Projecting the health and economic burden of aircraft noise

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Introduction

The Next Generation Air Transportation System (NextGen) is an automated flight system that has been implemented in the United States (US) airports since 2012. The new technologies of NextGen enables modernized air traffic control using Trajectory Based Operations. While NextGen has provided modern airspace management and increased operational efficiencies, there has been a growing number of noise complaints from residents of communities beneath the noise corridors of NextGen flight paths since the implantation of the system.

Similar to other types of noise such as road traffic, high levels of aircraft noise have been associated with annoyance[1], and many previous studies have pointed to biological pathways and the effects of aircraft noise on cardiovascular diseases,[2–7] anxiety and mental illness through noise annoyance and sensitivity,[8–10] and low birth weight.[11]

While NextGen improves operational efficiencies, public health investigations of increased levels of noise associated with NextGen can provide a broader view of societal effects of NextGen and help with shaping policies around noise mitigation. In this study, we aim to project the long-term health and economic burden of aircraft noise associated with the use of NextGen at the Baltimore Washington International (BWI) Thurgood Marshall Airport.

Methods

We developed a probabilistic Markov model using a Monte Carlo simulation to project the incremental health and economic burden of aircraft noise around the BWI Marshal Airport in Maryland since the implementation of the NextGen automated flight system (i.e., '*status quo*' arm) versus (vs.) pre-NextGen era (i.e., 'counterfactual' arm). We modeled impacts of aircraft noise on four health end points of annoyance, cardiovascular diseases (CVD), anxiety, and low birth weight (LBW). The time horizon of our model in the base case analysis was 30 years. We also projected the burden of aircraft noise over shorter time horizons of 10 years and 20 years.

Mathematical model: The Markov model allowed transitions of patients between three mutually exclusive health states, including “no CVD”, “CVD”, and “death”. The cycle length of the Markov model was one year. In each year, individuals in the model had a chance to transition from the “no CVD” state to either the “CVD” or “death” states. For prevalent and incident cases of CVD, we modeled the background rates of CVD hospitalizations and CVD-cause and all-cause mortality. Our model was stratified by age, levels of noise exposure, defined as <55 dB DNL, 55-60 dB DNL, 60-65 dB DNL, and >65 dB DNL, and levels of annoyance of residents, defined as highly annoyed ad not highly annoyed. The probability of high annoyance was defined based on the level of noise exposure. We modeled prevalence of anxiety as a function of the level of annoyance. Finally, we modeled the probability of birth with LBW annually over the time horizon of our study.

We modeled impacts of aircraft noise on risk of CVD hospitalizations, CVD mortality, development of high levels of annoyance, anxiety, and LBW. All the model parameters were informed from published studies in the literature (see **Table 1**). For the impacts of exposure to different aircraft noise levels on risk of CVD hospitalizations, we pooled data from two ecologic cohort studies.[2,3]

For the effect of aircraft noise on likelihood of high annoyance, we used data from a systematic review conducted by the World Health Organization (WHO) to get the likelihood of high annoyance as a function of aircraft noise exposure levels.[1] For the highly annoyed population exposed to aircraft noise, we then assumed a relative risk of anxiety compared with the general population using data from a Gutenberg Health Study (GHS), a population-based, prospective study in Germany.[8] Additionally, we used data from a rigorous moderated medication analysis that used structural equation modeling to inform the effect of aircraft noise-caused annoyance on health-related quality of life using longitudinal data from the NORAH Study—Noise-related Annoyance, Cognition, and Health Study.[12]

For the fetal health effect of aircraft noise, we used data from a US study that performed difference-in-difference analysis using all birth records in New Jersey between 2004 and 2016 to quantify the impact of NextGen noise levels above 55 dB DNL on the probability of LBW.[11]

To calculate the noise contours and exposure, we used data from an analysis conducted by the Harris Miller Miller & Hanson Inc. (HMMH) using data from before the Covid-19 pandemic,[13] since the number of departures and arrivals have been substantially impacted by the pandemic. For the status quo, the HMMH calculated the number of exposed individuals to different noise contours, i.e., 55-60 dB DNL, 60-65 dB DNL, 65-70 dB DNL, 70-75 dB DNL, and 75+ dB DNL, from operations data collected between February 2 and April 26, 2017, based on demographic data from 2010 US Census and 2016 American Community Survey (ACS)'s 5-year estimates.[13] For the pre-NextGen era, the HMMH used operations data collected between February 9 and May 2, 2012, adjusted for demographics.[13]

Model outcomes: We modeled health burden in terms of quality adjusted life years (QALYs), which captures both the longevity and health-related quality of life during years of life.

For economic burden, we modeled both direct medical and indirect costs of morbidity associated with CVD hospitalizations, history of CVD events, anxiety disorder, and LBW, as well as costs of mortality associated with CVD and LBW based on value of a statistical life in concordance with the published literature.[14–16] The direct medical costs for CVD and anxiety disorder included costs of medical care (inpatient visits, emergency room visits, outpatient visits, etc.) and prescription medications patients received that are attributable to the condition.[17,18] The direct medical costs of LBW included costs of delivery and hospitalizations associated with delivery, and follow-up outpatient visits that are attributable to LBW.[19] The indirect costs for CVD hospitalization and anxiety disorder included productivity loss attributable to the condition.[16,20] All cost estimates were adjusted to 2022 US dollars using the healthcare component of the Personal Consumption Expenditures price index.[21,22] Annual discount rate of 3% was applied to discounted outcomes.[23]

Simulation: We built a probabilistic model in a Monte Carlo simulation with 1,000 random iterations. In each iteration, a random set of values were drawn from the probability distributions of the model input parameters (see **Table 1** for probability distributions). We reported the mean and 95% credible interval [CrI] associated with the model outcomes of projected costs and losses of QALYs.

We also performed one-way sensitivity analyses, in which we changed the core input parameters of the model, including the health impacts of aircraft noise on risks of CVD hospitalizations, CVD-cause mortality, developing anxiety, and LBW condition, value of statistical life associated with CVD- and LBW-cause mortality, disutility values of CVD hospitalizations and anxiety, and all the direct and indirect medical costs within a plausible range informed from the published literature. The results of the one-way sensitivity analyses explore the projected health and economic burden of noise for a plausible range of the model input parameters.

The simulation model development and all the analyses were performed using the statistical programming platform R (ver. 3.6.3).[24]

Results

Projected economic burden at the individual-level: Our model enables lifetime projections of costs for an average person based on their starting age and the level of noise they are exposed to. For example, for a 40-year-old individual exposed to noise levels above 65dB DNL, the lifetime discounted costs would be $113,591; out of which $9,840 would be due to morbidity costs of CVD and anxiety, and $103,751 would be due to incremental mortality costs of CVD (**Table 2**). For the same individual, the lifetime undiscounted costs would be $292,553, with $19,373 for morbidity costs and $273,180 for mortality costs (**Table 3**). Similarly, for an average baby born whose parental exposure was above 55dB DNL, the incremental lifetime discounted and undiscounted costs due to morbidity and mortality of LBW were respectively projected as $22,813 and $166,995. The discounted results for other age groups are presented in **Table 2** and the undiscounted results are presented in **Table 3**.

Projected economic burden at the population-level: The projected number of exposed people to noise levels above 55 dB DNL after the implementation of NextGen provided to us by an analysis by HMMH is presented in **Table 1**.

Compared with the counterfactual arm (noise levels in 2012 pre-NextGen era), the discounted incremental 30-year costs associated with *status quo* (NextGen noise levels) were projected as $800,170,441, out of which $211,305,349 was for direct and indirect costs of morbidity, and $588,865,092 was for incremental mortality costs of CVD and LBW (**Table 4**). Out of the morbidity costs, $108,565,454 was due to CVD, $84,472,739 was due to anxiety, and $18,267,157 was due to LBW. Out of the mortality costs, $520,393,267 was due to CVD mortality, and $68,471,825 was due to LBW mortality costs. Similarly, the undiscounted incremental costs of *status quo* over 30 years were $1,227,303,196, out of which $325,094,401 was due to morbidity costs of CVD, anxiety, and LBW, and $902,208,795 was due to mortality costs of CVD and LBW. The incremental economic burden of *status quo* for other time horizons of 10 years and 20 years for both the discounted and undiscounted values are presented in **Table 4**.

Projected health burden at the individual-level: The discounted and undiscounted projected lifetime losses of QALYs based on starting age of the exposed individual and the levels of noise exposure are respectively presented in **Tables 2** and **3**. For instance, for an average individual with 40 years old exposed to 65+ dB DNL, the discounted lifetime losses of QALYs were projected as 0.62 (**Table 2**). For the same individual, the undiscounted lifetime losses of QALYs were 1.12 (**Table 3**). For a newborn baby whose parents were exposed to 65+ dB DNL, the discounted and undiscounted lifetime losses of QALYs were respectively projected as 0.05 and 0.19 due to increased probability of LBW. The results of losses of QALYs for other age groups are presented in **Table 2** (discounted) and **Table 3** (undiscounted).

Projected health burden at the population-level: The population-level impacts of noise on losses of QALYs are presented in **Table 4**. The discounted and undiscounted incremental losses of QALYs associated with *status quo*, relative to the counterfactual arm, over 30 years were respectively calculated as 13,915 and 20,749. The discounted and undiscounted incremental losses of QALYs associated with *status quo* for other time horizons of 10 years and 20 years are also presented in **Table 4**.

One-way sensitivity analysis: **Table 5** outlines the results of the one-way sensitivity analysis for the incremental health and economic burden of the current levels of noise in *status quo,* relative to the counterfactual arm, over 30 years. When the relative risk of CVD hospitalizations and mortality due to noise was changed from their lower to higher values (see **Table 1** for the low and high bounds), the discounted 30-year incremental costs and losses of QALYs associated with *status quo* changed from $231,252,130 to $1,372,083,107, and from 13,052 to 14,792, respectively.

When the relative risk of anxiety associated with high annoyance caused by aircraft noise was changed from 1.41 to 2.17, the discounted 30-year incremental costs and losses of QALYs associated with *status quo* changed from $762,105,082 to $847,192,356, and from 11,377 to 17,051, respectively.

When the incremental risk of LBW associated with aircraft noise was changed from 0.006 to 0.026, the discounted 30-year incremental costs and losses of QALYs associated with *status quo* changed from $748,941,429 to $851,269,860, and from 13,665 to 14,165, respectively.

When the value of statistical life associated with mortality of CVD and LBW changed from its base case value by 40%, the discounted 30-year incremental costs associated with *status quo* changed from $589,200,198 to $1,011,140,685. The details of the impacts of other input parameters on incremental health and economic burden of noise levels of *status quo* are presented in **Table 5**.

Discussion

In this project, we developed a mathematical model that enables projections of health and economic burden of aircraft noise at the individual-level. Our model quantifies losses of QALYs, direct and indirect morbidity costs, and mortality costs of CVD, anxiety, and LBW. For population-level impacts, we used exposure data from an analysis by HMMH that provided incremental exposure to different noise contours after the NextGen implementation around the BWI Airport. Using HMMH exposure data, we projected the population-level health and economic burden of aircraft noise over 30 years. Our model projected the discounted costs of noise associated with *status quo* as $800,170,441 over 30 years, out of which $211,305,349 was due to direct and indirect morbidity costs of CVD, anxiety, and LBW, and $588,865,092 was due to mortality costs of CVD and LBW. The discounted losses of QALYs associated with *status quo* over 30 years were estimated as 13,915.

Our model builds on a previous model that provided the economic burden of aircraft noise associated with 5 dB DNL reduction in the US.[25] The previous model showed a scenario in which a 5 dB DNL reduction in aircraft noise was associated with $3.9 billion annual economic savings due to reduced prevalence of coronary heart disease and hypertension for the whole

US population.[25] When we compare the previous model's per-person-exposed cost estimates against our per-person-exposed annual estimates for the morbidity costs of CVD, our estimates align with each other. However, compared with the previous model, our model carries additional features, such as modeling dynamic, longitudinal costs projections, modeling losses of QALYs, and adding other health end points.

Our model has some strengths. To our knowledge, it is the first open-cohort, public health model that quantifies both the health and economic burden of aircraft noise. This means unlike closed cohort models that only quantify outcomes for a pre-determined population, our model is able to incorporate the impact of changes in the population over time, such as population growth by modeling births and changes of the age composition of the population. The other feature of our model is its capability to model losses of QALYs and quantify the impacts of noise on multiple health end points, such as annoyance, CVD, anxiety, and LBW. Finally, given our model makes projections of noise impacts at the individual-level, its applicability is not limited to a specific airport or a particular setting; that is, if the number of people exposed to different categories of aircraft noise of our model are provided for a different scenario, our model can make projections of health and economic burden for such scenario.

Our model is also limited to some factors. First, the input parameters of our model are limited to the prior published studies. Therefore, our projections rely on accuracy of the health impacts quantified by the published literature. While we did our best to use the best available evidence, use data from cohort studies rather than cross-sectional studies, and be conservative in estimating treatment effects by pooling data from more than one resource of evidence once available, the health effects of noise are inevitably confined to observational studies. Observation studies are prone to confounding bias. But given it is unethical to randomize people to noise, in the absence of randomized control trials as the 'gold standard' of treatment effects, observational studies will remain the only source of evidence for effects of noise.

Our simulation model based on input data informed from prior published studies and an analysis by HMMH providing incremental exposure data to different noise levels after the NextGen implementation around the BWI Airport suggests a significant health and economic societal burden associated with aircraft noise at the population-level. Therefore, public health measures to mitigate noise are warranted.

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Table 1. Model input parameters for projecting the health and economic burden of aircraft noise

Model parameters	Input (SE or 95% CI)	One-way SA range	PSA distribution	Note
Population characteristics				
Maryland population[26]	Population by single year of age			2021 population from US Census Bureau
Annual number of live births in Maryland	70,000	-	-	Author assumption based on population data[27]
Prevalence of CVD (by age)[28]				Author estimation from the data
20-39	0.0125	-	-	
40-59	0.0791	-	-	
60-79	0.2113	-	-	
80+	0.3812	-	-	
Rate of CVD hospitalization in population[29]				Data from 2014 were retrieved
20-44	0.0014	-	-	
45-64	0.0110	-	-	
65-84	0.0333	-	-	
85+	0.0884	-	-	
Relative risk of CVD hospitalizations among individuals with prior history of CVD hospitalizations[17]	1.96 (1.67–2.30)	1.96 (1.67–2.30)		Author estimation from the data
Prevalence of anxiety disorder[30]				
20-29	0.223	-	-	
30-44	0.227	-	-	
45-59	0.206	-	-	
60+	0.090	-	-	
Relative risk of anxiety disorder among CVD patients[31]	1.66 (1.49–1.82)	1.66 (1.49–1.82)	-	
Prevalence of low birth weight among new born babies[27]	0.083	-	-	
Background mortality[32]	U.S. Life Tables	-		
CVD mortality[33]	Mortality due to major cardiovascular diseases from CDC wonder	-	-	
Relative risk of mortality for LBW for age 1-18 years old (by age)[34,35]				
<1	18.91	-		Author estimation from the data
1-18	2.71	-		Author estimation from the data
19+	1.11	-		

Model parameters	Input (SE or 95% CI)	One-way SA range	PSA distribution	Note
Noise exposure distribution				
Noise exposure distribution for Maryland population at the current exposure levels[13] (n)				
55-60 dB	111,668	-	-	
60-65 dB	16,531	-	-	
65+ dB	4,120	-	-	
Noise exposure distribution for Maryland population at exposure levels in 2012 pre-NextGen[13] (n)				
55-60 dB	52,204	-	-	
60-65 dB	10,054	-	-	
65+ dB	2,360	-	-	
Health effects of noise exposure				
Relative risk of CVD hospitalizations associated with aircraft noise exposure[2,3]				
55 < dB	1 (reference)	1 (reference)	-	
55-60 dB	1.03 (1.01-1.05)	1.03 (1.01-1.05)	Log-normal	
60-65 dB	1.07 (1.02-1.12)	1.07 (1.02-1.12)	Log-normal	
65+ dB	1.11 (1.03-1.20)	1.11 (1.03-1.20)	Log-normal	
Relative risk of CVD mortality associated with aircraft noise exposure[3]				
55 < dB	1 (Reference)	1 (Reference)	-	
55-60 dB	No effect	-	-	
60-65 dB	1.14 (1.01-1.29)	1.14 (1.01-1.29)	Log-normal	
65+ dB	1.16 (1.04-1.29)	1.16 (1.04-1.29)	Log-normal	
Proportion of highly annoyed individuals among those exposed to aircraft noise[1]				
55 < dB	0.094	-		
55-60 dB	0.313	-		
60-65 dB	0.407	-		
65+ dB	0.505	-		
Prevalence ratio of anxiety among highly annoyed individuals as a result of aircraft noise exposure[8]	1.75 (1.41-2.17)	1.75 (1.41-2.17)	Log-normal	
Risk difference of LBW associated with aircraft noise exposure[11]	0.016 (0.005)	0.016 (0.005)	Normal	
Costs				
Annual direct medical costs for patients with CVD				
Occurrence of CVD hospitalization during the year (incident or recurrent)[17]	$85,345 ($21,336*)	$85,345 ($21,336*)	-	

Model parameters	Input (SE or 95% CI)	One-way SA range	PSA distribution	Note
Annual costs for patients with a prior history of CVD hospitalizations[17]	$18,372 ($4,593*)	$18,372 ($4,593*)	-	
Annual direct medical costs for anxiety disorder[18]	$2,023 ($507*)	$2,023 ($507*)	-	
Annual indirect costs for patients with CVD hospitalizations[16]	$10,120 ($2,550*)	$10,120 ($2,550*)		
Annual indirect costs for anxiety disorder[20]	$369 ($92*)	$369 ($92*)		
Birth-related medical costs associated with LBW[19]	$69,897 (17,474*)	$69,897 (17,474*)		
Value of statistical life[14,15]	$10,174,225	$10,174,225 ($6,049,539 – $14,298,910)		
Price index for inflation[21]	PCE Price Index	-	-	
Utilities				
Average health state utility value associated with no health conditions[36]	0.851	-	-	
Disutility value associated with a CVD event[37,38]	0.283 (0.258-0.308)	0.283 (0.258-0.308)		
Annual disutility value associated with patients with a prior history of CVD events[37,38]	0.156 (0.137-0.175)	0.156 (0.137-0.175)		
Disutility value associated with anxiety disorder[39]	0.160 (0.040*)	0.160 (0.082-0.238)		
Disutility value associated with annoyance[12]	0.027	-		Author estimation based on data

All cost estimates are adjusted to 2022 US dollars. SA indicates sensitivity analysis; PSA, probabilistic sensitivity analysis; SE, standard error; CVD, cardiovascular disease; CDC, Centers of Disease Control and Prevention; LBW, low birth weight; PCE, Personal Consumption Expenditures.
*For the standard error we assumed a 25% coefficient of variation.

Table 2. Discounted incremental lifetime costs per person exposed to aircraft noise compared with an unexposed individual (exposed to < 55 dB DNL)

Exposure level	**55-60 dB**	**60-65 dB**	**65+ dB**
Incremental lifetime costs and losses of QALYs over lifetime for a 20-year-old person exposed			
Total incremental costs	**$3,972**	**$56,711**	**$69,017**
Incremental morbidity costs	$3,972	$5,654	$8,694
Incremental mortality costs	-	$51,058	$60,323
Total incremental losses of QALYs	**0.32**	**0.53**	**0.69**
Incremental lifetime costs and losses of QALYs over lifetime for a 40-year-old person exposed			
Total incremental costs	**$4,448.79**	**$95,769**	**$113,591**
Incremental morbidity costs	$4,448.79	$5,874	$9,840
Incremental mortality costs	-	$89,895	$103,751
Total incremental losses of QALYs	**0.26**	**0.48**	**0.62**
Incremental lifetime costs and losses of QALYs over lifetime for a 60-year-old person exposed			
Total incremental costs	**$3,959.78**	**137,809**	**$157,679**
Incremental morbidity costs	$3,959.78	4,298	$8,287
Incremental mortality costs	-	133,511	$149,392
Total incremental losses of QALYs	**0.16**	**0.34**	**0.42**
Incremental lifetime costs and losses of QALYs over lifetime for a baby born with prenatal exposure			
Incremental costs due to LBW			**$22,813**
Incremental losses of QALYs due to LBW			**0.05**

Annual discount rate of 3% was applied to all cost and QALY outcomes. All costs are expressed in 2022 US dollars.
QALY indicates quality-adjusted life year; LBW, low birth weight.

Table 3. Undiscounted incremental lifetime costs per person exposed to aircraft noise compared with an unexposed individual (exposed to < 55 dB DNL)

Exposure level	**55-60 dB**	**60-65 dB**	**65+ dB**
Incremental lifetime costs and losses of QALYs over lifetime for a 20-year-old person exposed			
Total incremental costs	**$11,538**	**$244,018**	**$302,727**
Incremental morbidity costs	$11,538	$14,020	$24,076
Incremental mortality costs	-	$229,998	$278,651
Total incremental losses of QALYs	**0.67**	**1.20**	**1.57**
Incremental lifetime costs and losses of QALYs over lifetime for a 40-year-old person exposed			
Total incremental costs	**$9,574**	**$238,806**	**$292,553**
Incremental morbidity costs	$9,574	$10,493	$19,373
Incremental mortality costs	-	$228,313	$273,180
Total incremental losses of QALYs	0.45	0.86	1.12
Incremental lifetime costs and losses of QALYs over lifetime for a 60-year-old person exposed			
Total incremental costs	**$6,488**	**$220,264**	**$262,322**
Incremental morbidity costs	$6,488	$5,795	$12,211
Incremental mortality costs	-	$214,469	250,111
Total incremental losses of QALYs	**0.23**	**0.48**	**0.61**
Incremental lifetime costs and losses of QALYs over lifetime for a baby born with prenatal exposure			
Incremental costs due to LBW			**$166,995**
Incremental losses of QALYs due to LBW			**0.19**

Annual discount rate of 0% was applied to all cost and QALY outcomes. All costs are expressed in 2022 US dollars.
QALY indicates quality-adjusted life year; LBW, low birth weight.

Table 4. Total incremental costs and losses of QALYs for Maryland population at the current exposure level (Nextgen) compared to the exposure level in 2012

	Mean (95% CrI)		
Time horizon	**30 years**	**20 years**	**10 years**
Discounted			
Total incremental costs	**$ 800,170,441 ($434,371,996 – $1,192,600,675)**	**$566,662,142 ($288,269,828 – $854,437,767)**	**$281,888,880 ($141,374,110 - $440,647,383)**
Total incremental morbidity costs	$ 211,305,349 ($166,797,950 - $262,788,785)	$152,186,904 ($120,024,553 - $191,155,531)	$77,833,087 ($57,563,502 - $99,763,343)
CVD	$ 108,565,454 ($94,958,747 – $121,929,722)	$74,029,148 ($59,966,316 - $86,527,368)	$33,113,769 ($24,428,492 - $41,489,953)
Anxiety	$ 84,472,739 ($46,181,924 – $135,301,148)	$64,292,295 ($35,310,136 - $101,934,160)	$36,769,367 ($20,391,522 - $57,544,025)
LBW	$ 18,267,157 ($7,680,413 – $28,510,059)	$13,865,461 ($5,363,735 - $22,273,735)	$7,949,951 ($3,482,039 - $12,690,105)
Total incremental mortality costs	$ 588,865,092 ($221,988,070 - $966,362,192)	$414,475,238 ($142,531,374 - $692,566,818)	$204,055,793 ($66,354,500 - $355,669,125)
CVD	$ 520,393,267 ($146,983,874 – $892,644,853)	$371,884,932 ($100,276,184 - $652,289,414)	$182,110,573 ($47,614,882 - $332,480,039)
LBW	$ 68,471,825 ($28,834,319 – $106,703,395)	$42,590,306 ($16,508,611 - $68,283,145)	$21,945,219 ($9,631,048 - $34,956,256)
Total losses of QALYs	**13,915 (11,348 – 17,285)**	**10,444 (8,485 – 12,938)**	**5,848 (4,725 – 7,286)**
Undiscounted			
Total incremental costs	**$ 1,227,303,196 ($671,945,070 – $1,817,490,757)**	**$759,378,856 ($390,127,738 - $1,141,292,369)**	**$324,116,542 ($163,442,229 - $505,697,058)**
Total incremental morbidity costs	$ 325,094,401 ($260,611,881 - $401,354,485)	$18,096,637 ($7,000,528 - $29,070,774)	$89,440,053 ($66,390,278 - $114,454,892)
CVD	$ 172,531,252 ($154,460,693 – $190,029,491)	$101,485,286 ($84,023,021 - $117,282,752)	$38,529,814 ($28,682,802 - $48,035,122)
Anxiety	$ 125,418,193 ($68,584,537 - $200,851,730)	$83,960,683 ($46,151,626 - $133,086,189)	$41,861,921 ($23,218,742 - $65,516,642)
LBW	$ 27,144,955 ($11,413,078 – $42,365,886)	$18,096,637 ($7,000,528 - $29,070,774)	$9,048,318 ($3,963,119 - $14,443,373)
Total incremental mortality costs	$ 902,208,795 ($345,754,978 – $1,470,234,771)	$555,836,250 ($195,155,389 - $922787375)	$234,676,489 ($77,199,240 - $408,391,286)
CVD	$ 806,153,220	$501,284,507	$209,801,626

	($240,536,897 - $1,367,787,904)	($140,171,425 - $871965791)	($56,005,258 - $381,815,635)
LBW	$ 96,055,575 ($40,453,477 - $149,676,840)	$54,551,744 ($21,145,662 - $87,457,827)	$24,874,862 ($10,916,844 - $39,622,573)
Total losses of QALYs	**20,749 (16,967 – 25,770)**	**13,684 (11,123 – 16,940)**	**6,668 (5,389 – 8,306)**

Annual discount rate of 3% was applied to the discounted outcomes, and 0% was applied to the undiscounted outcomes. All costs are expressed in 2022 US dollars. 95% CrI indicates 95% credible interval; CVD, cardiovascular disease; LBW, low birth weight; QALY, quality-adjusted life year.

Table 5. One-way sensitivity analysis for the discounted incremental costs and losses of QALYs over 30 years for Maryland population at the current exposure level ('*status quo*') compared with the counterfactual arm (exposure levels in 2012 pre-NextGen). Note both morbidity and mortality costs are included in the estimates.

	Base case	**Lower bound**		**Upper bound**	
Outcome	**Estimate**	**Estimate**	**% change**	**Estimate**	**% change**
Relative risk of CVD hospitalization and CVD mortality associated with aircraft noise exposure					
Total incremental costs	$800,170,441	$231,252,130	-71%	1,372,083,107	+71%
Incremental morbidity costs	$211,305,349	$140,248,488	-34%	282,513,203	+34%
Incremental mortality costs	$588,865,092	$91,003,642	-85%	1,089,569,903	+85%
Total incremental losses of QALYs	13,915	13,052	-6%	14,792	+6%
Relative risk of anxiety associated with aircraft noise exposure					
Total incremental costs	$800,170,441	$762,105,082	-5%	$847,192,356	+6%
Incremental morbidity costs	$211,305,349	$173,239,990	-18%	$258,327,264	+22%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	11,377	-18%	17,051	+23%
Incremental risk of LBW birth associated with aircraft noise exposure					
Total incremental costs	$800,170,441	$748,941,429	-6%	$851,269,860	+6%
Incremental morbidity costs	$211,305,349	$200,507,081	-5%	$222,103,618	+5%
Incremental mortality costs	$588,865,092	$548,434,348	-7%	$629,166,242	+7%
Total incremental losses of QALYs	13,915	13,665	-2%	14,165	+2%
VSL					
Total incremental costs	$800,170,441	$ 561,441,350	-30%	$1,038,899,533	+30%
Incremental morbidity costs	$211,305,349	$ 211,305,350	0%	$211,305,349	0%
Incremental mortality costs	$588,865,092	$ 350,136,001	-41%	$827,594,183	+41%
Total incremental losses of QALYs	13,915	13,915	0%	13,915	0%
Direct costs					
Total incremental costs	$800,170,441	$699,098,252	-13%	$894,028,948	+12%
Incremental morbidity costs	$211,305,349	$110,233,160	-48%	$305,163,856	+44%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	13,915	0%	13,915	0%
Indirect costs					
Total incremental costs	$800,170,441	$790,489,327	-1%	$809,851,556	+1%

Outcome	Base case	Lower bound		Upper bound	
	Estimate	Estimate	% change	Estimate	% change
Incremental morbidity costs	$211,305,349	$201,624,235	-5%	$220,986,464	+5%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	13,915	0%	13,915	0%
Disutility of CVD event and history of CVD event					
Total incremental costs	$800,170,441	$800,170,441	0%	$800,170,441	0%
Incremental morbidity costs	$211,305,349	$211,305,349	0%	$211,305,349	0%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	13,862	-0.4%	13,970	+0.4%
Disutility of anxiety disorder					
Total incremental costs	$800,170,441	$800,170,441	0%	$800,170,441	0%
Incremental morbidity costs	$211,305,349	$211,305,349	0%	$211,305,349	0%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	11,155	-20%	16,676	+20%
Relative risk of anxiety disorder among CVD patients					
Total incremental costs	$800,170,441	$798,869,223	0%	$801,395,117	0%
Incremental morbidity costs	$211,305,349	$210,004,131	-1%	$212,530,025	+1%
Incremental mortality costs	$588,865,092	$588,865,092	0%	$588,865,092	0%
Total incremental losses of QALYs	13,915	13,829	-1%	13,997	+1%

Annual discount rate of 3% was applied to all cost and QALY outcomes. All costs are expressed in 2022 US dollars.
CVD indicates cardiovascular disease; QALY, quality adjusted life year; LBW, low birth weight; VSL, value of a statistical life.