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Public acceptance of helicopters – the *virtual noise* component.

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ABSTRACT

A detailed study of noise complaints in the UK and USA makes it clear that the level of public acceptance of helicopters and heliports is generally low. It has been shown that helicopters operating in some areas are considered up to 15 dB(A) more annoying than fixed-wing aircraft. A review of case histories, press reports, information collected by industry associations together with a study of the various factors involved shows that the level of public acceptance can be considered to be a function of both acoustic (direct) noise and a non-acoustic element, termed *virtual noise*. The magnitude of the *virtual noise* component is not directly related to either the absolute level or to the character of the noise generated by helicopters, but it is *triggered* by the acoustic signal. Moreover, the effectiveness of helicopter noise in *triggering* the *virtual noise* element would appear to be more dependent on the subjective character of the sound than its absolute amplitude. The results of a number of studies show that the subjective reaction to the *noise characteristics* of the source and the *virtual noise* are of equal or even greater importance than the maximum noise level. It follows that attempts to address adverse reaction to helicopter operations by reducing *acoustic noise* at source or by traditional operational methods and without taking into account the impact of *virtual noise*, will be largely ineffectual. The importance of taking *virtual noise* into account when addressing the public acceptance of helicopters is discussed in the paper.

This paper is based on papers published jointly by the author with A (Tony), C. Pike in 1998¹, 1999² and 2007³, plus continuing studies by the author since that time.

1. INTRODUCTION

The development of helicopter operations in many parts of the world and particularly in Europe and North America is being restricted by objections about noise. The development of new heliports, and changes to services at existing facilities, tends to be controversial and is often rejected as a result of public opposition. Prime examples are the continuing debate about helicopter operations and heliport development in London⁴, the use of heliports in New York⁵ and helicopter sightseeing tours of the Grand Canyon⁶. This issue is also addressed in a report on non-military helicopter noise to the US Congress by the FAA⁷ and in a more recent study in the UK for Department for Environment, Food and Rural Affairs (Defra)⁸.

The reason for the apparent disparity between the reaction to helicopters and that of other forms of transport are addressed in this paper together with what is different about helicopters and what singles out helicopters for special attention?

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2. SOCIAL SURVEY RESULTS

A review of case histories, press reports and information collected by industry associations makes it fairly clear that helicopters and heliports in many locations have a low level of public acceptance. This was put into perspective a number of years ago when the results from a number of studies connected with the operation of helicopters in the United Kingdom was reported in 1993 by the Civil Aviation Authority (CAA)⁹. Figure 1, reproduced from this report, shows annoyance as a function of *noise level* expressed in terms of $L_{Aeq16 \text{ hour}}$. The noise metric L_{Aeq} expresses time varying A-weighted noise levels occurring during an observation period as a single constant value having the same acoustic energy. The 16 hour period from 7:00 to 23:00 is used for planning purposes in the UK. This metric is similar to the Day-Night Average, L_{DN} , metric used in the United States.

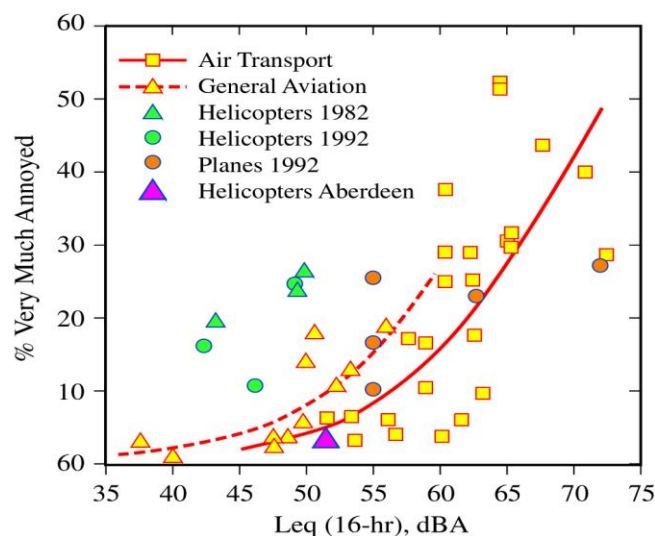


Figure 1: UK CAA Social Survey Results

In the 1982 survey, data was obtained by the CAA along the route of the Gatwick-Heathrow Airlink service (no longer operating) and at Aberdeen, Scotland, the major base for offshore oil industry helicopter operations in the North Sea. Figure 1 reveals that, relative to air transport (fixed wing) aircraft, helicopters operating in the London area were considered to be up to 15 dB(A) more annoying at the 10% and 20% *Very Much Annoyed Level*. The helicopter results contrast with those obtained in Aberdeen which showed no difference to fixed-wing aircraft. Ollerhead⁹ suggested this disparity in reaction could be explained in socio-economic terms: *"better off people tend to be more annoyed"*. Moreover it was believed that residents under the *Airlink* were disposed less favorably towards a helicopter shuttle service which was being used largely by first class passengers, whilst in the Aberdeen area, North Sea oil operations contribute significantly to the local economy

In the 1992 small scale study performed by the CAA⁹ in London at Fulham and Putney, and along the River Thames in the vicinity of Battersea and near one of the *London Helicopter Routes*. The results were similar to those for the *Gatwick-Heathrow Airlink* evaluated 10 years earlier (see Figure 1). The London flights were dominated by the corporate market using light/medium helicopters including a large number of Bell Jet Rangers and Long Rangers plus Aerospatiale (now Eurocopter) Dauphins, Sikorsky S76s and a few larger helicopters. Studies carried out by the *Greater London Council* in the

same time frame also confirmed an underlying concern of the residents about noise and safety of helicopters.

3. NOISE COMPLAINTS

Results similar to those obtained in London are common whenever helicopter complaints are examined. Analysis of the noise complaints also reveals a strong connection between noise and safety and the perception about safety plays a significant part in public reaction towards helicopters which has a direct bearing on the level of acceptance.

Another common misconception which influences the public attitude is that helicopters generally fly in an uncontrolled manner and the national authorities have little or no power over the flight paths/heights used. This is not correct, particularly in metropolitan environments in the US, Canada or Europe, but such misconceptions seem to be deeply rooted. A 1987 study for the AHS¹⁰ reported that the *"perceived intrusion of the helicopter into one's living space as evident by low flying is a significant negative factor"*. Another important issue is that of the low flyover height used by many helicopters, particularly in the USA. A study¹¹ made in Hawaii in 1994 as a result of the anti-tour helicopter lobby stated that people in rural areas felt that *"their home's privacy was invaded by helicopter flyovers"*. From these and other statements there appears to be a strong commonality in the response to helicopter noise irrespective of location or country being considered. Assessments also suggest that there is a strong relationship between the number of flights and the level of annoyance with an upper limit of just four or five flights per day before the annoyance becomes, in terms of the public unacceptable¹¹.

The magnitude of such negative response to helicopter operations as a result of noise is, on the surface, difficult to understand because most helicopters generate noise levels considerably below the internationally agreed noise certification limits and comfortably satisfy established community noise rating criteria and guidelines. The inference is that even relatively sophisticated noise rating methods based on complex objective measurements fail to account for the disturbance caused by helicopters. As a result of concerted opposition to helicopter operations it has been suggested that the noise criteria and limits associated with community rating procedures should be made more stringent. Although minor adjustments to the assessment criteria may be helpful, analysis of the issues indicate that such action will have little or no direct effect on the level of public acceptance. For example, a comprehensive study¹² of helicopter operations at a military airbase in the UK concluded that there was no meaningful correlation between the absolute helicopter noise levels and subjective annoyance. The authors of the study commented that the results confirm, for helicopters, the weak relationship between objective noise measures and subjective annoyance. Significantly, the same rating methods are generally considered to be successful in controlling the environmental impact of large commercial aircraft and other forms of transportation so there appears to be something different about the way in which helicopters are perceived.

Also if noise complaints associated with helicopter operations are examined it will be seen that often small helicopters which generate low overall noise will provoke the same level or more complaints than larger helicopters which produce much higher noise levels. Thus there is not a strong link between the maximum or peak noise level and public acceptance.

Another aspect which soon becomes clear when examining noise complaint information and from talking to those involved, is that the character of the helicopter sound is a very important factor. The more impulsive the sound, or the more tonal/“whine” noise, the more

likely there are to be complaints. In addition, it also soon becomes clear that these features are important when the helicopter is first heard and the actual sound level is 25 dBA or more lower than the maximum noise level which occurs during a flyover or fly-by. Unfortunately there is no known or generally agreed way to take these aspects of the sound into account.

4. PUBLIC ACCEPTANCE

Community noise rating procedures are considered to predict the impact of fixed-wing aircraft noise around airports and within local communities relatively well. This is not the case for helicopters and heliports, which appear to create a level of adverse reaction disproportionate to the measured or predicted noise levels. A partial explanation for the disparity between noise assessments and community reaction to helicopter operations has been identified^{1,2,3} as deficiencies in the rating methods. For a more complete analysis of the issues it is necessary to examine the way in which helicopter operations are perceived. Fixed-wing aircraft operations at airports typically involve a large number of flights per day and, because the noise characteristics of most of the large jets are similar to one another, the noise climate is relatively uniform. Away from airports aircraft fly at very high altitude so that noise levels on the ground are low. In addition, there is little concern over aircraft safety. Helicopter operations are very different. In general, the flight paths, unlike those used by fixed-wing aircraft, vary widely and so at any one location the noise pattern is much less consistent. There are also very large differences in both level and, more importantly, the character of noise created by different helicopters with some small helicopters often *sounding noisier* than larger ones. Overflights are also generally made at relatively low altitudes so that any concerns over safety are heightened.

A. Acoustic (Direct Noise) Stimulation

A generalized A-weighted sound pressure level time history of a helicopter flyover is shown in Figure 2 to illustrate the influence of various noise sources on overall noise level. The principal sources are main rotor thickness/high speed impulsive noise (HSI), main rotor blade/blade vortex interaction noise (BVI), main rotor wake/tail rotor interaction noise (TRI) and tail rotor noise (TR).

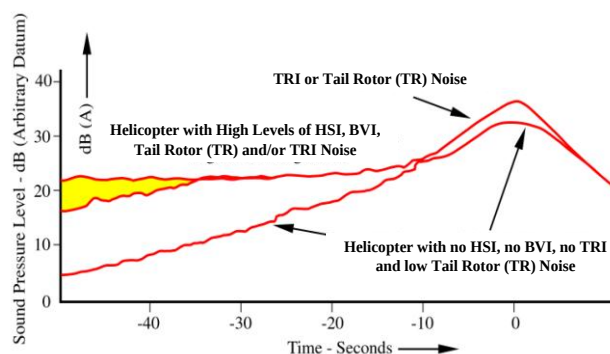


Figure 2: Generalized dB(A) flyover time history

HSI, TRI and TR noise are most pronounced during flyover. BVI noise is normally the dominant source during descent (landing) although TR and TRI noise can also be present. BVI can also occur on some helicopters during flyover/cruise flight and is pronounced during banked turns. In the case of tandem rotor aircraft, BVI occurs continuously, regardless of flight condition. Most importantly, it can be seen that the greatest effect of the intrusive sources occurs more than 10 dB(A) below the maximum value so they will have

little or no influence on time integrated units such as Sound Exposure Level (SEL) and Effective Perceived Noise Level (EPNL).

The idealized upper trace shown on Figure 2 represents a flight during which the impulsive sources are generated continuously. However, these sources often occur intermittently in which case the time history will exhibit relatively rapid increases and decreases in level. BVI and TRI are also particularly sensitive to control inputs and changes in wind speed and direction. These changes in noise level will be more marked on higher speed rotors simply because the sources are naturally more intense. From a subjective point of view the intermittent generation of the intrusive sources is equally or more annoying than if the sound occurred continuously and tends to draw immediate attention to the helicopter. This is important when considering annoyance.

B. Annoyance Stimuli

Assessments of surveys conducted in London and Los Angeles by the Author and A.(Tony) C. Pike for GKN Westland Helicopters (now AgustaWestland) together with information in the files of the HAI and general experience of the industry makes it clear that the subjective impression created by the impulsive noise sources is very important when considering public acceptance. Also, except in the case of tail rotor noise (TR), the *sources of interest* are mainly detected at levels well before the ‘– 10 dB down point’ i.e. the *position* on the sound pressure level time-history at which the level is 10 dB below the maximum or peak level.

A study of the various factors involved shows the level of public acceptance can be considered to be a function of both acoustic (direct) noise and a non-acoustic element, termed *virtual noise*, as illustrated in Figure 3.

The response to acoustic noise is a function of maximum noise level as defined by objective measurements and the subjective characteristics of the noise as it first becomes audible. The magnitude of the non-acoustic component (*virtual noise*) is not related directly either to the absolute level or to the character of the noise generated by helicopters, but it is *triggered* by the direct acoustic signal.

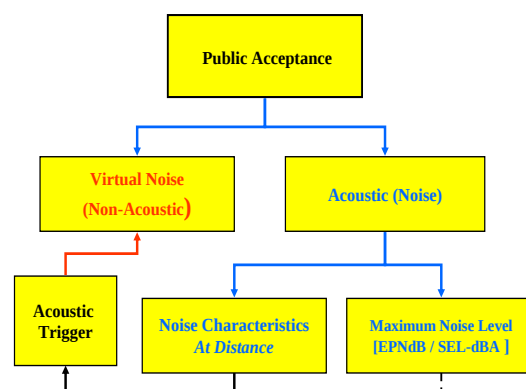


Figure 3: Elements of public acceptance

Even so the annoyance or level of public acceptance is usually quantified using measured noise levels as illustrated in Figure 1. Consequently the *virtual noise* element is treated,

for all practical purposes, in the same way as the direct acoustic energy (noise) radiated by the helicopter.

There are some situations in which resistance to helicopter operations occurs even though the relative levels of helicopter and ambient noise suggest the helicopter should not be audible. It would seem that in these situations the trigger for the *virtual noise* is visual. The surprise of suddenly seeing a helicopter, even when it cannot be heard, has been commented upon a number of times by the general public and may offer a partial explanation for concerns about sight-seeing operations around the Grand Canyon and New York. The number of occurrences when the *visual trigger* is significant, however, appears to be extremely small so that the topic is not addressed further in this paper.

It cannot be stressed highly enough that whenever adverse reaction to helicopter operations results from *virtual noise*, attempts to address the problem by reducing *acoustic noise* at source will be largely ineffectual.

It is not simply that the level of sound, at long range as the helicopter approaches or flies towards the observer, are higher than on helicopter models with little or no noticeable HSI, tail rotor (TR), TRI, or BVI noise, rather it is that the *tonal* and *impulsive* characteristics of these sources are in themselves more annoying and draw attention to the helicopter. Some rating criteria apply a +5 dB, or +10 dB, penalty to account for the extra disturbance if a tone or *whine*, similar to the sound generated by the tail rotor, is present in the acoustic (noise) signal. Many researchers argue that EPNL, and by implication the SEL, L_{DN} or L_{Aeq} metrics, give a realistic measure of both the source level and public response, implying that any increase in the sound associated with BVI, HSI, TRI and tail rotor noise is accounted for in full by metrics which take into account the duration. This however is not supported by the evidence.

The subjective rating of helicopter noise was investigated thoroughly in the late 1970s and early 1980s. One objective was to develop an impulsive correction that could be added to more conventional metrics to account for the subjective effect of BVI and tail rotor noise. Despite the considerable effort expended, the results of these studies in combination were considered by many to be largely inconclusive. After an extensive review of all the issues, the International Civil Aviation Organization (ICAO) chose in 1983 to use EPNL for helicopter certification, with the proviso that manufacturers *strive to eliminate intrusive noise sources*.

Even so in the context of adjustments to account for high levels of tail rotor and impulsive (BVI) noise it is worth noting that a review¹³ of the response of the general public to various noise source associated with military bases and operations, and the current 'adjustments' defined in the International Organization for Standardization (ISO) and the American National Standard Institute (ANSI) standards for various noise sources, concluded that the following *corrections* should be applied:-

Highly Impulsive Sound	+12 dB
Regular impulsive sound	+5 dB
Prominent discrete tones	+ 5 dB

These adjustments are to be added to measured or predicted Day-Night-average sound levels (DNL/L_{DN}) used in the USA but the values suggested are equally applicable to any of the standard noise metrics and agree well with the values determined by studies at

Westland Helicopters^{14,15} in the late 1970s. It is apparent that both the level and character of sound audible at distances greater than those involved in EPNL calculations play a major part in the rating or acceptance of helicopter noise by the general public. The tonal and impulsive quality of sound 15 to 25 dB(A) below the maximum noise level observed during any single event can influence the subjective response. It would appear that when the degree of blade vortex interaction (BVI), high speed impulsive/thickness noise (HSI), tail rotor interaction noise (TRI) and/or tail rotor tonal noise (TR) is pronounced these distinctive sources act as an audible cue, increasing the negative response to helicopter noise. These *low level triggers* are not accounted for in EPNL or SEL calculations which only accounts for acoustic energy within -10 dB of the maximum value.

C. Non-acoustic (*Virtual Noise*) Stimulation

Virtual noise is dependent on a wide range of inputs but is *triggered* initially by any distinctive feature of the acoustic signature and, to a far lesser extent, the absolute noise level. The studies based on U.K. data, supplemented by information from other locations, including that associated with *Airspur* who operated in the Los Angeles, California area in the early 1980's, show that the *noise characteristics* and *virtual noise* are of equal or even greater importance than the maximum noise level observed during a particular flyover or flyby event. It is difficult to ascertain precise values for these components because they are partly interrelated. For example, a helicopter generating BVI or HSI noise may cause annoyance directly, while at the same time acting as a *trigger* to highlight public opposition to some other aspect of the operation. The information available also suggests that sounds such as tail rotor *whine* and/or main rotor impulsive noise (BVI or HSI) also exacerbate concerns over the safety of the helicopter because the 'sound' may suggest (falsely) mechanical problems or conjure up an image of a helicopter crashing as often seen on television.

In the context of this evaluation it has been found that general aviation light propeller driven aircraft have a similar impact - at least in Europe. Research reported to ICAO based on studies conducted at the University of Southampton, Institute of Sound and Vibration Research (ISVR)¹⁶ has shown that a number of complaints attributed to the noise from general aviation aircraft are, in fact, related to other causes. This research attempted to classify complaints and to quantify the effect in terms of the equivalent A-weighted sound pressure level with the following results:

- | | |
|--|------------|
| a) negative reaction to leisure flying | + 5 dB(A) |
| b) poor community/airfield relations | + 10 dB(A) |
| c) fear of crashes | + 10 dB(A) |
| d) nobody acts on complaints | + 20 dB(A) |
| e) aircraft are flying too low | + 20 dB(A) |

It should be noted that these equivalences are not reversible, so that, for example, reducing noise levels by 10 dB(A) will not remove the fear of crashes.

It is also interesting that while the ISVR study¹⁶ was made at general aviation airfields dominated by light propeller driven aircraft, there was some helicopter traffic at one of the airfield sites studied. Examination of the results obtained indicates similar trends for both general aviation fixed-wing aircraft and helicopters, but it is difficult to be specific because the survey did not set out to highlight differences between helicopters and other forms of air traffic.

While it has not yet been possible to determine similar equivalence factors in such a precise manner, a review of other evidence suggests that the light airplane findings are generally applicable to helicopter operations. The main difference being that the first of the non-acoustical factors - negative reaction to *helicopter* flying - appears to be stronger than for general aviation aircraft and may be as high as 15 dB(A) at particularly sensitive locations. This is because the public at large often perceive helicopters to be engaged either in leisure flying or operating for no justifiable reason. As explained previously, however, if it is believed that helicopters provide a worthwhile service, as in the North Sea, the *virtual noise* factor can be very low or zero. Similarly, the concern over safety and fear of crashes in areas where flights are conducted over precise routes under air traffic control may be much less. Experience from Aberdeen, Scotland, where helicopters have become accepted much in the same manner as large fixed-wing transport aircraft, and in the Victoria/Vancouver area where *Helijet* operates a scheduled passenger helicopter service, supports this view.

Amongst the non-acoustic sources associated with airfield related disturbance, the work reported to ICAO¹⁶ found that fear of crashes was the most significant factor. Low flying, changes in the noise signature of the engine, and previous crashes increased anxiety. At one airfield where an accident had occurred shortly before the survey, concern was almost three times greater.

D. 'Startle' Effect

In order to further understand the aspects which influence *virtual noise*, some of the information in the *HAI Acoustic Committee* files for the period 1988/1998 related to US operations was re-examined by the author. In addition information from three public hearings relating to a heliport application in Northern Virginia was studied. This highlighted an additional effect related to the sudden occurrence of the sound of the helicopter, which can be best described as a *startle effect*, when the helicopter flies over. This appears to not only increase the annoyance but raises concern to many on the safety of the operation. This was not apparent when a detailed review of complaints related to operations in the UK was conducted a number of years ago. This may be partly explained by the fact that in general the *flyover heights* used by helicopters are higher in the UK, than in the US and thus the occurrence sound of a helicopter is less sudden. In the UK, the regulations require overflights to be made at 2000 ft unless specific ATC considerations dictate lower heights. On the other hand although some operators in the US use such heights, many operate at much lower heights of 500 ft, and even lower heights in some cases are not uncommon. The duration and hence the 'sharpness' of rise and fall of the acoustic signal, *startle effect*, will be much greater with helicopters flying at lower altitudes. Conversely the higher the flyover height the lower the maximum noise level and the longer the duration of the signal heard on the ground and hence a decrease in the *startle effect*.

The lack of quantitative data makes it impossible to draw any specific conclusions. Nevertheless it is postulated that the *startle effect* is a significant contribution to the *virtual noise* component and to the perceived safety of helicopter operations in many operations where low (500 ft or less) flyover heights are involved. Somewhat ironically, this effect is likely to be more pronounced as noise levels are reduced and more especially with significant reductions in the long range cues such as HSI, BVI and TRI noise.

5. REDUCTION OF VIRTUAL NOISE

Virtual noise can be effectively eliminated by removing the stimuli by which it is triggered. This ideal is normally not achievable on a real helicopter so the aim should be to minimize

the effect as far as possible. The study reported here has confirmed that the public have major concerns about safety issues and often do not fully understand the need for helicopter operations. Equally, the helicopter industry often underestimates the level of public apprehension and fear of accidents. Difficult situations are compounded if the community believes responses to complaints are either unsympathetic or dismissive. Problems exacerbated by a lack of diplomacy or tact mean that this *virtual noise* element can be equivalent to 15 dB(A) or more.

Even with action to understand complaints and associated concerns, the industry will still be faced with two major issues. Firstly the fear of accidents, and secondly the lack of appreciation on why helicopters *are required*, by large sections of the population. These *virtual noise* elements, which evidence suggests can amount to 15- 20 dB(A), can be resolved only by publicity campaigns. It is unlikely that these two issues can be tackled piece meal by individual operators so that the combined efforts of the European Helicopter Association (EHA), the AHS International, Helicopter Association International (HAI) and other associations and societies worldwide are required. The HAI Fly Neighborly programme, targeted at reducing nuisance by encouraging the use of noise abatement procedures, has shown that such concerted action can be very effective. Publicity aimed at highlighting the actual high levels of in-flight safety is also required if *virtual noise* is to be reduced. To achieve the desired reduction of non-acoustic sources the industry may, however, have to accept tighter operational control particularly in city environments.

Since it is such a strong component of public acceptance, there is great potential for improving the current situation if *virtual noise* can be reduced or eliminated by better public relations. A satisfactory situation in the broadest sense cannot be achieved until both sides appreciate and understand the concerns and needs of each other. The industry for its part must identify noise sensitive sites and alleviate problems by re-routing, increasing flyover heights, and revising operational procedures to resolve local noise issues.

A concerted effort by the manufacturers and the industry associations could dramatically reduce the non-acoustic component over a 2 to 3 year period. Conversely, there is sufficient evidence to conclude that if no action is taken, *virtual noise* will remain a highly significant factor in determining the degree of public acceptance to helicopter operations.

6. CONCLUDING REMARKS

The reaction to helicopters and heliports is dependent on several factors, some of which are completely unrelated to the sound generated by the helicopter. These non-acoustic phenomena described collectively as *virtual noise* are usually triggered by acoustic noise although there is some evidence of a visual trigger. The non-acoustic component can be more important than the actual level of the helicopter noise and often dictates the level of public response to helicopters. In addition it appears that the 'startle effect' resulting from low level flyover also contributes to annoyance, and perceived safety, of helicopter operations where such flights are used and/or allowed.

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