FORECASTING THE ENVIRONMENTAL IMPACTS OF AIRCRAFT FLEET DEVELOPMENT AT SCHIPHOL AIRPORT

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1 Introduction

1.1 Environmental Issues at Schiphol Airport

Amsterdam Airport has experienced high growth throughout the 1990's. This growth has resulted from a combination of factors:

- the (moderate) economic growth of the Netherlands and the Western European region;
- air fares, which have dropped considerably, especially through the introduction of new promotional fares; and, most particularly
- the growth in market share achieved by KLM and its partners.

Although KLM's business strategy has focused on attaining a bigger market share as a partner in one of the few *global networks*, the resulting growth of this strategy has surprised policy makers, especially from the point of view of environmental protection. In 1995 it was agreed that the development of Schiphol would be subject to environmental constraints. An important element in these constraints are the *noise zones*. According to these constraints a maximum of 15000 houses should be exposed to a predetermined noise level until 2003. After 2003, when the fifth runway is expected to be operational, this maximum must reduce to 10000 houses. The continued fast growth in the mid 1990's has, however, consumed much of this planned environmental capacity and, since 1998 only a limited traffic growth is permitted each year and additional measures have also been introduced to moderate further growth. Through the imposition of restrictions (during night hours) and differential charges, chapter 2 aircraft were largely eliminated by 2000, two years in advance of EU ban on these aircraft. In addition, the air transport policy - when granting access to Schiphol - takes the noise performance of the aircraft that are going to be used into consideration.

The effect of these short term measures was not sufficient. During the second half of 1997 it became clear that - despite of the measures that had already been taken - the noise limit would still be violated. The result was that that from 1st April 1998, Schiphol is *fully slot co-ordinated.* Moreover it was agreed that from 1998, 20000 extra slots will be granted annually, enabling a further growth from 380000 movements in 1998 up to a total of 460000 movements in 2002. The provision of these extra slots remains insufficient to keep pace with the expected requirement and has restricted the growth at Schiphol. Thus, these constraints have imposed economic costs on the airlines, and other users of the air transport system (and possibly also for the surrounding airport region. This situation at Schiphol is currently unique: slot co-ordination has been implemented for environmental reasons, and not by an operational capacity constraint[1].

1.2 Economic Efficiency of Regulation

The current (and anticipated future) impacts of these operational constraints have highlighted the importance of questioning how to implement a mixture of policies, to minimise the economic damage of restricted traffic volumes, within the limits that have been set. The existing slot co-ordination has a strong regulatory orientation. The co-ordination committee is using strict operational rules, and *grandfather-rights* are an important element in using these rules. This may however not necessarily be efficient. It does not guarantee that the best economic performers are given access to Schiphol. It may even lead to a situation that the environmental improvement of the measures is low, but the economic damage is considerable. And even more important: *Incentives* to improve environmental performance are not inserted into the system. When these incentives are available, a situation may be created by policy makers, that environmental (noise) costs are internalised in the system, stimulating airlines to use the most noise friendly aircraft at the most noise friendly times of the day. It may even mean that the effect of these incentives would be a potential growth in 2002 beyond the limit of 460000 movements, within the noise limits, although the effect of these policy measures may take more time. A mixture of measures leading to this, would be considered as efficient, as it limits economic damage, but has a considerable environmental performance.

1.3 Forecasting: The Schiphol Competition Model

The operation of the air transport industry involves a complex economic interaction between the airport, airlines, passengers and cargo shippers. As a consequence of these interactions, the imposition of policies designed to achieve a specific objective can often have perverse impacts. The current slot restraint policy, for example, may moderate the growth in aircraft movements at the airport. It may, however, by reducing the growth KLM can achieve, delay expansion and renewal of the airlines' aircraft fleet, or encourage the airlines to use larger (and noisier) aircraft. Since new aircraft are relatively quiet, the net result of these unplanned consequences could be a worsening of the environmental performance of the airport.

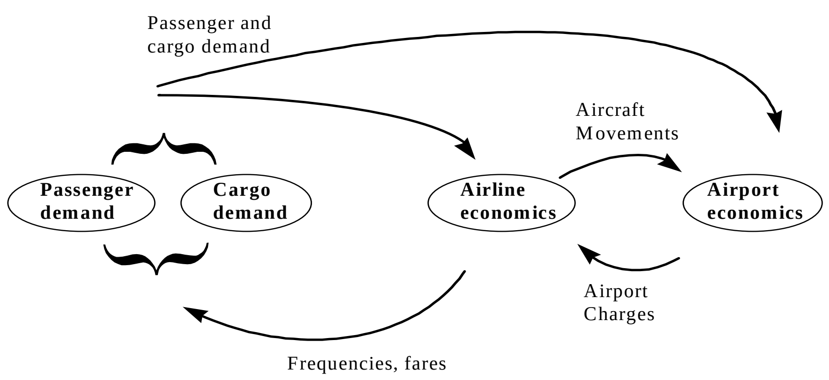
Methods to help develop an understanding of the environmental and economic consequences of policy measures have been developed throughout the 1990's. Unlike many air traffic forecasting systems, which assume unlimited airport capacity, the objectives of the Schiphol Competition Model (SCM) are to forecast under constrained capacity, arising from potential government policy measures. The basic framework of the model is thus to assess the impacts of these policies, relative to unconstrained forecasts. This provides a basis both to evaluate the impacts of policies and, through consideration of alternative scenarios, and to assess the robustness of potential government policies against exogenous uncertainties.

Alternative plans for Schiphol comprise up to five categories of policy measure intended to reduce airport activity:

- substitution measures are designed increase the attractiveness of high speed rail services relative to competing air routes;
- quotas, or slot control, limit the number of aircraft movements and can be applied to particular subsets of traffic, for example a ban on night traffic; quotas can also be imposed in terms of total passenger or cargo demand, although the practical mechanism to achieve these political targets is less clear;
- levies or landing charges can be applies uniformly or to specific types of aircraft or groups of aircraft movements; airlines have the potential to react and moderate their impact on passengers and cargo demand;
- (departing) passenger taxes, which directly affect demand but do not offer airlines the incentive to react to moderate the impact of policies (eg by changing the type of aircraft operated);
- variation in the level of subsidy for airport investment plans would cause the airport to vary charges to achieve target returns on investment.

The competition model comprises a set of integrated demand and supply modules that compute the economic impacts of the policies (Figure 1). Each of the modules of the model reflects relevant economic objectives. While the model system has been subject to continuous development, much of the operation has previously been explained (Ashley et al, 1995) and is not discussed further in this paper.

Figure 1: The Structure of the Competition Model



Following exploratory investigations in 1998, the Dutch Government decided to develop the SCM through the addition of new modules specifically designed to assess the impacts of scheduling (time of day) and fleet planning (the technology of aircraft operated). The remainder of this paper is devoted to the development of the capability to forecast fleet technology operated at Schiphol. The specific objectives of this are to understand the retirement and introduction of aircraft into the fleet and the effects of policies (eg differentiated landing charges) on this process.

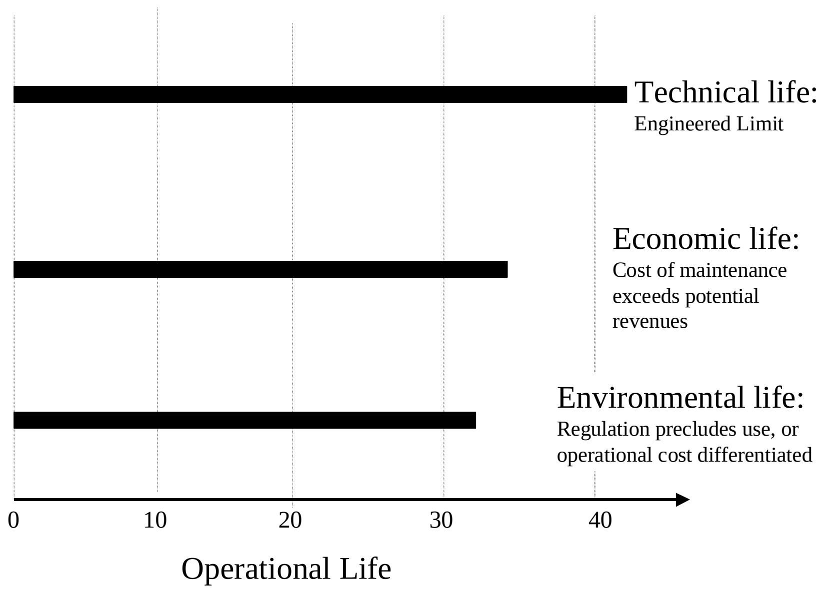
2 Forecasting Airline Fleet Development

There are two factors affecting the fleet development of an airline: provision of new capacity to meet the underlying growth in demand, and the ageing of aircraft currently operated. The timing of these, together with the technological advances of the aircraft and engine manufacturers, determine the fleet owned and operated by an airline. For regulators, the primary factors of concern are the rate of growth of the airline industry (which may result in faster rate at which new, and relatively environmentally efficient, aircraft are introduced into the fleet) and the phasing out of older and less environmentally efficient aircraft.

2.1 Aircraft Operating Life

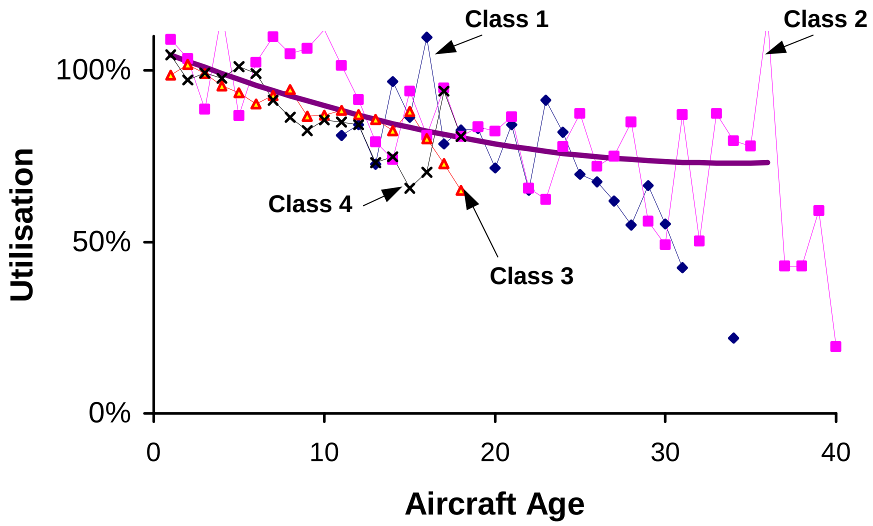
There are a number of factors influencing the operational life of new aircraft before discussing the airline fleet decision processes. The operational life of an aircraft which need to be established can be thought of as the shortest of its technical, or engineering, life, its economic life and its environmental life, as illustrated in Figure 2.

Figure 2: Illustration of factors Influencing Aircraft Operating Life



The technical life of an aircraft may, currently, exceed 40 years. However, as the aircraft ages, the time and cost is required to maintain it increases. Figure 3 illustrates how the revenue earning potential (revenue earning hours flown) of aircraft tends to decline with the age of the aircraft. The figure contrasts different aircraft technologies (class 1 being chapter 2 aircraft, class 2 being aircraft which just achieve chapter 3 certification and class 3 and 4 representing progressively quieter and more modern aircraft). While it is interesting to note that a similar decay in performance is apparent, irrespective of aircraft technology[1], the clear implication is that the revenue earning hours flown decline and (by implication) maintenance costs increase with age (in this we take a broad perspective of maintenance, including, for example refurbishing aircraft interiors).

Figure 3: Variation of Aircraft Utilisation (relative to that of a new aircraft of same size category) with Age of aircraft



Source: ACAS database, December 1999

2.2 Aircraft Ownership

There is a wide spectrum of methods by which airlines can own aircraft. These range from outright ownership, long term aircraft leasing (typically for 7-15 year terms), short term leasing and 'wet lease' of complete aircraft and crew. (The latter is relatively expensive and generally only appropriate for start up and to respond to occasional unexpected market and operational developments.) The financial products used for aircraft ownership are becoming increasingly sophisticated and blurring the distinction between outright ownership and leasing[3]. For modelling purposes we therefore consider the distinction between long term and short term, rather than owned or leased.

Given that airlines' long term strategic business planning time horizon is typically 3 to 5 years in the future, there is a need to balance the typically lower costs of long term ownership against the associated risk. We represent KLM strategy by identifying specific 'core' aircraft types. Aircraft are typically possessed under long term arrangements where the number of aircraft of that type in the fleet is moderately large, and the aircraft type serves the major routes. The other aircraft types where KLM operate a smaller number of aircraft, typically have shorter term ownership.

Environmental policy can have two broad forms: restrictions which prevent aircraft being flown; and costs (eg differentiating airport landing charges, or potentially en-route charges, by the environmental impact - the aircraft technological class in our exposition). If direct restrictions on operation apply sufficiently widely they would additionally impact on the second hand aircraft market prices. In this paper we are considering local policies at Schiphol airport and do not, therefore consider this wider indirect impact.

2.3 Airline Aircraft Replacement Decision Making

The decision to replace aircraft is based on the profitability of new aircraft relative to old aircraft. Operating costs comprise capital and direct operating costs and revenue earning potential is affected by maintenance requirements, as summarised below.

- Aircraft capital costs are affected by: current list price for new aircraft by size and technology class; a premium for customisation; discounts for multiple orders.
- Direct operating costs comprises: maintenance, fuel, crew, and charges (airport and en-route).
- The revenue earning potential of an aircraft is a function of its utilisation (hours flown). This will also affect the calculation of the fleet size required to serve the demand. (We have illustrated how utilisation decays with aircraft age in Figure 3 above).

We have assembled a database on aircraft operating performance from a wide range of sources, including: Airline Business, Air Transport World, Avmark Aviation Economist, Airclaims 1999, AERO (Hancox, 2001), ACAS database (December 1999), recognising that much of these data are drawn from US DoT form 41 returns. Information from our database is used in the following illustrations.

To illustrate the potential implications of our analysis that form the economic basis for the FVM, we have illustrated in Figure 4 how the costs and revenues may vary as an aircraft ages. This illustration has been made for an aircraft of capacity type 8 and technology class 2 (equivalent to a 747-300 type held in the KLM fleet). In summary, this figure illustrates that:

- Initially the cost of a new aircraft is dominated by the significant burden of capital costs where these are some 44% of the total annual cost to the airline;

- At about 10 years old, the burden of capital costs falls to about 35% of the total annual costs, other costs are slightly lower than their initial levels. Up to 10 years there has thus been a steady fall in total costs to a level that is about 20% lower than the initial costs;

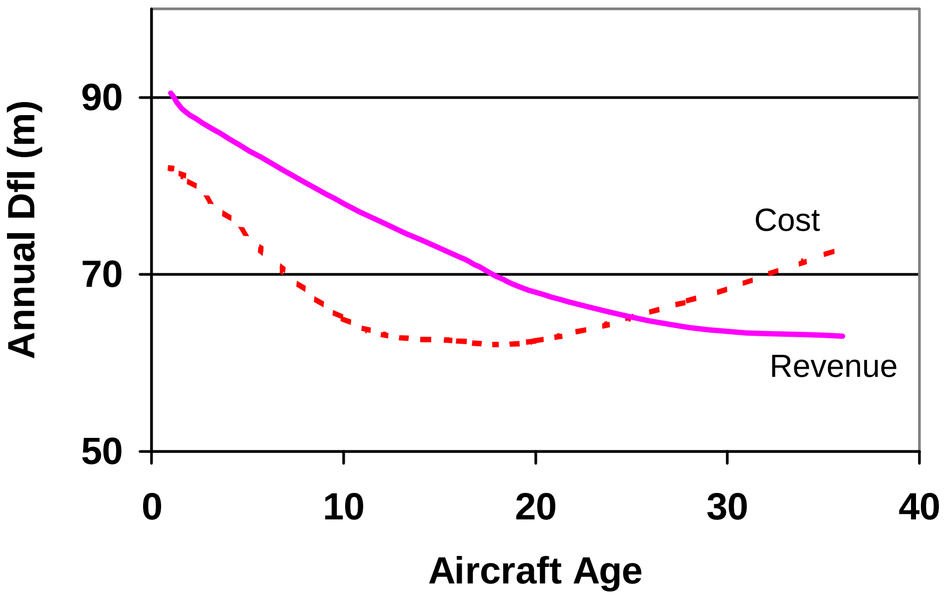
- From 12 years onward the maintenance costs rise significantly although reduced aircraft utilisation reduces some of the other costs in compensation. Capital costs continue to decline significantly;

- At 15 years the total costs of operation are reduced by 25% compared to the initial costs and, similarly, at 25 years the aircraft total costs are only two thirds of their initial levels.

Figure 4: Variation in Annual 747-300 Operating Cost with Age

Figure 5 illustrates further how the revenue earning potential declines with utilisation (and aircraft age). Our data indicates a moderate decline in revenue and suggests that the aircraft generates most profit for the airline between about 5 and 15 years of age. The decision to replace an aircraft it is not, however, directly determined by the intersection of these two lines. There are substantial costs associated with operating different types of aircraft and discounts available if several aircraft can be ordered at the same time. The aircraft may also be converted for freight, with different cost and revenue relationships. The implications are that the decision relates to the fleet rather than individual aircraft. In addition, the illustrative figure assumes no changes in costs (such as crew and fuel prices) or yields, and the relative cost of continuing to operate an ageing fleet must be compared with the costs of operating new(er) aircraft. An important trend in this regard over the past 3 decades has been the continuing technological investment by manufacturers which has increased capital costs and reduced direct operating costs.

Figure 5: Balance of Cost and Revenue (B747-300) with Aircraft Age



3 Illustrative Forecasts

We have implemented a model, the fleet vintage model, to simulate the fleet decision process of the airlines based at Schiphol. The method of operation is to evaluate the expected profitability of alternate fleet structures of airlines operating at Schiphol. The process simulates dynamic evolution of the fleet over time through a series of steps. Each step involves a projection of movements over the next 3 years (by interpolation from other SCM modules), and selection of the fleet forecast to yield the highest return on capital.

In scenario forecasting (without constraining measures), the inputs to the model are forecasts of aircraft manufacturing trends: the implications of future innovation in terms of the characteristics of new production aircraft (ie trends in capital costs and operating costs). Figures 6 and 7 contrast two illustrative forecasts of the model. There are substantial differences in the forecast growth rates (reflecting differences in scenario assumptions relating to economic growth and aviation costs), which, as illustrated have substantially different implications in terms of growth forecasts for aircraft movements at Schiphol airport. The higher rate of growth in the first scenario together with relatively faster technological progress is reflected in the earlier introduction and greater penetration of newer technology aircraft in the fleet forecast to operate at Schiphol. Currently most aircraft are substantially quieter that the minimum Chapter 3 requirements and fall into our technology band 3. Quieter aircraft (technology band 4) are currently at the beginning of their production cycle and are expected to dominate the fleet purchases during the next decade. In Figure 6 we see that the purchase of these aircraft (in small part replacing older aircraft) results in these aircraft being used for more than half the movements at Schiphol, whereas in Figure 7 both the rate of retirement and increase in fleet size are slower resulting in more movements by noisier aircraft. This forecast trend extends further with the introduction of newer (quieter) aircraft technology (type 5) occurring later and more slowly in Figure 7.

Figure 6: Illustrative Movement Forecasts (High Economic Climate: 'Global Competition')

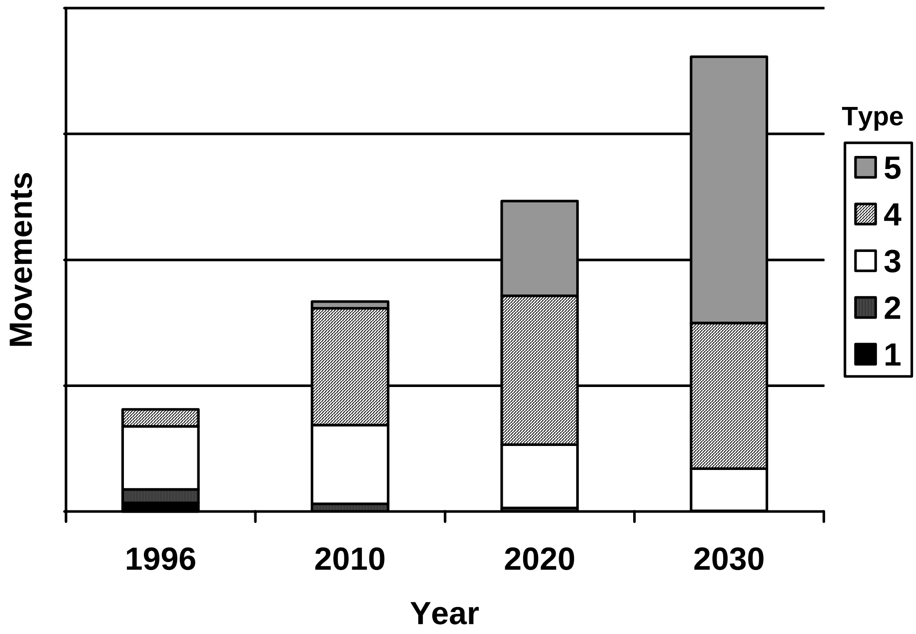
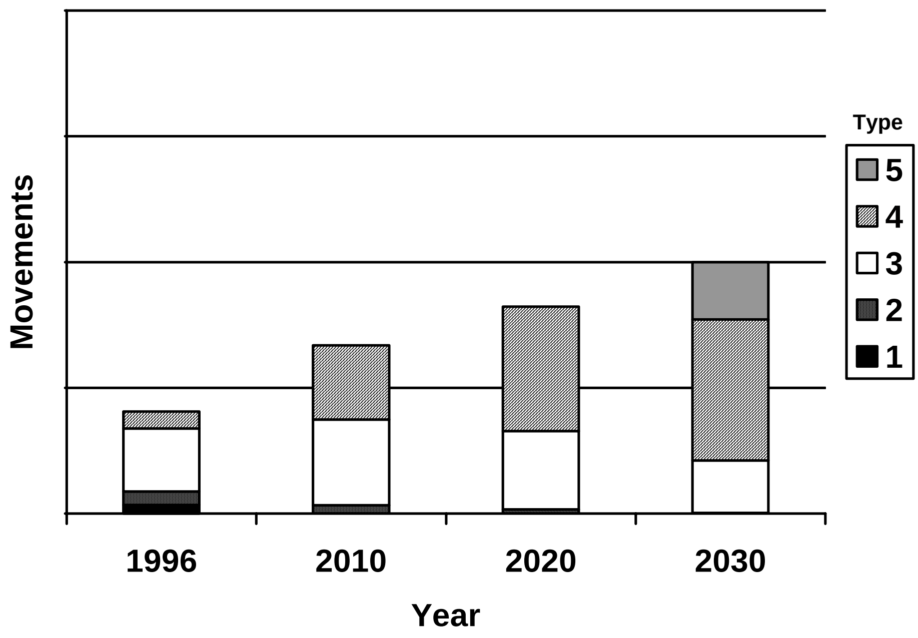


Figure 7: Illustrative Movement Forecasts (Low European Economic Growth: 'Divided Europe')



For policy assessment (of Schiphol airport), the charges for accessing Schiphol may vary by aircraft type (technology class and aircraft size) and certain types of aircraft may be banned. These costs and restrictions affect the relative cost of alternate fleet options and thus the replacement decisions are influenced. It is noted, however, as illustrated in Figure 4, that landing charges comprise perhaps 3 or 4% of total operating costs: a large differential in the charges for different types of aircraft is required to effect a significant change in the fleet composition, and this is only likely to affect the *fleet* related decisions of carriers based at Schiphol.

4 Conclusions

During the past 20 years, through the phasing out of chapter 2 aircraft, the noise footprints of most airports has very substantially reduced, despite the large increase in aircraft movements. To achieve this manufacturers have made substantial investments in airframe and engine technology. The result now is that the capital cost of new aircraft is a very large proportion of the total ownership cost (ie relative to total operating costs) with the result that airlines may be less willing to pay for continued investment in the future or may choose to operate their existing aircraft fleet for longer.

Through the model we have developed to assess fleet development we have illustrated how the fleet operated at Schiphol may develop and how this might be affected by economic uncertainties in future world development. It appears likely that the environmental impacts resulting from a high growth rate of aviation activity would, in part, be offset by the more rapid introduction of newer technology (quieter) aircraft. The environmental policy for Schiphol airport should consider the role improved technology may have and within this framework define options to encourage airlines to operate quieter aircraft.

References

Ashley D., Hanson P., Veldhuis J., 1995, A policy-sensitive traffic forecasting model for Schiphol Airport', Journal of Air Transport Management Vol 2, No 2

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Notes

1. Depending on the assumptions of peak patterns, estimates of long term runway capacity at Schiphol suggest an annual operational capacity in the region of 600000 movements, considerably in excess of the current 400000 movements, ignoring environmental implications.

2. The data also demonstrates that more modern aircraft (in a higher class) tend to achieve more revenue earning hours per year which is not illustrated in this figure which presents the relative performance as a function of age.

3. In terms of cost, a large lessor is often able to negotiate a better discount from manufacturers and in some cases can obtain lower cost of finance . These can be considered to offset their management costs and profit requirements.