes do not compensate for the loss of potential revenues, but it fills up the noise contour faster and reduce the number of potential day flights.

VII. Conclusion

This research concluded that noise restriction has the impact in limiting the number of flights. Rotterdam Airport's infrastructure could accommodate about 4.5 million passenger's annually and could get 3 more times revenues. Unfortunately, due to the present operation quota, it only serves 1.5 million passengers per annum. As the 35 Ke contour could not be exceeded, the number of movements is approximately 20-25%

less than the restricted quota. It is also noted that night surcharge is applied to aircraft landing or taking-off during night curfew hours but the flight revenues generate are far less since it associate with lost of flights during the day. Night flight is been penalised by the factor of 10, and this is equivalent to Qty 10 movements of day flights.

The night surcharge is not equal between Commercial and Business Jet, especially light weight Business Jet, since it is being calculated based on the maximum take-off weight of the aircraft. Since the airport capacity being limited by noise restriction, Rotterdam Airport probably need to consider whether the multiple Business Jet flights bring in more revenue for the airport as this may effect the operational strategy of the airport.

It is not just noise and the cost of penalties, one of the main underlying research themes of this paper is the need to consider revenue management in conjunction with noise management so that the airports revenue is maximized within the set of constrains imposed on them, whether noise or flight number quotas. This paper illustrates that economic trade-offs must be considered if Rotterdam Airport wants to maximize revenue while staying with the noise legislated boundaries. Finally, the results highlight the huge impact that the night time noise penalties make on restricting day time capacity and influencing an airport's potential for revenue generation.

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