O’Hare International Airport Noise Pollution: A Cost-Benefit Analysis

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I. Introduction

Today's ever expanding world is highly dependent on air travel. O'Hare airport shoulders some of the most air travel in the world; according to official airport activity statistics from the last few years, O'Hare has been accommodating an average of 5,000 extra flights per year. The benefits from an airport serving so many citizens, however, do not come without costs. The frequent flights coming in an out of O'Hare each year put a strain on the surrounding communities, and a major consequence of such high density air traffic we here would like to examine is noise pollution. By the end of our cost-benefit analysis we will determine whether or not it is economically efficient to undertake noise abatement policies to benefit the surrounding O'Hare communities.

To measure potential benefits, several methods are employed. First, a contingent valuation survey is conducted to give us a sense of the value an individual places on reducing airplane noise. Second, numerous studies are consulted to shed light on the negative health and learning effects resulting from aircraft noise disturbances. Third, an econometric regression demonstrating hedonic pricing is used to illustrate the property value differences associated with airline noise emissions. Fourth, the averting costs of residential sound insulation are used to measure benefits through people's willingness to pay.

As mentioned earlier, where there are benefits, there are almost always costs. We measure costs in our analysis in two separate ways. First, we use averting costs again to reveal the potential costs of solutions to noise elimination. Second, we explore how noise emissions standards force airlines to install costly sound-muffling devices called "hush kits." By the end of our analysis we aim to arrive at a solution from our cost-benefit analysis calculations and thereby impart a deeper understanding of the issues surrounding O'Hare noise pollution.

II. Benefits

Contingent Valuation

The theory behind the contingent valuation method is relatively straightforward: if we are interested in how much an individual values the existence of a given environmental amenity, we should simply ask that individual. In situations where no market exists for people to reveal their preferences, the method seems like an excellent substitute. However, despite this apparent simplicity, complications can quickly arise which have caused some to doubt the accuracy of this tool.

The potential variation of many factors- how respondents are selected, the way in which questions are posed, the accuracy of the responses-have caused critics to question the consistency and effectiveness of the contingent valuation method. As seen in Stavins' Economics of the Environment, great debate exists in the academic field on its reliability. We as a group, however, believe that the method is one useful tool to help determine the benefits an individual derives from the existence or abatement of a given environmental phenomenon. Thus, we have chosen to employ the contingent valuation method as one of several tools to determine the benefit of a reduction of noise pollution from O'Hare Airport.

Well aware of the many criticisms and critiques of contingent valuation, we designed and administered our survey as carefully as possible. Our first task was to create the survey itself. After consulting an Institute of Local Government Studies of

Denmark study by Thomas Bjorner et al., we posed our first important question as follows:

How would you describe the noise from airplanes from O'Hare Airport?

a) Extremely Annoying
b) Very Annoying
c) Moderately Annoying
d) Slightly Annoying
e) Not Annoying

Using different levels of annoyance as possible answers was described in the study as "following standard guidelines in socio-acoustic surveys" (Bjorner, Pg. 1). The purpose of this question was mainly to get the respondents to think about the issue, and most importantly to set up the questions that followed in the survey.

Advocacy groups and concerned residents cite both annoyance and adverse health conditions as affects of O'Hare noise pollution. Therefore, our next question was designed to reveal the derived benefit the respondent would receive were the noise to be reduced *due to the annoyance* of the noise. The following scenario was given:

Suppose that someone came to you and told you he could either eliminate the noise from O'Hare Airport or pay you an annual sum of money in order to compensate you for having to endure the annoyance of the airplane noise. What is the lowest sum of money you would need each year to make you prefer to deal with the annoyance the noise causes you and/or your family than to choose to have the noise eliminated?

If the respondent slightly prefers dealing with the noise while receiving compensation to having the noise eliminated, the value of compensation the respondent names will be a monetary measure of the derived benefit (plus Epsilon) of reduced annoyance due to a decrease in noise pollution.

After this, we hoped to target the benefit *from improved health* due to a reduction in noise pollution. We asked a whether or not the noise from O'Hare Airport caused any adverse health conditions, such as stress or sleeplessness for the respondent and his or her family. Many respondents answered this question by saying that they did not believe they were affected adversely, but because a number did, we felt the study of adverse health benefits warranted a closer look, and the issue is examined in the section on health benefits. Thus, we believe that small annoyances, such as disturbance due to sleep loss, are captured within the stated compensations due to annoyance. However, more serious conditions, such as hypertension and heart disease, are calculated separately in the section on health, and will be added to the benefits computed in this section due to annoyance.

Our final question was intended to determine the income characteristics of the household. It asked:

Considering the income classes listed below, which category best describes this household's total pre-tax income for the year 2003?

Less than $40,000
$40,000-$60,000
$60,000-$80,000
$80,000-$100,000
$100,000-$120,000
$120,000-$140,000
More than $140,000

The purpose of this question was to determine if the amount of compensation the respondent named was correlated to their annual income. As it turned out, however, most of the respondents were in relatively similar income brackets, and while the responses to this question are included on the Survey Summary in Appendix 1, the data from this question was not included in the computation of total benefits.

With the survey designed, it was now our job to determine the population to be studied. In 1979, the Federal Government put together the Federal Interagency

Committee on Urban Noise (FICUN), which included the EPA, the FAA, and the Department of Defense, among others. In a 1980 report by the committee, the Day-Night Average Level (DNL) of 65 dB was established as the noise level above which noise pollution became a problem. "The FICUN generally agreed that standard residential construction was compatible for noise exposure from all sources up to DNL 65 dB" (Federal Register, pg 1). The O'Hare Noise Compatibility Commission describes DNL as "a 24-hour time-averaged sound exposure level with a 10 dB nighttime (10pm-7am) weighting" (O'Hare Noise Compatibility Commission). In other words, DNL measures the level of noise in a given area over a full 24 hours, taking noise that occurs at night into account more heavily due to its greater likelihood of disturbing those who are asleep.

A DNL contour map describes an area inside which DNL is at or above a given level. We were able to obtain a DNL 65 dB contour map from the O'Hare Noise Compatibility Commission, and based on the aforementioned information, decided that the communities that lay on or within this contour map were to be our population of interest for the contingent valuation study. Schiller Park, Illinois was one town that stood within the DNL 65 dB contour, and we chose to sample households from this community.

Group members walked door to door on several streets in Schiller Park to administer the surveys. After explaining to the potential respondents the motivation for the study, the questions were posed to the residents. Some residents refused to participate in the study, but because it is ambiguous whether those who chose to respond were subjectively more or less affected by the noise pollution, we have little concern of self-selection bias. When the survey was administered, the amount of time it took to complete varied somewhat based on the speed with which the respondents answered the questions, and also based on the number of questions the respondents had for the interviewers.

Though the requirement for the law of large numbers was satisfied with N=36, certain characteristics of the data resulted in some inconsistencies between the different summary statistics. For example, an outlier of $1,000,000 existed in the data for annual compensation due to annoyance. The group member who gathered this piece of data reported that the respondent had been very passionate in expressing his dislike for the noise, and had described the noise as "Extremely Annoying." While it is impossible to conclude that the respondent was untruthful, it also is likely that this value was over exaggerated. The average annual compensation per household due to annoyance with the outlier was computed to be $39,865, while the value excluding the outlier was $12,432. This difference, when multiplied many times to extrapolate information for the entire population of interest, could result in a gross overestimation of the benefit of noise reduction to the DNL 65 dB region. Therefore, we compute total benefit using the value excluding the outlier at the conclusion of the paper.

Another interesting characteristic of the data resulted in a striking difference between the average and median compensation for adverse health affects. Respondents often felt that the noise did not cause them or their families any adverse health affects and put a minimum compensation to deal with the noise of $0. However, when respondents did feel the noise had resulted in undesirable health conditions, they understandably stated a relatively high compensation. Therefore, the average, which was computed to be $2, 414, was brought up well above the median of $50. Because of this great range, we were once again motivated to study the issue of the adverse health affects of noise pollution more closely in the section on health affects.

Benefits due to a reduction in annoyance were computed in the following way: The total population on and within the DNL 65 dB contour map was determined by adding up the populations of the townships that stood on and within the contour. This was calculated to be 168,950 people using data from the year 2000 (see appendix 1 for townships included) (City-data.com). Then, because the responses received in the survey were for households, we divided this number by the average number of household members in our sample data, 3.472, to arrive at an estimate of 48,660 households.

Therefore, to determine the annual benefit due to reduced annoyance, the number of households was multiplied by the summary statistic for compensation due to annoyance. For example, using the average compensation due to annoyance including the outlier, the computation was:

48,660 X $39, 865 = $1,939,830,900

Discounting a stream of this annual benefit (AB) for ten years at an r=.03, we have:

$$AB + \frac{AB}{(1.03)} + \frac{AB}{(1.03)^2} + \ldots\ldots\ldots + \frac{AB}{(1.03)^{10}} = \$17,000,000,000$$

Once again, by using the average compensation due to annoyance excluding the outlier, the computed annual benefit and the discounted benefit was much smaller. Calculating total annoyance compensation using data excluding the outlier:

48,660 X $12,432 = $604,941,240

Discounting a stream of this annual benefit (AB) for ten years at an r=.03, we have:

$$AB + \frac{AB}{(1.03)} + \frac{AB}{(1.03)^2} + \ldots\ldots\ldots + \frac{AB}{(1.03)^{10}} = \$5,310,000,000$$

Given the scale of our survey, however, such data inconsistencies are to be expected. With more time and resources to conduct the survey, our sample size could have been much larger, and the inconsistencies in the data would have likely disappeared. Despite this, the data collected through the contingent valuation method was very valuable in conducting our analysis. We have chosen to think of our data as way of making an estimate of annual benefits of reduced annoyance due to an abatement of noise from O'Hare, and also as a way to crosscheck some of the other ways benefits have been computed in this paper, such as hedonic pricing and averting costs. By coupling this estimate with the benefits from improved health, we believe we have a relatively accurate measure of Total Benefits.

Health and Learning Benefits

To compare the costs and benefits of designing a policy that reduces airline noise pollution one needs to take into account the health effects caused by noise at such levels. As of right now, airlines do not pay for doctor's visits, medicine, etc. for the individuals damaged by their noise. Thus, any reduction in the number of health problems caused by noise is considered a benefit to the group subjected to airline noise.

In 1978, the EPA issued a report documenting the deleterious effects of airline noise. At the time, the EPA determined that airline noise accounted for hearing loss, high blood pressure, heart disease, excess of certain hormones in the blood stream, tense muscles, sleep depravity, and diseases related to stress such as ulcers, asthma, headaches, and colitis. The EPA found that noise affects the unborn as stress affects the mother. The results of a study showed a higher prevalence of premature births and low birth weights. An important point that the EPA makes is that even if one is accustomed to noise, one's body continues to feel its negative effects (Environmental Protection Agency).

Thankfully, airline noise has been reduced substantially since 1978. However, some of the above-listed health effects are still caused by airline noise. Perhaps the easiest negative effect to recognize is stress. About 70% of people living in flight patterns admit to being "bothered" or "annoyed" by the noise. These people who complain are often unable to perform regular household activities/functions such as conversing, reading, watching television, listening to music, or falling asleep. One can imagine how being unable to enjoy many activities at home and unable to let any fresh air into the house (an open window lets in even more noise) would lead to higher levels of stress. In a study done by Bronzaft, individuals in the flight paths of airplanes "…perceived themselves to be in poorer health" (Bronzaft; AReCO).

One of the largest complaints to airline noise is in regards to sleep depravity. A quote that captures this is from an interview with doctors studying the effects of airline noise, "Imagine your telephone ringing 3-4 times per night" (Doering). The members of households underneath flight paths feel that the airlines disturb their sleep patterns. As we all know, having a lousy night's sleep can be a drag for a number of reasons. Along with feeling tired and grumpy, Stansfeld and Matheson reported other results both during and after noise exposures during sleep. "Noise exposure during sleep may increase blood pressure, heart rate and finger pulse amplitude as well as body movements. There may also be after-effects during the day following disturbed sleep; perceived sleep quality, mood and performance in terms of reaction time." Although more research needs to be done, there may be a link between noise and psychological disorders. However, this is hard to determine since the frequent headaches, loss of sleep, and stress could be only some the direct causes (Matheson; Saporito).

Environmental noise (airline noise) has been shown to increase the chances of hypertension (high blood pressure). Residential exposure to airline noise increases the odds of hypertension and the level of noise is related to the percentage of individuals who have (or will get) hypertension. In an experiment adjusted for age, sex, smoking, and education, individuals exposed to aircraft noise levels above 55 dBA are seen to be 60% more likely to develop hypertension. Individuals exposed to levels above 72 dBA are 80% more likely to develop hypertension. Keep in mind that the communities around O'Hare are exposed to levels between 55 and 70 dBA (Rosenlund; Matheson; Saporito).

Studies have shown that there is a correlation between high blood pressure and heart disease. Thus, these individuals exposed to airline noise have a greater chance of getting hypertension, an ailment that is correlated to heart disease (Russell).

To evaluate the total benefits related to reducing airline noise one needs to take all of these health effects into account. Stress related to annoyance and the bothersome effects of sleep depravity are harder to estimate because they are better described as willingness to pay to avoid. These results are recorded in our contingent valuation. The benefits analyzed here are those related to the reduction of hypertension and heart disease linked to high blood pressure. This data is important because a substantial number of individuals indicated health related issues in our contingent valuation. It is likely that their symptoms were related to high blood pressure.

Using the Rosenlund study, individuals exposed to airport noise are 60% more likely to develop hypertension. The study done by Russell explains that the costs for screening hypertension amount to around $121 (in 1975 dollars). Treatment averaged around $200 annually. Since it is difficult to estimate the combined effects of inflation and technological innovation, the screening numbers will stay as they are. However, the cost of prescription drugs has risen substantially, so tripling the treatment to average $600 annually seems appropriate. Of course, treatment for hypertension is not perfect, and Russell presents a correlation between blood pressure and heart disease. Using a lower level of systolic pressure (yet still above normal) to represent the positive effects of the treatment, an individual (averaging men and women) still stands roughly a 30% greater chance of getting heart disease. This percentage is close to the relative death rates in regards to similar blood pressure levels. Thus, it can be interpreted that an individual exposed to airline noise pollution stands an 18% greater chance of getting heart disease (or dying – high blood pressure). The willingness to pay to live or not have heart disease is extremely variable, especially for different age groups. Costs of treating of heart disease is the only simple way to estimate the benefits of reducing heart disease even though this will drastically under represent the willingness to pay to avoid it. Using data from Health on the Net Foundation, the average health care costs for treating heart disease were about $3400 per case. The total health related benefits regarding hypertension and blood pressure related heart disease are $43,640,000 annually (see table for breakdown). However, it is very important to note that this figure deals only with screening and treatment costs for these conditions only - it does not comment on willingness to pay to avoid these conditions or other possible symptoms/inconveniences caused by noise pollution. (Heart Disease; Russell)

Along with having negative health effects on children and adults, environmental noise (particularly airline noise) can damage unborn children. Pregnant women exposed to aircraft noise are more likely to give birth prematurely. "…the length of gestation in female infants to be inversely correlated to maternal residential noise exposure from an airport ($r = -0.49$; $P = .0008$)." Also, birth weights of newborns whose mothers lived nearby airports are shown to be significantly lower. The chances of such events occurring are 5% more likely near by an airport than in a less noisy environment. Clearly, no one can put a price on such a sad occurrence; the willingness to pay to avoid this catastrophe would be enormous (American Academy of Pediatrics).

Health Effects (Benefits)	
O'Hare Community Population	200,000
Normal Population with Hypertension	0.10
Effects of Noise Creating Hypertension	0.06
O'Hare Pop. Hypertension Due to Noise	12,000.00
Costs of Screening (assume all screened)	24,200,000.00
Treatment of Hypertension - O'Hare due to Noise	7,200,000.00
Heart Disease Caused by Noise	0.02
Cost of Heart Disease Treatment Due to Noise (O'Hare)	12,240,000.00
Total Annual Benefits	**43,640,000.00**
Ten Year Benefits Discounted at 3%	**383,425,793.35**

Studies on the effects of airline noise pollution go beyond health and make an impact on the learning abilities of children as well. Children living and going to school in areas underneath flight paths are at a substantial learning disadvantage compared with kids living in unaffected areas. The most noticeable problems are seen in the children's reading abilities, but studies have shown that speech, memory, and even mental health are also compromised (Hygge; Lercher; Lang; Matheson).

In the study conducted by Staffan Hygge children were monitored before and after the opening of a new airport and the closing of an old airport. Children were tested once before the opening (or closing) and then twice after the opening (or closing). The study found that children in the area of the new airport had worsened at tests dealing with reading and memory. The group living near the airport that closed improved at both of these tests. Speech perception was impaired for the children living by the new airport (Hygge).

In a study done at Cornell, researchers came up with similar results as Hygge but stated that having load ambient noise makes children "tune out" sounds. In turn, children have more difficulty picking up speech patterns and recognizing words. Children in noisy areas have difficulty learning the language, and this is a factor leading to trouble with reading. Children living near or under flight paths were about 3-4 months behind (on average) in reading level, and scored significantly lower on standardized tests (Lang; Matheson).

Mental health of children in noisy areas may be at stake. Children in such areas were rated by their teachers and by themselves on questions regarding mental health. Teachers rated children in the noisy areas to have lower mental health and poorer classroom performance compared with children living in quieter areas. However, only children with pre-existing health problems listed themselves as having lower mental health (Lercher).

To compute the benefits of reducing airline noise on the learning/mental health of children one would need to have an abundance of knowledge. How much would parents be willing to pay to save their child's reading skills, speech abilities, and mental health? One must keep in mind that these are vital for a successful future and allow a child to reach his or her potential. For example, a child with sub-par reading and speaking skills may not graduate from high school, and will not have as good a chance at being financially stable. In this sense, there is no particular value that can be placed on the ability to learn properly as a child. For some, the benefits may be priceless, yet others may value them less. For the sake of setting a value on this benefit, looking at a future salary may be the best measure. It is well documented that individuals unable to complete high school earn substantially less on average than those that get their diploma. If we assume that kids with lesser abilities growing up will (on average) be behind others throughout life, then an annual salary differential of $7000 seems a reasonable assumption. Of course, there is no data on aircraft noise pollution leading to salary differential, so this is just speculation on what we do know (regarding mean/median salary for people with and without diplomas – census bureau). The benefits of improved learning that leads to higher salaries measures $87,500,000 annually (see table for breakdown). Also, it is most important to remember that this value is attributed to the salary differential and says nothing about willingness to pay to avoid these problems. As mentioned before, to some people the ability to learn properly may be priceless, so this salary differential would be the minimum possible value an individual would be willing to pay. It is likely that most people living in such areas are not familiar with these studies on learning patterns.

After analyzing the total health and learning benefits to the community for reducing airline noise pollution we find an annual total of $131,140,000. Discounted at 3% over the course of ten years would bring a benefit of $1,152,210,324. It is essential to keep in mind that this amount is the lower bound for benefits, relating only to the health costs and salary differential. We all know that the costs of being sick are greater than the price of a pill as a cure (feeling bad, less productive at work, unable to enjoy certain activities, etc.). Most people would pay more to reduce chances of getting high blood pressure, heart disease, giving birth prematurely, or giving children a normal chance to succeed. The actual values including willingness to pay to avoid such problems (assuming the community is aware of the drawbacks to noise pollution) could easily be 5 times greater than the amounts listed here.

Learning Effects (Benefits)	
Number of Affected Children in Area	50,000.00
Percentage of Affected Children Severely Damaged	Unknown, say 25%
Value of Damages to Learning Abilities (Annual)	**87,500,000.00**
Ten Year Benefits Discounted at 3%	**768,784,530.66**

Hedonic Pricing

Hedonic pricing is a method of estimating the benefits of an environmental policy or regulation. It is a technique of direct comparison whereby two goods that should, ceteris paribus, have identical valuations are exposed to certain exogenous factors that alter the price ratio between them. One of the commodities essentially serves as a control while the other is exposed to the exogenous factor. The price differential between the two commodities is then compared in order to judge the effect that the exogenous variable has upon the price of the good.

In the case of environmental policy, Hedonic pricing helps to measure a marginal damage function. A marginal damage function measures the benefits that would be received by a certain individual or group of individuals if something that causes damages were to be reduced by a given amount. For example, if a community is situated on a lake where paper mills and industrial plants contaminate the water, the marginal damage function would specify the benefits accrued to this community for a given level of contamination reduction. Hedonic pricing is used to estimate this function by direct comparison or regression analysis.

Real estate and housing are the most common goods subject to Hedonic pricing measurements. Suppose there are two houses with identical characteristics (i.e. square footage, lot size, number of bedrooms, etc.) except one is located near a nuclear power plant and the other is not. A Hedonic pricing analysis would compare the price differential between the two houses and, as long as all else is identical and constant, attribute the difference in prices to the fact that one house is closer than the other to the nuclear power plant. If House A costs $125,000 and is located near the nuclear power plant while House B costs $175,000 and is not located near the nuclear power plant, then we could say that the removal of the power plant would allocate $50,000 of benefits to the owners of House A.

Instead of simply comparing data on two similar houses near and far from O'Hare International Airport as in the nuclear power plant example, we ran a multivariable regression on our data for more accurate results. In our study of noise pollution around

O'Hare International Airport, we collected a sample of 55 homes located between 1 and 16 miles away from the airport and conducted a regression analysis on the data in order to estimate the benefits of living farther away from the airport. We decided to collect a broad range of data on each house to ensure that any variables that explain housing price were controlled for so as not to create bias in our estimator of interest – miles away from the airport. The data we acquired came from www.realtor.com, a database of houses and land being offered by various realtors around the country. We collected the following data on the homes in the sample: square footage, miles away from the airport, number of bedrooms, number of bathrooms, age (of the house), lot size, garage size, fireplaces and number of stories. We also gathered data on whether houses did or did not have the following: patio, skylight, pool, basement, air conditioning. This data can be used in dummy variable form as further controls on the housing price regression. The data table can be found in Appendix 2.

To avoid problems of multicollinearity and herteroskedasticity, we followed a similar housing experiment carried out in *Introductory Econometrics* by Jeffrey M. Wooldridge. For example, by running a regression between square footage and number of stories, we found that the two variables were correlated at a statistically significant level. Hence, using both of these as explanatory variables in the regression for housing price would have caused multicollinearity between the explanatory variables and violated one of the necessary assumptions for using multivariate regressions. After conducting several tests for multicollinearity, we found that the variables bathrooms and number of stories did not need to be included in the regression. To avoid any issues with heteroskedasticity, we used a heteroskedasticity-robust regression when running our experiment.

In addition, we found that many of the dummy variables took on the same value across the whole sample. This discovery eliminated the necessity to include fireplaces, pools, patios, basements, skylights, and air conditioning. Using variables that are uniform across the sample size may cause unnecessary bias that could be avoided by leaving them out altogether. We also chose not to use age in the regression because it is an unreliable predictor of housing price. Because many houses are renovated and may have an inverse or direct relationship between age and price, we decided that using age could only add bias to our analysis. After sorting through all the bias-causing variables we decided to use number of bedrooms, square footage, miles away from the airport, and lot size as our main explanatory variables.

Because our data came from a wide range of areas that have their own location-specific characteristics that affect the price of a given house, we used dummy variables that correspond to the zip code that a house is located in. For instance, one area may have a higher crime rate or have noise pollution coming from other sources such as trains. In order to control for these local variations, we included the dummy variables so that we would not have biased estimators as a result of local characteristics that could not be explicitly accounted for in the regression equation.

After carefully selecting the variables that should be used in the equation we specified the following functional form:

$$\text{Price} = \hat{a}_0 + \hat{a}_1(\text{miles away}) + \hat{a}_2(\text{bedrooms}) + \hat{a}_3(\text{sq. feet}) + \hat{a}_4(\text{lot size}) + \hat{a}_5(60641) + \hat{a}_6(60634) + \hat{a}_7(60707) + \hat{a}_8(60646) + \hat{a}_9(60618) + \hat{a}_{10}(60176) + \hat{a}_{11}(60106)$$

Price is the dollar sale value of the specific house divided by 100, miles away is the straight line distance from the airport to the house, bedroom sis the total number of bedrooms in the house, sq. feet is the square footage of the house excluding garage, lot size is the square footage of the plot the house is on, and the various numbers correspond to dummy variables for the zip codes the houses are located in. After running the regression in Stata with and without robustness to heteroskedasticity, we obtained the following results:

Without Robustness to Heteroskedasticity

Source	SS	df	MS
Model	263249.396	10	26324.9396
Residual	60593.8726	44	1377.13347
Total	323843.268	54	5997.09756

Number of obs	=	55
F(10, 44)	=	19.12
Prob > F	=	0.0000
R-squared	=	0.8129
Adj R-squared	=	0.7704
Root MSE	=	37.11

price	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
milesawa	10.34827	4.329288	2.390	0.021	1.623166	19.07338
bedrooms	15.19738	6.90223	2.202	0.033	1.286844	29.10791
sqfeet	.1231351	.0147624	8.341	0.000	.0933834	.1528867
lotsize	-.0028926	.0068513	-0.422	0.675	-.0167005	.0109153
var1	13.14851	46.515	0.283	0.779	-80.5963	106.8933
var2	-12.52706	51.96058	-0.241	0.811	-117.2467	92.19261
var3	-70.12667	43.68974	-1.605	0.116	-158.1776	17.92421
var4	-71.02887	57.07592	-1.244	0.220	-186.0578	44.00008
var5	(dropped)					
var6	-42.8396	66.08572	-0.648	0.520	-176.0266	90.34741
var7	-51.14482	68.76125	-0.744	0.461	-189.724	87.43437

_cons	67.09084	71.57666	0.937	0.354	-77.16244	211.3441

With Robustness to Heteroskedasticity

Number of obs = 55
F(8, 44) = 24.38
Prob > F = 0.0000
R-squared = 0.8129
Root MSE = 37.11

price	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf. Interval]	
milesawa	10.34827	3.393979	3.049	0.004	3.508158	17.18839
bedrooms	15.19738	8.547776	1.778	0.082	-2.029535	32.42429
sqfeet	.1231351	.026323	4.678	0.000	.0700846	.1761855
lotsize	-.0028926	.0063122	-0.458	0.649	-.015614	.0098289
var1	13.14851	25.75368	0.511	0.612	-38.75463	65.05165
var2	-12.52706	29.15437	-0.430	0.670	-71.28384	46.22971
var3	-70.12667	21.60417	-3.246	0.002	-113.667	-26.58632
var4	-71.02887	25.74705	-2.759	0.008	-122.9186	-19.13911
var5	(dropped)					
var6	-42.8396	45.56788	-0.940	0.352	-134.6756	48.99642
var7	-51.14482	43.79508	-1.168	0.249	-139.408	37.11836
_cons	67.09084	51.42585	1.305	0.199	-36.55115	170.7328

The coefficient of interest in the regression is miles away. We can see that this variable is statistically significant at the 95% level in both the regression without robustness to heteroskedasticity and the regression with robustness to heteroskedasticity. As a side note, number of bedrooms is statistically significant at the 95% level in the regression without robustness to heteroskedasticity but only significant at the 90% confidence level in the other regression. Square footage is significant at the 95% level in both regressions. Lot size is insignificant in both regressions at even the 90% level. The R-squared value of .8129 in the first regression essentially means that 81.29% of the variation in housing price can be explained by the variables we included in our analysis.

Although the R-squared value can be a misleading indicator of a regression success, our value of 81.29% adds robustness to our choice of explanatory variables.

The coefficient on miles away is 10.34827 in both regressions. To interpret this coefficient we must look at the scale used for housing price. Because the housing prices collected were divided by 100, the coefficient on miles away from the airport is 1/100th of the change in housing price associated with a one mile movement away from the airport. Hence, if one were to start out at the airport and move one mile away, his or her house value would increase (on average) by $10,348.27. It is important to note that this linear regression will only work within a certain distance from the airport because the effect of the airport's noise dissipates logarithmically over distance. For instance, the difference in the price of a house 30 miles away from the airport and one that is 31 miles away from the airport will not necessarily be priced $10,348.27 differently. It is probably only safe to use this figure from anywhere between 1 and 12 miles away from the airport.

The reasoning behind using the Hedonic Pricing method was to cross-check the results from the Contingent Valuation surveys and to see if the method was applicable to the scenario of airport noise pollution. In the Contingent Valuation surveys participants who were surveyed fell within the 65 DNL area (the level that corresponds to serious disruption) that covers approximately a 1-2 mile radius around the airport. The average willingness to pay, expressed by those residents surveyed, to place themselves outside the 65 DNL range was $12,000. In order to place themselves out of this range, the residents would have to move approximately 1 mile farther away from their current place of residence. According to our regression analysis, a 1 mile move away would cost an extra $10,348.27. This amount is strikingly close to the results obtained from the Contingent

Valuation study. It appears that the Hedonic Pricing method both succeeds as a proxy for a marginal damage function and as a cross-check to the Contingent Valuation survey.

III. Costs

Direct Costs

We would now like to examine the direct costs associated with noise abatement programs in general and then tailor the findings to O'Hare International airport. We will examine the cost of programs that decrease noise through the utilization of aircraft modification methods called "hush kits" and then look at the costs of eliminating airplane ground noise with Ground Runup Enclosures (GRE's). According to Cyle Cantrell, program director of the Residential Sound Insulation Program, 90% of O'Hare noise emission results from aircraft flying in and out of the airport and 10% results from the Ground Runups.

Currently, all aircraft flying to and from O'Hare are required to meet Stage 3 noise standards. These standards, passed in 1990 by Congress as the Aviation Noise and Capacity Act, mandated that all aircraft engines in the U.S. commercial fleet be updated to meet the criteria of Stage 3 noise levels by the end of the year 1999. The overall effect of these measures resulted in a reported 50% decrease in aircraft noise. The Silent Skies Act of 1999 issued a directive to the Secretary of Treasury that by December 31 of 2001 regulations would be issued outlining Stage 4 noise standards. U.S. commercial fleets would have to meet the Stage 4 standards by the end of 2011, allowing ten years for the transition. Their hope was that the Stage 4 emissions standards would decrease aircraft noise by another 40%, effectively abating noise by a total of 70% over about twenty years

(The initial decrease resulting from Stage 3 regulation would abate from 100% to 50%. Stage 4 regulation would decrease 40% of that existing noise, thus abating from 50% to 30%, ultimately effecting a 70% noise abatement) (Silent Skies Act of 1999).

While there is little people can do to set limits on the steadily increasing size of airplane traffic, homeowners can invest in soundproofing technologies including insulation and double-paned windows. Beyond this, it is possible to make airplanes run as quietly as current technology may allow. The most popular method airplane companies used to meet standards without actually buying new airplanes is through the installation of "hush kits".

Residential Soundproofing

There are a number of things a household can do to reduce the noise level in the living area. The most obvious decision would be to move to another location (see hedonic pricing). If this is not feasible, there are some measures that can be taken to decrease the amount of noise penetrating the house. The city does not pay for most houses to be sound-proofed (especially those under 70 dBA), so individuals would have to take measures into their own hands.

The city of Chicago suggests a number of methods to reduce noise. Some of these methods are more effective and cost efficient than others. Beginning with the most efficient procedure (most effective for the cost), here is a list of popular sound-proofing methods: installing double pane (or triple pane) windows, installing storm windows, replacing regular doors with prime doors or storm doors, or putting in weatherstripping. These are more advanced and expensive methods: wall modifications, ceiling modifications, upper-level insulation, wall insulation, full insulation. Most forms of insulation require an advanced air conditioning/circulation system (O'Hare Noise Compatibility Commission).

By far the most effective way to reduce noise is by installing double pane or triple pane windows. This costs about $400 per window and reduces the most noise per dollar. Replacing the doors are the second most effective method, with prices beginning at $200. According to the contractors at Progressive Home Improvement, all other methods (listed above) are very costly for their level of effectiveness. "If the new windows aren't enough, then you should probably move" (Progressive). Jack Saporito said that a minimum full-house sound insulation would cost about $33,000. The city insulated 850 homes in year 2000 for about $33,000 each – the whole project cost about $30 million. The houses considered for this project had at least 70 dBA of airport noise (Saporito; Progressive; Noise Pollution Clearinghouse; HomeDepot).

Soundproofing (Costs)		
Households	50,000.00	
		Ten Year Benefits
Installation of Triple Pane Windows (avg. house)	300,000,000.00	229,925,019.70
Installation of Prime/Storm Doors	15,000,000.00	11,496,250.99
Full Sound Insulation Minimum (avg. house)	1,650,000,000.00	1,264,587,608.37

Hush Kits

When airplanes are fitted with hush kits, the chief areas in which such modification occurs are "the fan, the exhaust nozzle/thrust reverser and the nacelle" (Spiegel 2). With regards to the fan, two things are done. First, the engine bypass ratio can be changed. Higher bypass ratios generally mean that the engine has been recalibrated so that less thrust generated and thus less noise is emitted. Second, the fan section itself can be insulated to keep out noise. Changing the exhaust nozzle results in the altering of "the turbulent mixing of high velocity jet exhaust with air," one of the main culprits in the production of aircraft noise (Spiegel 3). The final alterations deal with the nacelle. These modifications are concerned with insulating the entire engine with Sound Absorbing Materials, or SAM's. All of these modifications are present in hush kit installations. It is important to note that these hush kit methods are permanent and rather costly.

Let us now directly examine the costs of such hush kit installation. Since Stage 4 noise standards are not required to be met until the end of 2011, let us investigate the total costs of hush kit programs that served to meet Stage 3 guidelines and then apply the findings as best we can to the meeting of Stage 4 standards that are currently in process. There are numerous hush kit vendors, and they all sell at different prices. To simplify the upcoming calculations, I average the list prices of the 'low weight' and 'high weight' hush kits that some of the vendors provide. Here is table showing the individual prices charged by certain vendors and the total cost of hush kits by 1999 as calculated by Ariel Aviation:

Aircraft Type	Vendor	Orders	List Prices (note: totals=prices*orders)	Taxes/kit, 5%, 5yrs (disc @ 3%)	(Taxes/kit)*(#orders)
B727	FEASI	726	$2,250,000.00	$627,717.06	$455,722,585.56
	Raisbeck	107	$1,250,000.00	$348,731.70	$37,314,291.90
	Dugenair	47	$1,550,000.00	$432,427.31	$20,324,083.57
	BF Goodrich	45	$7,500,000.00	$2,092,390.20	$94,157,559.00
Total B727		880	$2,177,600,000.00		
B737	Nordam	348	$1,800,000.00	$502,173.65	$174,756,430.20
	AvAero	110	$1,200,000.00	$334,782.43	$36,826,067.30
Total B737		458	$758,400,000.00		
DC-9	ABS	500	$1,750,000.00	$488,224.38	$244,112,190.00
Total DC-9		500	875,000,000		

DC-8	Burbank	94	$3,000,000	$836,956.08	$78,673,871.52
Total DC-8		94	$282,000,000		
Total All Aircraft		1932	$4,093,000,000.00		$1,141,887,079.05

TABLE 1 (Ariel Aviation)

Thus, the average cost of one hush kit for each plane would be $4,093,000,000/1932= $2,118,530.02. However, when calculating the costs of such hush kits, it's important to note that penalties in the form of fuel taxes are levied against airlines using hush kits because the hush kits actually lead to decreased fuel efficiency. The fuel tax penalty is 5% for every year. I here assume that on average airlines install hush kits on their planes in the fifth year, 1995, the halfway point in the ten year span required for airlines to comply with regulations (the specific way the phase-out occurs is too complicated and confusing to get into here; for the sake of generalization we say that on average the planes install hush kits around 1995). Thus, the total fuel penalty is 5% a year for 5 years, discounted at a factor of 1/1.03 (this is the discount factor Ariel Aviation chose in the 1999 CAR Aircraft Value & Asset Management Conference). The calculations of the fuel penalties for each particular hush kit surveyed are as follows:

1. For example: FEASI B727 Hush Kits, 726 orders:
    a. $2,250,000*0.05 + 112,500/1.03 + 112,500/(1.03^2)+…112,500/(1.03^5) = $627, 717.06 in fuel penalties paid by the airline after installing the hush kit.
    b. Multiply $627,717.06 by 726 (the number of orders put out to FEASI) to get $455,722,584.51 in total fuel penalties paid by airlines using this particular hush kit.

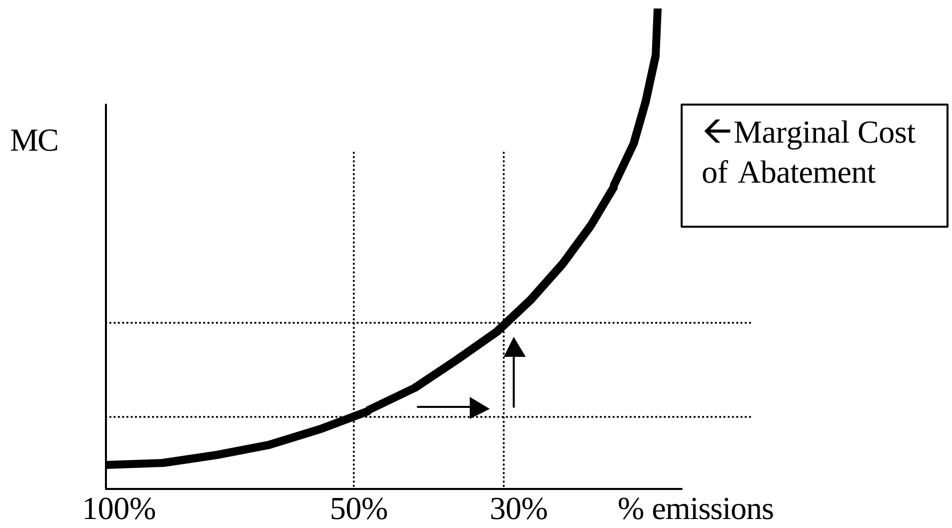
After the total fuel penalties paid by airlines using each hush kit are tallied (all of this is represented in the attached Table 1), we add them together and get the total cost incurred from the paying of fuel penalties alone by the airlines industry: $1,141,887,079.05. The 'total' is represented by the 1932 retrofitted planes surveyed by Ariel Aviation; this is of course not the total amount of planes outfitted in the entire U.S. commercial fleet, but this particular point is not as important as it firm seems. What we will be doing finding the total cost of hush kit installation including fuel taxes in the 1932 planes surveyed and dividing that number by 1932 to get the average cost of abatement per plane using hush kits.

To begin, now we must add the total discounted cost of penalties over the ten years to the total cost of the hush kits originally installed. Thus, add $1,141,887,079.05 to $4,093,000,000.00. The total cost including penalty payments turns out to be $5,234,887,079.05. Now we divide this number by the number of aircraft surveyed (1932) and get the average cost of hush kits per plane over the ten years spanning the Stage 3 compliance, which turns out to be $2,709,568.88.

We now try to figure out the increase in cost for each operation, after the hush kit installation, of the resulting 50% decrease in noise generated by the aircraft in fly-ins and fly-outs, or operations. Recall that we assumed on average airlines install hush kits five years into the ten year transition period. Each aircraft pays $2,709,568.88 for the hush kit. Dividing $2,709,568.88 by five, we find that each aircraft pays an average of $541,913.77 per year. According to Cyle Cantrell, the program director of the O'Hare Residential Sound Insulation Program, the average number of operations for each aircraft per day at O'Hare is 1/2 (that is, on average, the same aircraft flies in or out of O'Hare once every two days). Dividing $541,913.17 by (365/[1/2]) therefore gives us the cost of the hush kit per airplane operation: $742.34. Finally, we look at the annual total cost of hush kits at O'Hare that effected a 50% reduction in noise from operations. We find this by multiplying the cost of hush kit per operation by the number of operations at O'Hare in 1999, which was approximately 902,000: $742.34*902,000= **$669,590,680** (Airport Activity Statistics).

We can also find the average cost of the use of hush kits per day at O'Hare from 1995-1999. The total number of operations at O'Hare in 1999 was approximately 902,000 and has been going up, on average, five thousand operations per year. Thus, we assume that the average number of operations at O'Hare in the 1994-1999 period was 892,000 ([902,000+897,000+892,000+887,000+882,000]/5 =892,000). Dividing 892,000 by 365 gives us the amount of aircraft operating once at O'Hare airport per day: 892,000/365= 2443. Thus the average cost of the use of hush kits per day at O'Hare from 1995-1999 was (2443*1484.69)= $3,627,106.50.

Recall that the Silent Skies Act of 1999 issued a directive to the Secretary of Treasury to outline Stage 4 noise standards. These standards were defined in 2001 and aimed for another 40% decrease in aircraft noise by 2011, bringing down abatement from 50% to 30%, as explained earlier in the essay. We assume that the airlines will use upgraded hush kits to retrofit their aircraft, but there is currently no data available to illustrate the costs of such an upgrade. We assume, however, that the increase in costs associated with the further decrease of noise levels will be substantial, as noted by the increasing slope of the Marginal Cost curve we have often discussed in class shown in the following example:



As shown in the graph above, it becomes more costly to abate noise, as a result of the need for more technologically advanced sound-muffling methods, as further emission standards are set (the 50% standard stands for Stage 3 and the 30% standard stands for Stage 4).

Ground Runup Enclosures

Cyle Cantrell has also made us aware how O'Hare airport has abated aircraft noise through Ground Runup Enclosures. Before each plane's operation, it is required to go through a ground runup test where mechanics run the engine to make sure it sustains full power. This test generates a great amount of noise for a continuous period of time that can be heard by residences and schools in the surrounding areas. By 1997, O'Hare Airport had built Ground Runup Enclosures, sometimes referred to as "Hush Houses," that served to decrease the noise produced by engine test runs before aircraft operation.

The Ground Runup Enclosure (GRE) itself is a three-wall facility fifteen meters high made up of stainless steel "baffling" material that decreases engine noise by dampening it (Ground RunUp Enclosure). Furthermore, these facilities are angled toward the middle of the airport, helping to deflect the engine noise from the surrounding communities.

The cost of implementation of these facilities was $3,200,000. It would be nice to find the cost of the GRE's as divided by the number of operations per day, but since we have no idea how long these GRE's will be in service we cannot find the average fixed cost over the lifetime of such technology. However, we did find out from Cyle Cantrell that engine tests are responsible for about 10% of all aircraft noise, while the noise generated from fly-in and fly-out operations make up approximately 90% of the total. Cyle told us that in-house evidence shows that GRE's decrease aircraft ground noise 24%, a 2.4% decrease in total aircraft noise (24[0.10]%=2.4%). Since hush kits helped reduce aircraft noise 50% by 1999, and since operations represent 90% of total aircraft noise, the hush kits implemented to meet Stage 3 standards helped decrease aircraft noise by a total of 50(0.90)%, or 45%. Thus, according to our findings, by 1999 noise at O'Hare was reduced by 45%+2.4%, or 47.4%, as a result of both hush kit installations and Ground Runup Enclosures.

Ideas For Future Low-Cost Abatement Alternatives

As mentioned earlier, airplane operations at O'Hare are increasing at an average rate of 5,000 a year. This has compelled the city of Chicago to expand O'Hare airport to accommodate the growing air traffic. Such an expansion is a bane to environmentalists, as air and noise pollution from aircrafts, apart from the increased car traffic that would result from a growth in the number of flights, is certain to rise dramatically.

In our interview with Jack Saporito, director of AReCO (Alliance of Resident Concerning O'Hare), we learned of an economically feasible alternative to O'Hare expansion that would be both less costly and more environmentally friendly. The most convincing argument for an alternative option revolved around the "Wayport," a system of smaller airports lying outside O'Hare that could take on a greater capacity of flights made up of passengers using the airport as a transfer stop to their final destination (Martin). In the city of Chicago's case, DuPage and Palwaukee airports (and even Midway) could be used to make up such a Wayport system, effectively decreasing air traffic at O'Hare and consequently decreasing aircraft noise in O'Hare's surrounding neighborhoods. Thus, by more efficiently allocating transfer flights to these outlying Wayport airports, as well as directing more freight and cargo air traffic there, O'Hare noise will be decreased substantially and the huge cost of expansion, estimated to be up to $32 billion, would be forgone.

Jack also talked to us about the lower costs of a Wayport system relative to a large airport expansion for cities without any feasible outlying airports to handle the increased air traffic. Jack estimated the cost of such a Wayport system to be $5-7 billion dollars, much less than a large airport expansion. For Chicago, he said, the situation is even simpler, for we have outlying airports that could shoulder the burden of increased flights. Acting on this alternative Wayport option would thus result in lower costs and dodge the future noise increases that would be created by the increased flights into an enlarged O'Hare.

IV. Conclusion

The final step in our analysis is to compare our computed Total Costs with Total Benefits. From there we can decide whether the suggested measures are, from an economic standpoint, appropriate to implement. To do this, we determine the present values of the benefits and costs by discounting the costs and benefits for 10 years at an interest rate "r" of .03. Therefore, we chose to study the stream of costs and benefits for the next ten years. It is important to note, however, that we used 1990-99 costs of hush kits to proxy for the next ten years because that was the only data available for that technological device. The interest rate of r=.03 was chosen because data on hush kit fuel penalties used this interest rate, and so for consistency this "r" was used in all calculations. The final results are exhibited below:

TOTAL BENEFITS and TOTAL COSTS of Noise Abatement
Stream of Benefits Due to Reduced Annoyance for 10 years at r=.03: $5,310,000,000
Stream of Benefits Due to Improved Health for 10 years at r=.03: $1,152,210,324
TOTAL
BENEFITS:
Summing the two values above, we arrive at:

$6,462,210,324

Stream of Costs for Hush Kits for 10 years at r=.03: $729,703,847
Stream of Costs for Installation of Triple Pane Windows and Insulated Doors: $1,264,587,608
TOTAL COSTS:
Summing the two values above, we arrive at:

$1,994,291,455

TB>TC!

Thus, according to our results the benefits of reducing noise near O'Hare Airport far outweigh the costs of sound insulation and "hush kits." Therefore, it is our recommendation that a policy of hush kits and sound installation be implemented for the airplanes flying over the communities surrounding O'Hare Airport. However, whether such a recommendation will be heeded likely will be settled in the arena of politics, not economics.

NOTE: Many of the figures are estimations, and therefore the conclusion may be flawed.

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