Impacts of Airports on the Quality of Life of Surrounding Communities

by

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B.S. Aerospace Engineering, Georgia Institute of Technology (2018)

Submitted to the Institute for Data, Systems, and Society
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Abstract

London Heathrow Airport has both beneficial and detrimental impacts on surrounding communities such as, for example, job creation and noise. The population living in the airport's proximity notices, cares about, and perceives its impacts which have often been studied only partially in literature. This thesis used the concept of Quality of Life to look at impacts multi-dimensionally. A framework was developed and used to systematically analyze Quality of Life impacts of Heathrow Airport using both spatial and regression analysis methods at different spatial resolutions with data collected from statistical authorities and social media. Low spatial resolution analysis found a beneficial impact of proximity to Heathrow Airport for economic conditions, accessibility & connectivity, health, and well-being metrics. Opportunities to verify this analysis with higher-resolution data were sought, but limited data was available. Housing transaction data was available at both low and middle spatial resolutions, and a beneficial impact of proximity to Heathrow Airport was observed at both levels. Counterfactual analysis found that the Heathrow Region performed better than many other regions for housing values and health metrics, and worse for certain well-being/happiness metrics. Additionally, high spatial resolution social media data was collected to analyze perceptions, sentiments, and opinions posted in proximity to Heathrow Airport. This analysis found that aviation and aviation-noise tweets skew negatively as compared to all tweets and that sentiment closer to the airport skews more positively than in the Greater London Region.

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Chapter 1

Introduction

Airports have both beneficial and detrimental impacts on the Quality of Life of surrounding communities. Quality of Life is influenced by different factors such as economic (e.g. employment), health (e.g. through noise), and social (e.g. through connectivity). Impacts of airports include that the air transport industry is estimated to support over 2 trillion USD in economic activity globally (3.6% of global economic activity), as well as over 65 million jobs (International Air Transport Association 2018). Some people are potentially adversely impacted by noise with 2.5 million people living under the L_{den}[1] 55dB noise contours for 47 major airports in Europe (European Union Aviation Safety Agency 2018).

One airport that has been the subject of public debate surrounding the impacts of both its operations and expansion plans is London Heathrow Airport. Impacts of London Heathrow include that it employs 76,000 people (Heathrow 2020), and that an estimated 440,000 people are exposed to noise levels over 55dB L_{den} (European Environmental Agency 2001).

The goal of this thesis was to define a framework which captures the Quality of Life impacts of airports on surrounding communities. This framework was applied to the case of London Heathrow Airport to understand its impact on surrounding communities from a more holistic perspective. Quality of Life, a concept which has

[1]Day-evening-night level: Noise metric with a penalty of 10 dB for night-time noise and an additional penalty of 5 dB for evening noise

been used in literature to measure individual well-being, was used to study the multi-dimensional impacts of airports on surrounding communities.

The thesis proceeds as follows. The second chapter describes existing work that has been done related to the community impacts of airports. The third chapter looks at Quality of Life as a concept, and then develops an airport-specific framework for analyzing the Quality of Life of surrounding communities. The fourth chapter evaluates available statistical data using the framework developed in Chapter 3 to quantify impacts of London Heathrow Airport on communities within 60 kilometers of the airport. The fifth chapter uses counterfactual analysis of several metrics within the framework developed in Chapter 3 to gain additional insights into the community impact of London Heathrow and to compare communities surrounding the airport with other communities in the Greater London Area. The sixth chapter evaluates social media sentiment data using the framework developed in Chapter 3 to measure perceptions, sentiments, and opinions about London Heathrow Airport. The seventh chapter outlines a scorecard which offers insights into all dimensions of airport Quality of Life impacts, and follows the Quality of Life structure developed in the previous chapter. The final chapter concludes.

Chapter 2

Community Impacts of Airports

This chapter looks at existing studies on the community impacts of airports on surrounding communities.

2.1 Partial Analysis

Most existing analyses of the community impacts of airports analyze partial impacts of airports. These analyses often focus on the economic impacts (e.g. job creation) which are beneficial for communities surrounding airports (Brueckner 2003; Campante and Yanagizawa-Drott 2017), environmental impacts (e.g. climate and air quality), or noise impacts which are detrimental for communities surrounding airports (Basner, Babisch, et al. 2014; Goines and Hagler 2007).

2.1.1 Economic Impacts

Most economic studies have focused on opportunities created by airports and the associated business growth and ease of transport within catchment areas, and have found a beneficial economic impact of airports on surrounding communities. InterVISTAS (2015) have identified four types of economic impacts: Direct, Indirect, Induced, and Catalytic. Direct, Indirect, and Induced impacts can be categorized under demand-side economics impacts as they capture airports' impacts on macro-

economic demand. Direct impacts of airports relate to the economic activities at and near the airport. Indirect impacts are linked to the economic activities related to the airport supply chain. Induced impacts include economic impacts due to the spending of money earned by employees who work either directly at the airport or indirectly in a business which relies on the presence of the airport. Catalytic impacts are enabling impacts which capture how airports act as inputs to economic systems (Allroggen and Malina 2014) including that large hub airports attract headquarters of large corporations and other high-growth, high-value services sectors (Stilwell 2013).

The beneficial economic impacts of airports have been analyzed in various empirical studies. Brueckner (2003) studied the link between aviation traffic and employment and concluded that the level of airline service is linked to employment. He found that for service-related industries, an increase in enplanements is linked to an increase in employment. No employment impact was found in other sectors such as manufacturing. Campante and Yanagizawa-Drott (2016) analyzed the impact of long-distance flights and total economic activity, which they measure through night lights. They found that air links generate business links and economic activity, but also create local, and potentially global, spatial inequality. Additionally, air links promote business links and the movement of people, which stimulate the movement of capital. Allroggen and Malina (2014) studied the impact of air transport on economic development. They found that the impact differs amongst airports in Germany and that this is driven by "opportunity costs of airport capital and by positive output effects from air transport connectivity" which may be linked to differing traffic characteristics such as served destination or frequencies at airports.

2.1.2 Environmental Impacts

Air Quality and Climate Impacts

Combustion emissions at airports have been shown to reduce air quality around airports (Yim et al. 2015; Wolfe et al. 2014). Yim et al. (2015) concluded that each year, approximately 5,000 people residing near airports (i.e. within 20 kilometers) die due

to aviation-attributable $PM_{2.5}$[1], with about 1,900 people in Europe alone. Wolfe et al. (2014) found that at distances greater than 6 kilometers from airports, air quality impacts are dominant over noise impacts. They also concluded that aviation- induced climate change has a higher cost than the cost of both noise and air quality impacts.

Grobler et al. (2019) estimated that the total Climate and Air Quality Social Cost (CAQSC), i.e. climate and air quality costs, in 2015 USD per tonne of fuel burn for landing and take-off, which directly impacts surrounding communities, is 730$. Yu et al. (2004) found that sulfur dioxide is an appropriate tracker for emissions at Los Angeles International Airport as well as at Hong Kong International Airport. Carslaw et al. (2006) built upon the techniques developed by Yu and examined the nitrogen dioxide and nitrogen oxide emissions at London Heathrow Airport. They found that the dominant impact of emissions from nitrogen oxides near the airport is linked to road traffic, but that aircraft impacts can be detected up to at least 2.6 kilometers. Most of the literature has concluded that these are adverse impacts.

Noise Impacts

Noise impacts of airports come from a variety of sources including aircraft and road traffic and have a broad range of impacts. Aircraft noise influences communities underneath flight tracks, with over 2.5 million people living under L_{DEN}[2] 55dB noise contours for 47 major airports in Europe (European Union Aviation Safety Agency 2018). The 55dB noise level is considered to be the threshold at which health problems emerge (Hansell et al. 2013; Lawton and Fujiwara 2016; Lefèvre et al. 2017).

Wolfe et al. (2014) found that noise damages are higher than air quality and climate impacts within 6 kilometers of an airport with fewer than 1.25 million operations per year with average damages estimated to be 41$ per year per person (Wolfe et al. 2014).

There are a plethora of studies on the health impacts of noise. Basner et al. (2017) concluded that there are negative impacts of aviation noise on the cognitive skills of

[1] Atmospheric Particulate Matter with a diameter of less than 2.5 micrometers

[2] Day-evening-night level: Noise metric with a penalty of 10 dB for night-time noise and an additional penalty of 5 dB for evening noise

children as well as on sleep. Additionally, there are contrasting studies on the impacts on well-being with some having found a link between reported annoyance and well-being but no link to actual noise level (Praag and Baarsma 2005; Dolan, Peasgood, and White 2008; Basner, Clark, et al. 2017), and others having found a link to actual noise level (Kroesen et al. 2010). There is also mixed evidence on the impacts of noise on psychological health (Hardoy et al. 2005; Morrell, Taylor, and Lyle 1997). A recent study found that a 10dB increase in aircraft and/or road noise exposure could be linked to a higher risk for several cardiovascular diseases (Basner, Babisch, et al. 2014). The Hypertension and Exposure to Noise Near Airports: the HYENA Study found that long term noise exposure, and in particular nighttime aircraft noise and road noise, can increase risks of hypertension (Jarup et al. 2008). There are a variety of other studies which show the possible impact of aviation noise on sleep, levels of annoyance, and psychological health. Some of these studies are shown in Table 2.1.

Hedonic price analysis has often been used to obtain estimates of the effects of aviation noise on housing prices (Bateman et al. 2001; Nelson 2004; Eibich et al. 2015; Mense and Kholodilin 2013). Van Praag and Baarsma (2005) analyzed whether the low cost of housing offsets the impact of aviation noise near Amsterdam Airport and found that the detrimental impact of aviation noise outweighs the positives of lower housing prices. Dekkers and van der Straaten (2009) estimated that a 1 dB noise reduction provides a marginal benefit of 1459 Euros per house. Eibich et al. as well and Mense and Kholodilin studied the impact of flight paths on housing prices. Eibich et al. (2015) found that there is a decrease in house prices as a flight corridor approaches as well as an impact on health. Mense and Kholodilin (2014) found that property prices reduce when flight paths for proposed expansions are published. There is a beneficial amenity impact of proximity to the airport, but a detrimental impact of noise.

Table 2.1: Summary of Noise and Health Literature

Health Area	Example Literature	Summary
Cardiovascular Health	Basner, Babisch, et al. 2014; Jarup et al. 2008; Babisch 2014	Detrimental impact of aviation on cardiovascular health.
Sleep	Basner, Babisch, et al. 2014; Jones 2009; Michaud 2007; Hume, Brink, and Basner 2012; Miedema and Vos 2007; Basner and Siebert 2010	Evidence of a detrimental impact on sleep, but Jones and Michaud et al. (Jones 2009; Michaud 2007) claim that methodology differs amongst the studies so findings are not conclusive.
Annoyance	Babisch 2014; Janssen et al. 2011; Schreckenberg et al. 2010; Kempen et al. 2009	Annoyance has increased and is present in both adults and children. There are many facets of annoyance unique to individuals and which are difficult to quantify.
Psychological Health	Haines et al. 2001; Stansfeld et al. 2009; Floud et al. 2011	There has been some evidence of a link between psychological health and aviation, but it is not concrete.

2.2 Cost-Benefit Analysis Frameworks

Cost-benefit analysis (CBA) has often been used to analyze the impacts of projects and to assess the Kaldor-Hicks Efficiency of a project. Kaldor-Hicks Efficiency stipulates that an outcome is efficient if the beneficiaries of a project can hypothetically compensate the losses of others (Oxford Reference 2020).

In the United States, the Federal Aviation Administration (FAA) requires the use of CBA when a project needs more than 10m USD in funding. To assess projects, the FAA looks at whether there is a net benefit to society from a project (Federal Aviation Administration 2019).

However, an issue with using CBA is that it accepts potentially significant distributional impacts. For this thesis, the aim was to analyze the multi-dimensional impacts of airports and build upon existing literature to create a Quality of Life impact framework for community impacts of airports.

2.3 Mechanisms of Community Engagement for Airports

The economic, environmental, and noise impacts discussed above have impacts on the communities surrounding airports. Policymakers recognise that environmental and noise impacts are often raised as an issue of public concern, whereas economic impacts are seen to be beneficial to communities. In fact, noise impacts are already the first area of environmental complaints within the European Union (European Parliament and the Council of European Union 2002). Additionally, airports realize the need to build relationships with community groups and understand their multi-dimensional impacts by using tools such as scorecards (Porter, Norman, and Oh 2018).

In a number of communities, airport operators have addressed negative impacts by sponsoring mitigation methods such as sound insulation or by building parks. At Heathrow, for example, many projects are supported through the Heathrow Community Trust which obtains funding from noise regulation violation fines as well as

fundraising by Heathrow staff (Heathrow Community Trust 2020). Communities have also sought consultation and closer collaboration on decision making with other surrounding communities with the aim of increasing public trust in the authorities. At Heathrow, for example, the Heathrow Community Noise Forum is a platform for discussion. This is also the case at other airports such as at Boston Logan airport with the Massport Community Advisory Committee (Massport CAC) which aims to represent communities impacted by the operations at the airport.

Chapter 3

Quality of Life Framework

The concept of Quality of Life enables multi-dimensional analyses of the impacts of airports on the population in surrounding communities. The Organisation for Economic Co-operation and Development (OECD) defines this concept as the "notion of human welfare (well-being) measured by social indicators rather than by "quantitative" measures of income and production" (Organisation for Economic Co-operation and Development 2005). The World Health Organization's Quality of Life Group sees Quality of Life as "individuals' perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns" (World Health Organization 2019b).

Quality of Life measures have also been developed in medical literature as subjective individual measures to assess symptom relief and the resulting impacts on physical, functional, emotional, and social well-being (Cella 1994). This concept has also been used in social studies, notably to analyse attributes of well-being such as living conditions in cities or metropolitan areas (Rogerson 1999). Various studies have been conducted and many surveys are often collected to measure it. For example, the European Quality of Life Survey (EQLS) assesses objective life situations and associated perceptions by (i) using a multidimensional measurement concept for assessing different life domains; and (ii) combining assessments of objective information with subjective views (Shucksmith et al. 2009).

For this thesis, Quality of Life was defined as being related to an individual's

perception of their life and therefore could be used to analyze the multi-dimensional impacts of airports on surrounding communities.

3.1 Existing Quality of Life Frameworks

There are several existing general measurement frameworks related to Quality of Life. For this thesis, the most applicable ones are shown in Table 3.1.

Table 3.1: Eurostat and ONS Quality of Life Frameworks

Eurostat Framework (Eurostat 2017a)	ONS Framework (Office of National Statistics 2019)
Material Living Conditions	Where we live
Productive or other main activity	What we do
Health	Health
Education	Education and skills
Leisure and social interactions	Our relationships
Economic security and personal safety	Personal finance The economy
Governance and basic rights	Governance
Natural and living environment	The natural environment
Overall experience of life	

The Eurostat framework, shown in Table 3.1, has been used to measure Quality of Life in the European Union. It was developed based upon the recommendations of the Commission on the Measurement of Economic Performance and Social Progress, also known as the "Stiglitz-Sen-Fitoussi Commission", and of the European Commission's GDP and beyond Communication. The goal of this framework is to measure changes in quality of life and to measure macroscopic conditions (Eurostat 2017b).

The UK Office of National Statistics (ONS) Measures of National Well-being Framework, shown in Table 3.1, was developed as part of the ONS Measuring National Well-being Programme to measure the well-being in the country and identify specific regions or indicators which need to be addressed to improve well-being (Office of National Statistics 2018a).

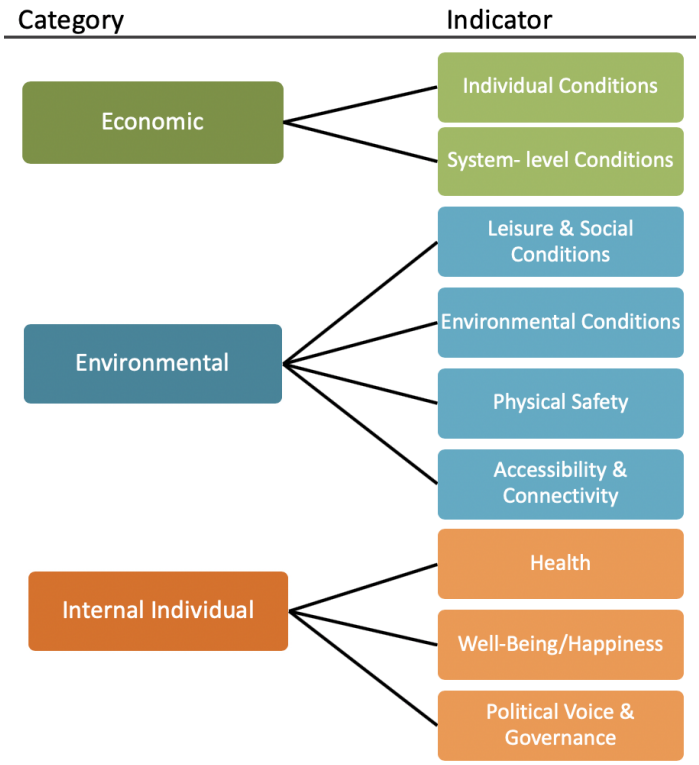

Figure 3-1: Airport-Specific Quality of Life Attribute Structure

3.2 Development of an Airport-Specific Quality of Life Framework

The frameworks presented above look at the national level. To analyze airport-specific impacts, a multi-dimensional community-level framework was necessary.

The frameworks in Table 3.1 served as the foundation for the creation of the airport-specific Quality of Life framework for this thesis. In particular, the Eurostat Quality of Life Framework (Eurostat 2017a) was a key component in defining the framework for this research. Attributes of interest, obtained from the frameworks in Table 3.1, such as Economic and Physical Safety, Natural and Living Environment, and Health were identified, and a framework was developed.

The Quality of Life framework developed for this thesis has nine attributes which are broken down into three categories: economic, environmental, and internal individual. The developed framework is summarized in Figure 3-1.

The economic category has two attributes. These relate to individual level economic metrics, including material living conditions and system-level conditions, which look at the system level state of the economy and are related to catalytic impacts discussed in Chapter 2.

The next category, environmental or external quality of life includes four attributes: Leisure and Social Conditions, Environmental Conditions, Physical Safety, and Accessibility & Connectivity. Leisure and Social Conditions are opportunities for participating in non-work-related activities and having interpersonal exchanges. Environmental conditions are linked to air quality, climate, water quality, noise levels, and environmental services and amenities. Physical safety relates to the risk for the physical integrity of the human body. Accessibility & Connectivity is defined as mobility for individuals and goods and opportunities for interaction.

The final category in this framework is Internal Individual which relates to personal quality of life. There are three attributes within this category. The first one is health, which covers length of life and assesses mortality and morbidity impacts which are discussed in Chapter 2 (Jarup et al. 2008; Babisch 2014; Miedema and Vos 2007; Haines et al. 2001). The second is well-being/happiness which relates to the perception of being comfortable, healthy, and happy, as discussed in the previous chapter (Praag and Baarsma 2005; Dolan, Peasgood, and White 2008; Basner, Clark, et al. 2017). The third and final attribute within the Internal Individual category is Political Voice and Governance which is the perceived involvement in policy-making and decision making such as involvement in community engagement mechanisms such as the MassPort CAC for Boston Logan Airport.

The framework developed in this thesis was built upon past work, most notably the Eurostat and ONS frameworks which are shown in Table 3.1. A comparison of these two frameworks with the one developed in this thesis is shown in Table 3.2.

Table 3.2: Comparison of Different Frameworks

Eurostat Framework (Eurostat 2017a)	**ONS Framework (Office of National Statistics 2019)**	**Thesis Framework**
Material Living Conditions Productive or other main activity Education Economic security	Where we live What we do Education and skills Personal finance	Individual Economic Conditions
	The economy	System level Economic Conditions
Health	Health	Health
Leisure and social interactions	Our relationships	Leisure and Social Conditions
Personal safety		Physical Safety
Governance and basic rights	Governance	Political Voice and Governance
Natural and living environment	The natural environment	Environmental Conditions
		Accessibility & Connectivity
Overall experience of life		Well-being/ Happiness

Chapter 4

Evaluating Available Statistical Data using the Quality of Life Framework

For the purpose of analyzing Quality of Life attributes in communities surrounding an airport, a dataset of metrics related to the attributes in Figure 3-1 was compiled from a variety of sources at different spatial resolutions. This chapter evaluates statistical data using the Quality of Life Framework that was developed in the previous chapter.

4.1 Data Sources

In an effort to empirically analyze the Quality of Life impacts in communities surrounding London Heathrow Airport, available data related to attributes in the framework developed in Chapter 3 was sought and a community data set was compiled. There was very limited statistical data available. A summary of the identified data, the data resolution, and sources is shown in Table 4.1.

The Office of National Statistics in the United Kingdom publishes a range of economic, well-being, accessibility & connectivity and health data which is mostly available at the district level which are outlined in red as shown in Figure 4-1.

For the well-being/ happiness attributes, the data used was collected by the Office of National Statistics through surveys where questions are asked related to life satis-

faction[1], happiness[2], worthwhile[3], and affect[4]. (Office of National Statistics 2018b).

Table 4.1: Data Overview

	Attributes	Metrics	Data Source	Spatial Resolution
Economic Conditions	Individual Conditions	Hourly Wage per Inhabitant (GBP)	ONS	Low (District)
		Housing Transactions (GBP)	ONS	Low (District)
		Housing Transactions (GBP)	HM Land Registry	Middle (LSOA)
	System- level Conditions	Gross Value Added per Employee (GBP)	ONS	Low (District)
		% Living Below Minimum Wage	ONS	Low (District)
		Unemployment Rate	ONS	Low (District)
Environmental	Accessibility & Connectivity	Drive Time to Central London (min)	Google Maps	High (Geo-loc)
		Transit Time to Central London (min)	Google Maps	High (Geo-loc)
		Percent of premises that have 4G	ONS	Low (District)
Internal Individual	Health	Age standardized mortality rate (Weighted average of ASMR per 100, 000 persons, weights are the proportions of persons in the corresponding age groups of the WHO standard population" (World Health Organization 2019a)	ONS	Low (District)
		Deaths per 1000 population	ONS	Low (District)
	Well-being/ happiness	Life Satisfaction (feeling of satisfaction with life overall)	ONS	Low (District)
		Happiness (feeling of happiness yesterday)	ONS	Low (District)
		Worthwhile (feeling that things one does are worthwhile overall)	ONS	Low (District)
		Affect (feeling of anxiety yesterday)	ONS	Low (District)
		Perception of Noise	SONA Study	Middle (LSOA)
		Social Media	Twitter	Middle (LSOA)

The district level data is at a low spatial resolution and may not adequately capture heterogeneities which may exist in communities surrounding London Heathrow Airport due to localized impacts, such as noise. Figure 4-2 shows the 2017 noise contours[5] overlaid over districts around the airport.

[1]Overall, how satisfied are you with your life nowadays?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

[2]Overall, how happy did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

[3]Overall, to what extent do you feel that the things you do in your life are worthwhile?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

[4]Overall, how anxious did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

[5]1 dB step with the innermost contour representing 72 dB and the outermost contour representing 54 dB L_{eq}, 16h (sound level averaged over the year from 07h00 to 23h00)

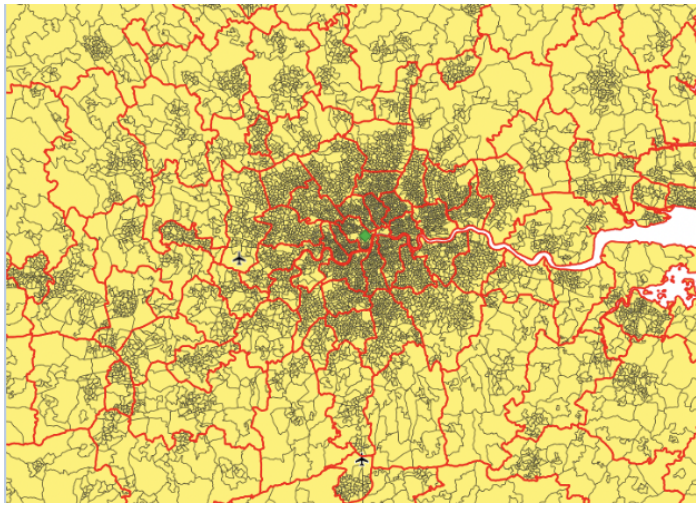

Figure 4-1: Geographical Regions around London Heathrow

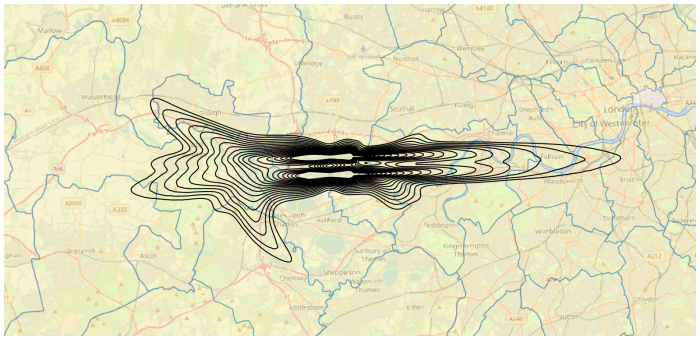

Figure 4-2: 2017 Noise Contours and Districts

To analyze the noise impacts, one would need to analyze the impacts in areas of expected impact. However, noise impacts do not follow district boundaries. For example, the district that the airport is in is over 115 km^2 and contains noise impacts in the southern area, yet in the data it is assumed that metrics are the same throughout, thus not accounting for heterogeneities which may be present.

Housing transaction data is available at a higher spatial resolution, e.g. the Lower Layer Super Output Areas (LSOAs) level, from the HM Land Registry. Figure 4-1 shows LSOAs, outlined in black.

4.2 District Level (Low Spatial Resolution) Results

The low resolution data shown in Table 4.1 was analyzed using mapping and regression analysis.

4.2.1 Data Maps

Mapping was used to examine possible spatial patterns for various variables and is shown in Figures 4-3 to 4-8. In these maps, potential positive and negative impacts are captured through proximity and noise, respectively. Therefore, noise contours using the metric L_{DEN}[6] were overlaid onto the maps.

Economic Conditions

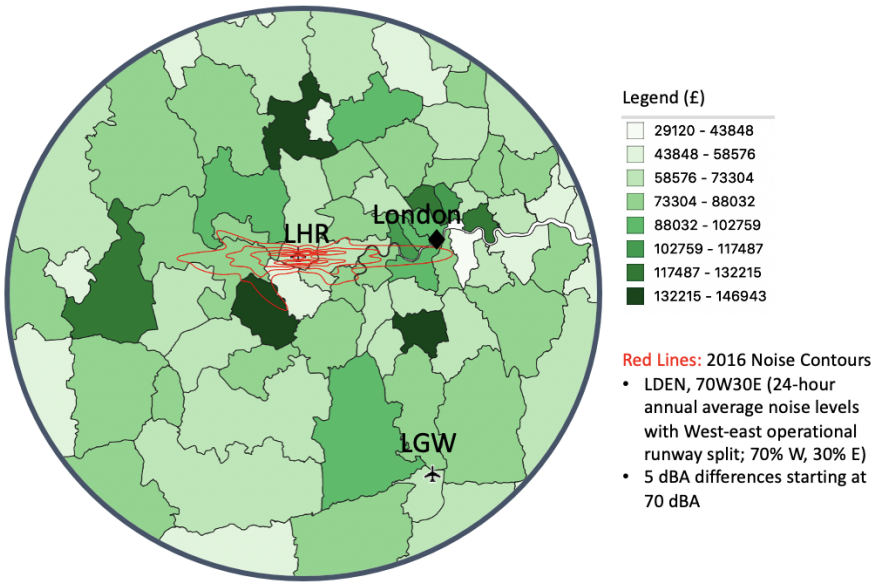

Figure 4-3: Gross Value Added per Employee

[6]Day-evening-night level: Noise metric with a penalty of 10 dB for night-time noise and an additional penalty of 5 dB for evening noise.

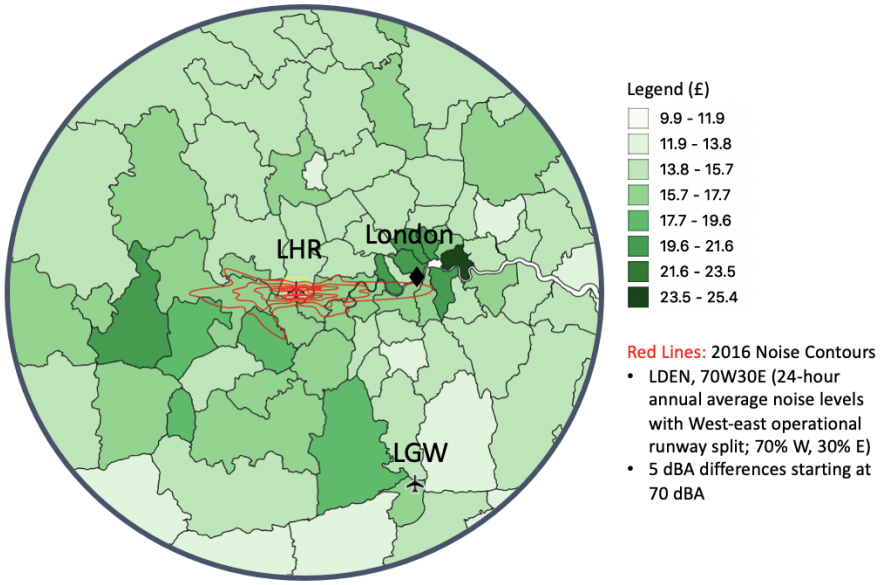

Figure 4-4: Hourly Wage

Survey Reported Well-Being/Happiness

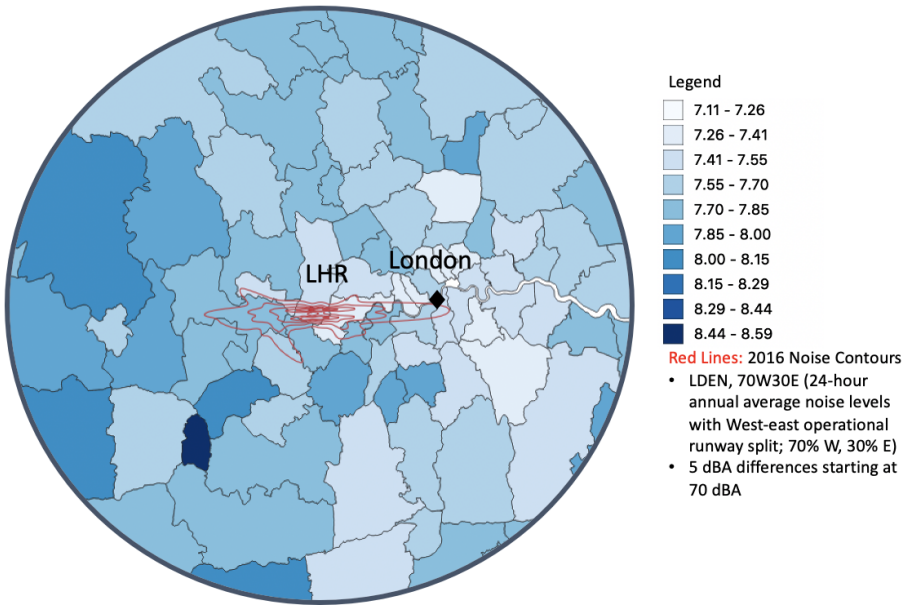

Figure 4-5: Survey Reported Life Satisfaction

Overall, how satisfied are you with your life nowadays?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

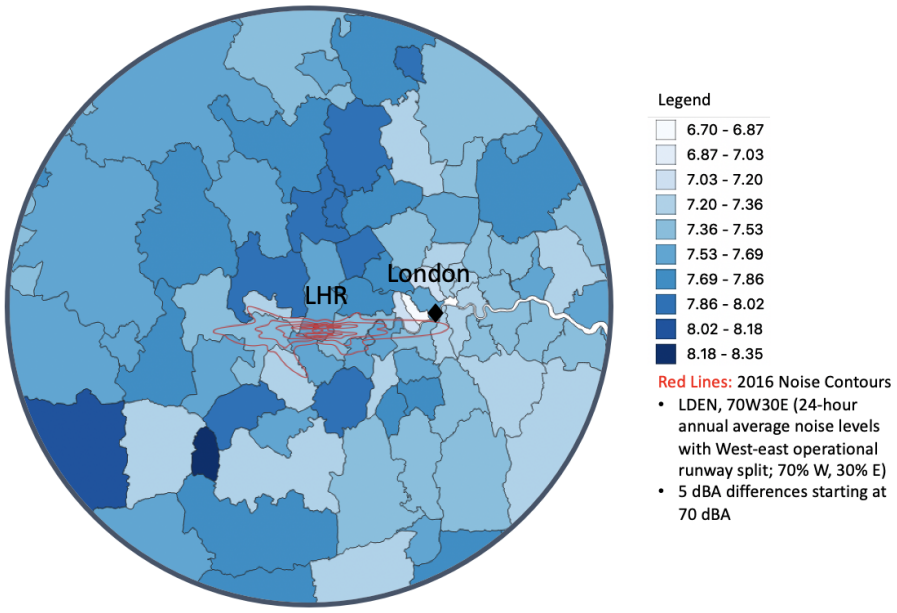

Figure 4-6: Survey Reported Happiness

Overall, how happy did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

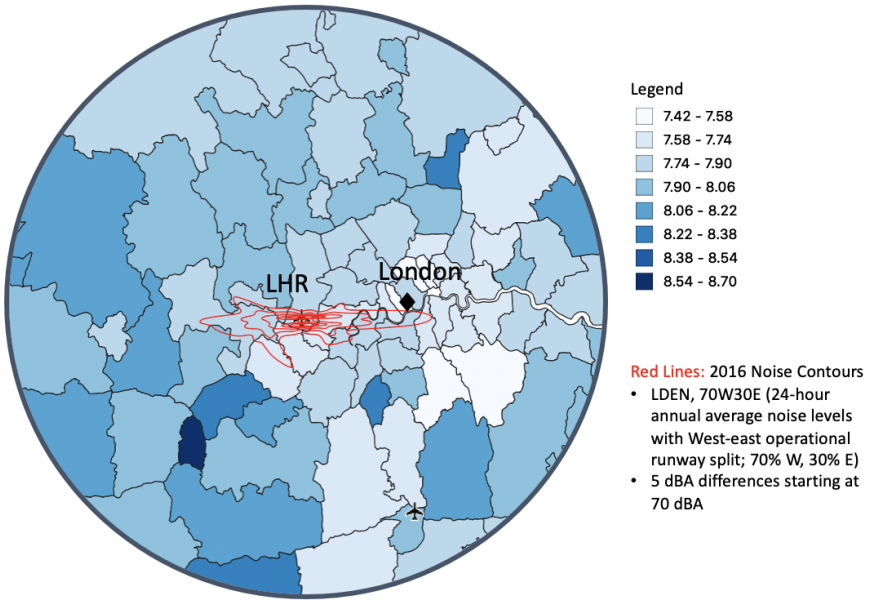

Figure 4-7: Survey Reported Worthwhile

Overall, to what extent do you feel that the things you do in your life are worthwhile?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

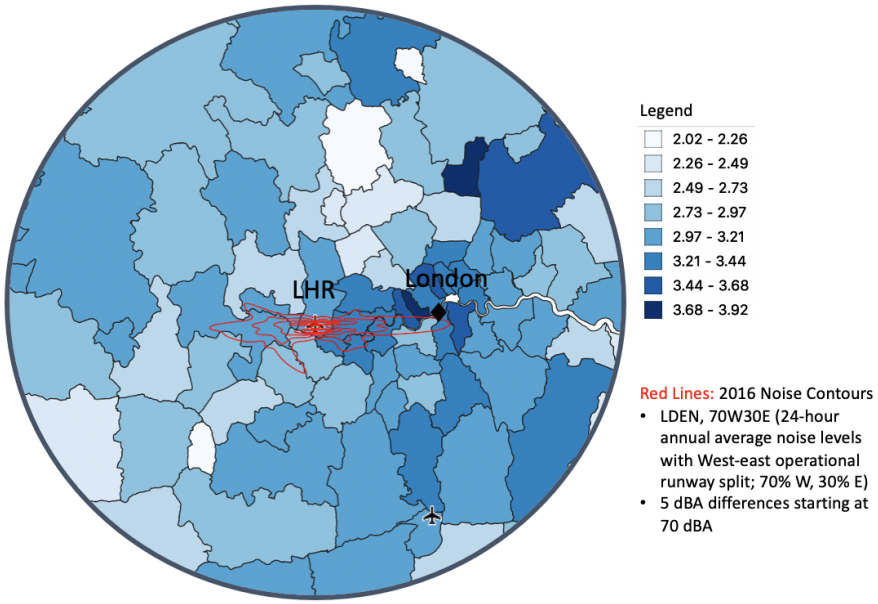

Figure 4-8: Survey Reported Affect

Overall, how anxious did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

For economic data, data maps for hourly wage and gross value added per employee were examined. For well-being/happiness, life satisfaction, happiness, worthwhile, and affect were analyzed. The results show no discernible airport related spatial trends, although impacts of proximity to Central London can be seen.

4.2.2 Multivariate Regression Analysis

While maps allow for visual inspections of the data, they cannot disentangle the impacts of multiple confounding factors on a particular outcome variable.

Methodology

To disentangle these impacts, regression analysis was utilized. It sets out to explain an outcome variable, y (e.g. Hourly Wage per Inhabitant), as a linear function of confounding factors, x_1 to x_n, a stochastic error term, ϵ, and a constant θ. The

equation used for regression analysis is as shown in Equation 4.1.

$$y = \theta + \alpha_1 * x_1 + \alpha_2 * x_2 + ... + \alpha_i * x_i + \epsilon \tag{4.1}$$

When controlling for confounding factors, it was important to consider not only proximity to London Heathrow Airport, but also to Central London (defined as Buckingham Palace) since Central London is a major economic center and thus may also have its own impacts. Additionally, as there is a possible impact from London Heathrow Airport, there may also be an impact from London Gatwick Airport as it is also a major airport in the London Region. Therefore, distances to London Heathrow Airport, Central London, and London Gatwick Airport were controlled for in this regression model and calculated from the centroids of each district.

Additionally, when analyzing the impact of London Heathrow Airport, there are possible confounding factors related to the Quality of Life framework. Other available data related to dimensions of Quality of Life is controlled for and includes Gross Value Added per Employee, Hourly Wage per Inhabitant, Life Satisfaction (feeling of satisfaction with life overall), Happiness (feeling of happiness yesterday), Worthwhile (feeling that the things that one does are overall worthwhile), and Affect (feeling of anxiety yesterday).

In this analysis, only districts with centroids within 60 kilometers of Heathrow Airport, a similar range to what is used in literature such as Allroggen and Malina (2014), were considered.

Results

The results of the multivariate regression are summarized in Table 4.2 and full results are shown in Appendix A. The R^2 value serves as a measure of model fit. The models do not explain the significant share of variance in the outcome variable. It is important to note that the analyses conducted in this thesis did not aim to identify cause and effect of the exogenous variables x_1,...,x_n onto community outcomes but rather to describe observed empirical relationships between variables. The analysis

was not causal but rather shows correlation. The wording of beneficial or detrimental impacts does not preclude causality in this context.

Table 4.2: Summary of Low Spatial Resolution Statistical Data Results

	Metric	Distance to LHR (km)	Distance to Central London (km)	R^2
Economic Conditions	Gross Value Added per Employee (GBP)	-509**	-1.31	0.15
	Hourly Wage per Inhabitant (GBP)	-0.0438**	-0.00501	0.16
	% Living Below Minimum Wage	0.0437	-0.198***	0.55
	Unemployment Rate	0.0203	-0.0637***	0.31
	Housing Transaction Values (GBP)	-3204**	-2581**	0.38
Health	Deaths per 1000 population	0.00767	0.0513***	0.55
	Age standardized mortality rate (Weighted average of ASMR per 100, 000 persons, weights are the proportions of persons in the corresponding age groups of the WHO standard population"(World Health Organization 2019a)	2.61***	-1.13	0.15
Well-being/ Happiness	Life Satisfaction (feeling of satisfaction with life overall)	-0.00434**	0.00776***	0.39
	Happiness (feeling of happiness yesterday)	-0.00631***	0.00585***	0.26
	Worthwhile (feeling that things one does are worthwhile overall)	-0.00276	0.00623***	0.28
	Affect (feeling of anxiety yesterday)	0.00478	-0.00793***	0.22
Accessibility & Connectivity	% of premises with broadband > 30 Mb/s	-0.0621	-0.0842**	0.24
	% of premises with 4G services	-0.0867*	-0.224***	0.57
	Drive time to Western Central London (min)	0.490***	-0.653***	0.89
	Transit time to Western Central London (min)	0.336	1.23***	0.65
	Drive time to Eastern Central London (min)	-0.282***	1.14***	0.90
	Transit time to Eastern Central London (min)	-0.165	1.40***	0.71

* The data is presented with asterisks which represent the statistical confidence level, with one asterisk (*) indicating at least a 90% confidence level, two asterisks (**) indicating at least a 95% confidence interval, and three asterisks (***) indicating at least a 99% confidence interval.
** A cell is shaded in green if there is a beneficial gradient related to the metric and in red if there is a detrimental gradient related to the metric.

For Economic Conditions, our results indicate that there is a beneficial impact of proximity to London Heathrow Airport for gross value added per employee and hourly wage per inhabitant. This result is in line with literature which indicates that there is a beneficial economic impact of airports (Campante and Yanagizawa-Drott 2017; Brueckner 2003; Allroggen and Malina 2014). We also find a beneficial impact of proximity to the airport as well as of proximity to Central London for housing transaction values. On the other hand, for the statistically significant results, there is a detrimental impact of proximity to Central London for the percentage of the population living below the minimum wage as well as for unemployment rate.

Health metrics suggest that there is a beneficial impact of proximity to London

Heathrow Airport for Age-Standardised Mortality Rate (ASMR)[7] and of proximity to Central London for deaths per 1000 population.

The analysis of well-being/ happiness metrics suggest that there is a beneficial impact of proximity to London Heathrow airport for Life Satisfaction and Happiness, but a detrimental impact of proximity to Central London for these metrics. There is also a detrimental impact of proximity to Central London for worthwhile and affect.

For accessibility & connectivity metrics, there was a beneficial impact of proximity to Central London for all metrics. For London Heathrow Airport, we found a beneficial impact of proximity for percent of premises with 4G services and for driving time to Western Central London (defined as Paddington Station). On the other hand, there was a detrimental impact with proximity for driving time to Eastern Central London (defined as Bank Station). This may be due to the fact that London Heathrow Airport is located to the west of Central London, and to get to Eastern Central London, one would need to drive through the city which would balance out the beneficial impact of getting to Western Central London.

The low spatial resolution analysis indicates an overall beneficial effect of proximity to London Heathrow Airport when controlling for several variables. However, spatial resolution is low and may not capture local effects.

4.3 LSOA Level (Medium Spatial Resolution) Results

4.3.1 Multivariate Regression Analysis

Methodology

Higher resolution data was sought to validate results obtained at the low spatial resolution level, but limited data was available for analysis. Similarly to the process

[7] "Weighted average of the age-specific mortality rates per 100,000 persons, where the weights are the proportions of persons in the corresponding age groups of the WHO standard population" (World Health Organization 2019a)

for the low spatial resolution analysis, the following metrics related to dimensions of Quality of Life were controlled for Gross Value Added per Employee, Hourly Wage per Inhabitant, Life Satisfaction (feeling of satisfaction with life overall), Happiness (feeling of happiness yesterday), Worthwhile (feeling that the things that one does are overall worthwhile), and Affect (feeling of anxiety yesterday) were controlled for as were the distances to Central London and London Gatwick Airport.

Results

The results from the multivariate regression for house transaction values with proximity to London Heathrow Airport for both low and medium spatial resolutions are shown in Table 4.3.

Table 4.3: Low and Medium Spatial Resolution Housing Transaction Data Analysis

	Value of housing transactions (GBP)	
	Low Spatial Resolution	Medium Spatial Resolution
Distance to LHR (km)	-3204**	-1825***

* The data is presented with asterisks which represent the statistical confidence level, with one asterisk (*) indicating at least a 90% confidence level, two asterisks (**) indicating at least a 95% confidence interval, and three asterisks (***) indicating at least a 99% confidence interval.

A beneficial trend with proximity to London Heathrow Airport is present at both spatial resolutions. However, the magnitude of this effect is weaker at the higher spatial resolution. One potential driver of this difference is that higher resolution analysis may better capture heterogeneities which are present at the community level.

Existing literature suggests that airports can have both a detrimental and beneficial impact on house prices in surrounding communities (Mense and Kholodilin 2013; Eibich et al. 2015; Praag and Baarsma 2005). Positive impacts are linked to proximity whereas negative impacts are linked to noise. We followed the literature and studied both potential noise impacts and proximity impacts in a multivariate regression. The results are shown in Table 4.4.

We found a beneficial amenity impact of being close to the airport (value of having access to employment opportunities and air transport connectivity) and a detrimental

Table 4.4: Amenity versus Noise Impact Medium Spatial Resolution Analysis

	Values of housing transactions (GBP)
Distance to LHR (km)	-2259***
Distance to Central London (km)	-904***
Distance to LGW (km)	-354**
Noise Level (dB)	-3796**
Hourly Wage per Inhabitant (GBP)	12336***

* The data is presented with asterisks which represent the statistical confidence level, with one asterisk (*) indicating at least a 90% confidence level, two asterisks (**) indicating at least a 95% confidence interval, and three asterisks (***) indicating at least a 99% confidence interval.

noise impact. In fact, the magnitude of the detrimental impact of 1dB noise is approximately the same as the benefit of being 2km closer to Heathrow Airport. These two impacts can be disentangled due to the heterogeneous noise exposure around Heathrow Airport, as seen in Figure 4-2. The primary noise exposure from flight operations at Heathrow are primarily east and west of the airport. Therefore, there are areas to the north and the south of the airport which are not directly impacted by the overflights and their associated noise. These communities can benefit from the amenity impact whereas the communities east and west of the airport are exposed to noise while also potentially benefiting from airport proximity.

Perception of Noise Impacts

Researchers have also discussed the impacts of noise attitudes on house prices (Praag and Baarsma 2005; Dolan, Peasgood, and White 2008; Basner, Clark, et al. 2017).

We analyzed such noise perceptions towards aircraft noise using the Survey of Noise Attitudes (SONA) study from 2014. The study interviewed 2,000 adults in the UK living in high exposure areas and in particular examined the perception of noise. This data was available for each respondent, with their corresponding LSOA identified. For this analysis, we focused on the question "thinking about the last 12 months or so, when you are here at home, how much does noise from aircraft, airports or airfields, bother, disturb or annoy you?," which had the following response options: 1: Not at all, 2: Slightly, 3: Moderately, 4: Very, and 5: Extremely (Civil Aviation Authority 2017).

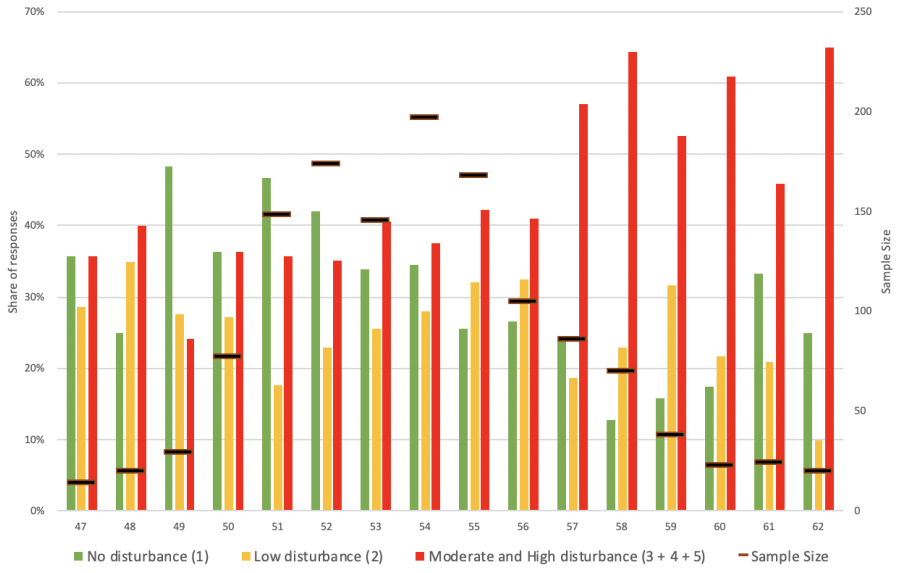

Figure 4-9: Perceived Disturbance and Noise Exposure

Figure 4-9 shows the share of respondents for no, low, and moderate and high noise disturbance. Noise levels at which there are less than 10 respondents were omitted.

Literature suggests that the driver may be an individual's perception of noise (Praag and Baarsma 2005; Dolan, Peasgood, and White 2008; Basner, Clark, et al. 2017). The observed response behavior may be driven by individual sensitivity and as shown by Phun et al. (2015) and Thomas and Lever (2003), wealth. We analyzed the impact of noise on the percentage of individuals in a LSOA (as defined in Equation 4.2). This metric was created since the SONA Study surveys numbers of individuals in different LSOAs and thus it was necessary to standardize to be able to compare LSOAs.

$$\text{Percent disturbed} = \frac{\text{Number of respondents in each LSOA in categories 3-5}}{\text{Total number of respondents in each LSOA}} \quad (4.2)$$

Table 4.5 shows the results between perceived aviation disturbance (measured by the SONA study through the question above) and an available data source which can be used as a surrogate for wealth (housing values), while controlling for distance to Heathrow and Central London. Housing values show a level of investment in a

specific location and thus can be used as a surrogate for wealth. The results imply that there is a relationship between more expensive houses in a LSOA and a higher percentage of individuals that report moderate and high levels of noise disturbance. This also suggests that wealthier individuals are more sensitive to noise disturbance and thus perceive it more, as has been shown in literature (Phun, Yai, and Hirata 2015; Thomas and Lever 2003).

Table 4.5: Relationship Between Perceived Disturbance and Wealth

	Percent Disturbed
Housing Value (GBP)	2.02E-07***
Noise Level (dB)	0.02374***

* The data is presented with asterisks which represent the statistical confidence level, with one asterisk (*) indicating at least a 90% confidence level, two asterisks (**) indicating at least a 95% confidence interval, and three asterisks (***) indicating at least a 99% confidence interval.

The regression analysis derived from the SONA data may have limitations and is potentially subject to selection bias since the sample only includes individuals exposed to 51 dB LA_{eq},16h during an average summer day. Additionally, the linear regression model used in this analysis does not cap the percentages at 0 and 100 %. It is important to recall that the analysis presented in this chapter is not causal but rather shows correlation.

Chapter 5

Counterfactual Analysis using the Quality of Life Framework

This chapter compares the region that London Heathrow Airport is in to other regions equidistant from Central London.

5.1 Methodology

In an effort to gain additional insights into the community impact of London Heathrow, a model for running counterfactual analysis was developed. In this model, we aimed to benchmark the communities surrounding the airport with other communities in the Greater London Area. As a starting point, we assumed that proximity to Central London has a dominant confounding effect on Quality of Life Outcomes. Therefore, we benchmarked the Heathrow Region to other regions which are equidistant to Central London. This was done by creating a donut shape where Central London is in the middle. In this setup, the Heathrow region was compared to seven regions, as shown in Figure 5-1.

Outcomes were calculated using the data shown in Table 4.1. To obtain the average value for each sector, population weighting of each district or LSOA in the sector was used. For each sector j, we calculated the outcome metric as shown in Equation 5.1, where population i is the population of the district or LSOA that is

in sector j assuming a uniform population distribution and δ is the set of districts or LSOAs in a sector j.

$$\text{Outcome j} = \sum_{i \in \delta} \frac{\text{Population i}}{\sum_{j \in \delta \pm i} \text{Population j}} * \text{Outcome i} \tag{5.1}$$

The outcome value in the LHR Region was compared to the value in each non-LHR region (sectors 1-7) as well as the average of these regions. A pooled standard error t-test was used to determine if there was a statistically significant difference between samples ($p<0.15$)[1]. The outcome variable of each sector is shaded in green or red depending upon whether it has significantly better or worse outcomes than the Heathrow region. Additionally, the Heathrow region is shaded if there is a statistically significant difference with other regions. It is shaded in green if it has better outcomes than the average of the non-LHR regions and in red if it has worse outcomes than the average of the non-LHR regions. Asterisks are used to represent the significance level[2].

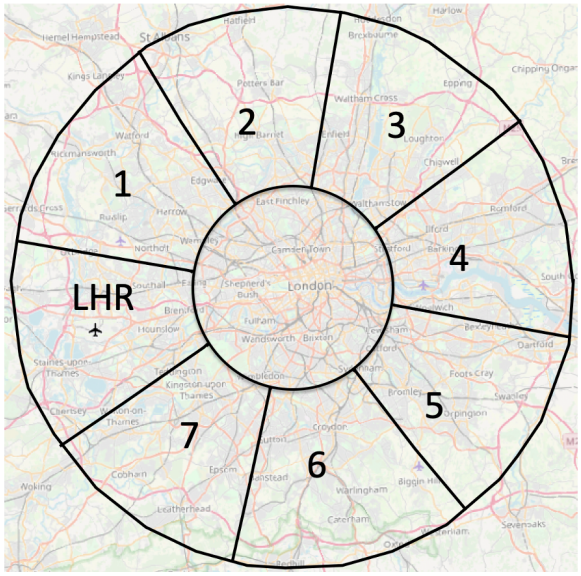

Figure 5-1: Sectors

[1]A p-value of 0.15 selected due to small sample size (22 districts in donut). P-values shown in Appendix B

[2]One asterisk (*) indicates at least a 85% confidence level, two asterisks (**) indicate at least a 90% confidence interval, and three asterisks (***) indicate at least a 95% confidence interval.

5.2 Results

The counterfactual analysis was conducted for metrics in the economic, health, and well-being/happiness metrics.

5.2.1 Economic Conditions

Counterfactual analysis was conducted for the economic metrics Gross Value Added Per Employee and Housing Transaction Values. The results are shown in Figures 5-2 and 5-3, respectively.

The Heathrow region performs better than the average of other regions for Housing Transaction Values. There is no statistically significant difference between the Heathrow sector and other sectors for Gross Value Added Per Employee.

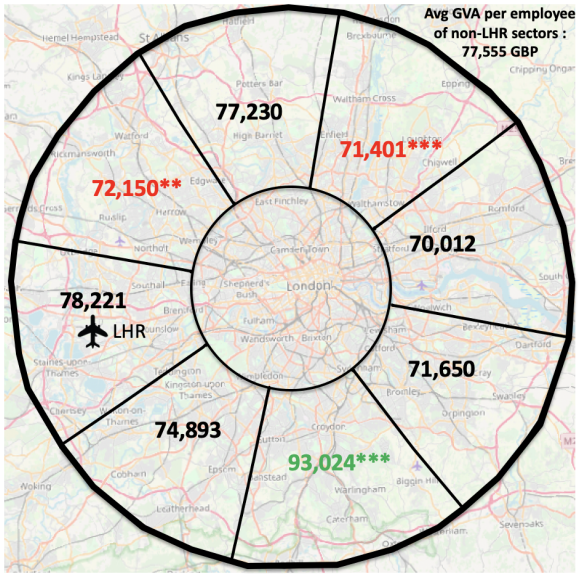

Figure 5-2: Gross Value Added Per Employee

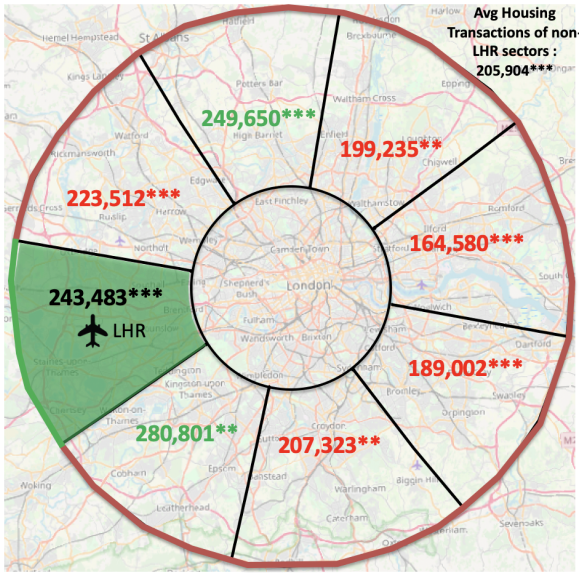

Figure 5-3: Housing Transaction Values

5.2.2 Health

Counterfactual analysis was conducted for the health metrics deaths per 1000 population and Age-Standardised Morality Rate (ASMR)[3]. The results are shown in Figures 5-4 and 5-5, respectively.

In general, the Heathrow region performs better than the average of other regions for Deaths per 1000 Population and Age-Standardised Morality Rate.

[3] "Weighted average of the age-specific mortality rates per 100,000 persons" (World Health Organization 2019a)

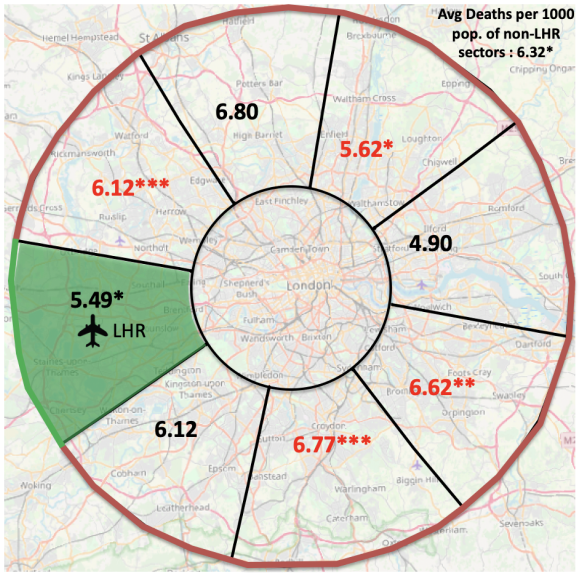

Figure 5-4: Deaths per 1000 Population

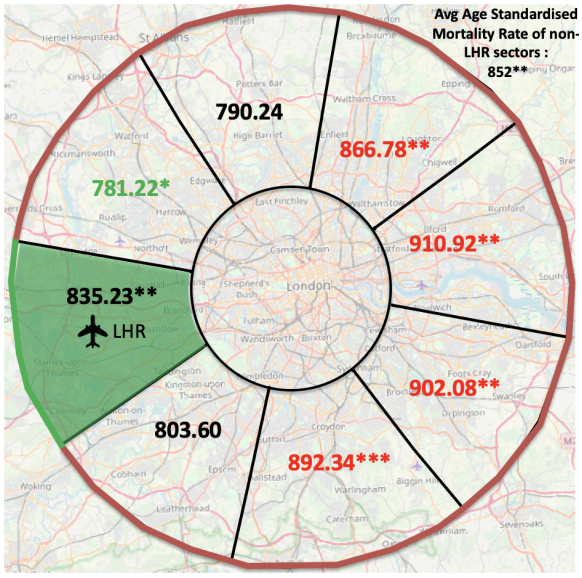

Figure 5-5: Age-Standardised Morality Rate

5.2.3 Well-being/ Happiness

Counterfactual analysis was conducted for the following well-being/happiness metrics: Life Satisfaction (feeling of satisfaction with life overall), Happiness (feeling of happiness yesterday), Worthwhile (feeling that the things that one does are over-

all worthwhile), and Affect (feeling of anxiety yesterday). The results are shown in Figures 5-6 to 5-9.

The Heathrow region performs worse than the average of other regions for Life Satisfaction, Happiness, and Worthwhile. There is no statistically significant difference between the Heathrow sector and other sectors for Affect.

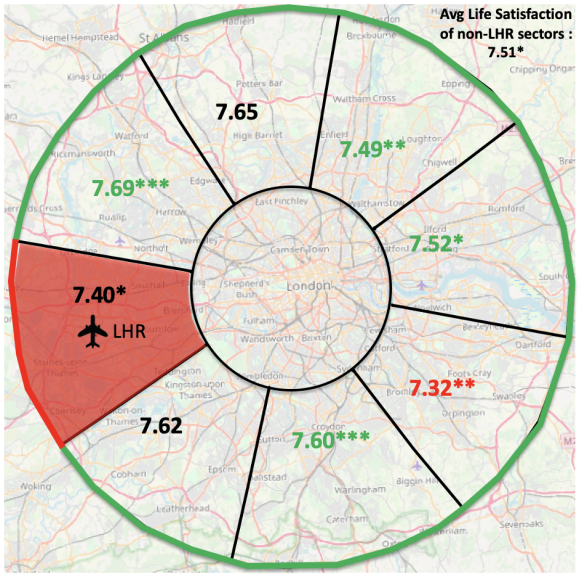

Figure 5-6: Survey Reported Life Satisfaction

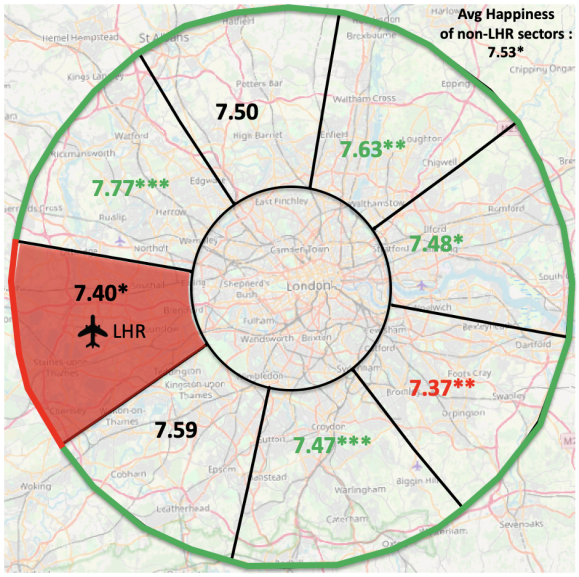

Figure 5-7: Survey Reported Happiness

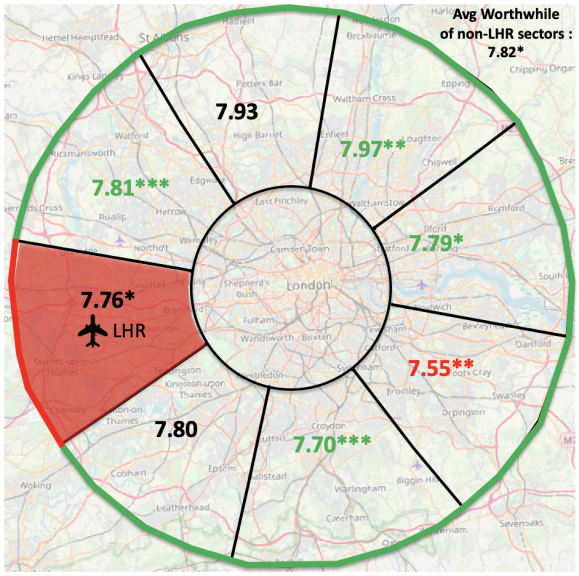

Figure 5-8: Survey Reported Worthwhile

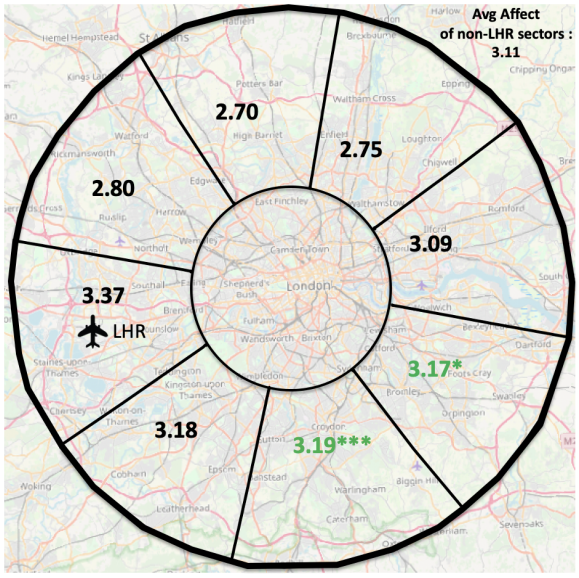

Figure 5-9: Survey Reported Affect

Chapter 6

Evaluating Social Media Sentiment Data using the Quality of Life Framework

An opportunity to obtain higher spatial resolution data was gained by looking at social media data. This data provided additional insight for Quality of Life, and in particular for Well-being/ Happiness.

6.1 Data Collection

Data was collected using the Twitter API in collaboration with Dr. Lishuai Li from the City University of Hong Kong using a 50-mile collection area to analyze sentiment within the Greater London Region. A 15-mile subset of this data was also considered to look at sentiment within the region near Heathrow. A map of the collection area is shown in Figure 6-1 (Google Maps 2020). The Greater London Region area is shown in gray and the Heathrow region is shown in yellow. Approximately 29 million tweets were collected from March 2019 to January 2020. Parameters collected include the content of each tweet, as well as the location, date, and time of submission. This data was used to measure perceptions, sentiments, and opinions about London Heathrow Airport.

The collected data was analyzed using the SentiStrength Machine Learning Algorithm developed at the University of Wolverhampton. This algorithm scored texts on a scale from -4 to 4 with -4 representing a strongly negative mood, 0 representing a neutral mood, and 4 representing a strongly positive mood. It was developed based on MySpace posts and comments from the UK which were human classified. It is described by Thelwall, Buckley, Paltoglou, et al. (2010) and has been used to study the sentiment in tweets as well as in news articles (Thelwall, Buckley, and Paltoglou 2011; Giannopoulos et al. 2012). Additionally, it was used to classify tweets for the London Olympics and the 2014 Super Bowl and create light shows based on the sentiment of the tweets (Grossman 2012; Forbes 2014).

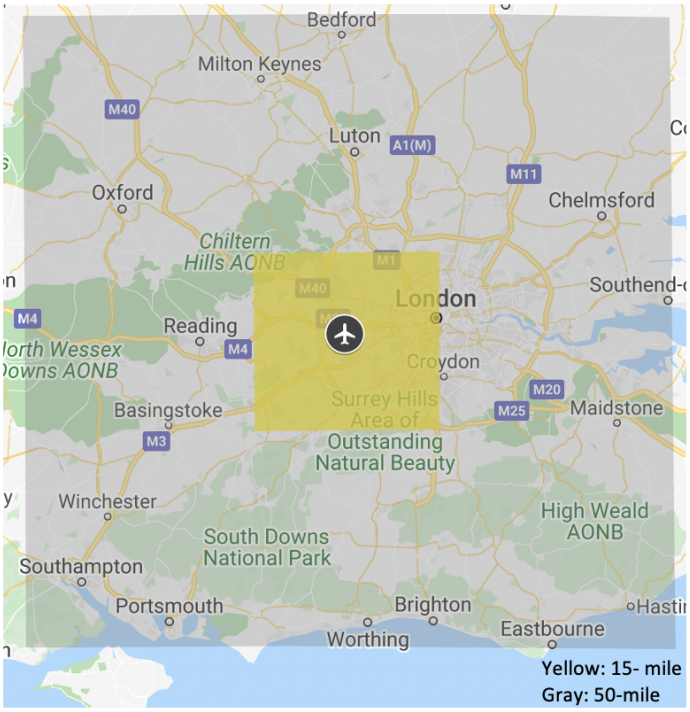

Figure 6-1: Tweet Collection Areas

6.2 Greater London Region Analysis

6.2.1 General Sentiment

The results of sentiment scoring using the SentiStrength Algorithm are shown in Figure 6-2.

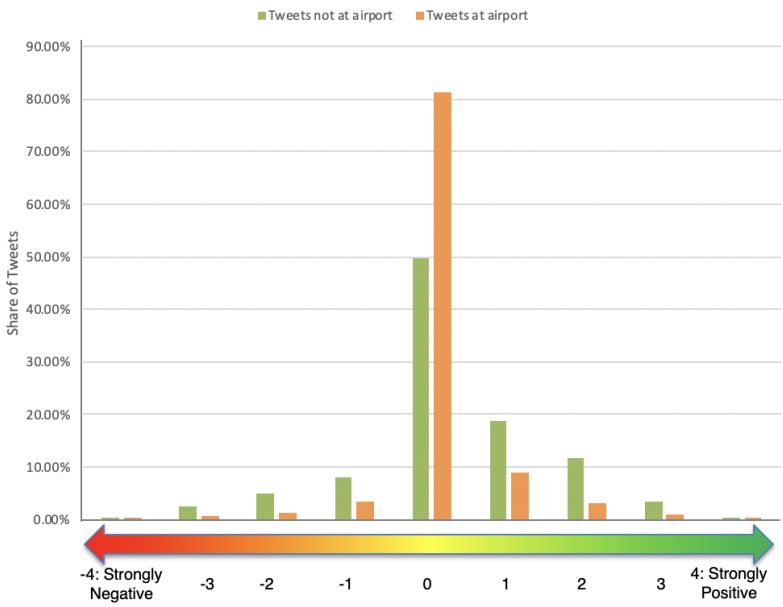

Figure 6-2: Distribution of Tweet Sentiments for all tweets within 50-miles of London Heathrow Airport

Tweets at the airport have an average sentiment of 0.096, and tweets not at the airport have an average sentiment of 0.273. Most tweets both at and not at the airport were neutral, with approximately 80% of tweets at the airport being neutral. When analyzing these tweets, we found that many tweets classified as neutral by the algorithm do not convey sentiment but rather information. Examples are shown in Table 6.1. Therefore, neutral tweets were left out for sentiment and happiness analysis. The re-normalized data is shown in Figure 6-3.

Non- neutral tweets at the airport[1] have a sentiment score of 0.511, and tweets not at the airport have a sentiment score of 0.542.

[1]Within the airport perimeter

Table 6.1: Sample Neutral Tweets

Example tweets at the airport	Sample tweets: • "At Heathrow, waiting for my vacation!" • "@HeathrowAirport just landed from Toronto"
Example tweets not at the airport	Sample tweets: • "Chelsea plays today @ChelseaFC" • "Went to the British Museum today for the first time"

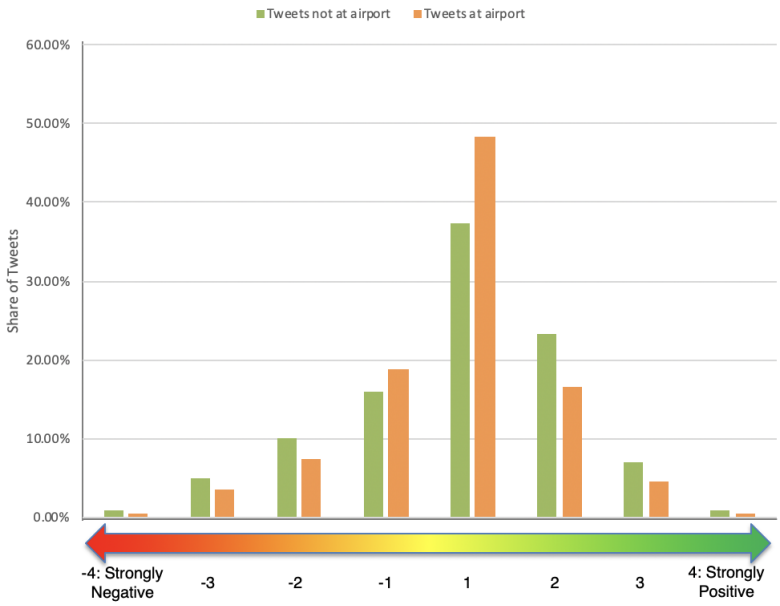

Figure 6-3: Distribution of Tweet Sentiments for non-neutral tweets within 50-miles of London Heathrow Airport

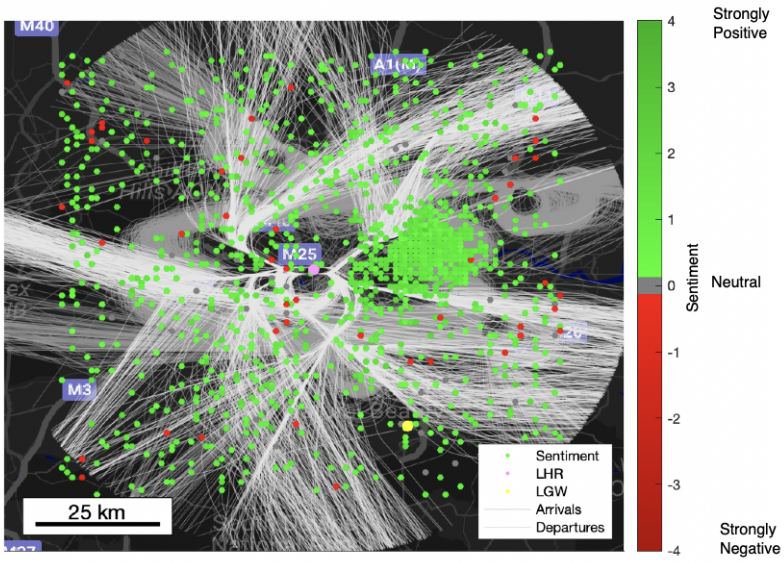

Figure 6-4: Spatial distribution of average sentiment of non-neutral tweets within 50-miles of London Heathrow Airport

The sentiment scores derived from the collected tweets are a metric within the well-being/ happiness attribute. The first method for looking at this metric was through mapping. For this, sentiment scores of non-neutral tweets were averaged in one-kilometer by one-kilometer grids. The resulting grid, which only considers cells with more than five tweets, is shown in Figure 6-4.

No clear airport-related trends were discernible. For example, there was no visual indication that the sentiment of tweets under flight tracks was more negative than of those not under flight tracks. To confirm this, a regression model was run using the number of overflights per grid while accounting for confounding factors such as distance to Central London. No statistically significant trend was observed. The regression result is shown in Appendix A.

However, many of the collected tweets may not contain information on Quality of Life as it relates to the airport. We, therefore, extracted tweets which contain Quality of Life information related to the airport as well as tweets related to noise exposure. Two keyword filters were used for this purpose.

1. **Aviation related tweets:** Aviation related tweets were filtered using the words airport or LHR or Heathrow or airplane or aeroplane or plane or wing. This

filter aims to identify tweets which directly relate to the aviation sector and the airport.

2. **Aviation-noise related tweets:** Aviation and noise related tweets were filtered using the words Airport or LHR or Heathrow or airplane or aeroplane or plane or wing AND noise or noisy. This filter aims to identify tweets which talk about noise impacts of aviation.

6.2.2 Aviation Related Tweets

The full sample contains approximately 250,000 non-neutral tweets that were classified as aviation related. Figure 6-5 shows the sentiment for non-neutral tweets both with and without the aviation related filter. The average sentiment is 0.542 for all tweets and 0.481 for aviation related tweets which suggests that the population in the Greater London Region tweets more negatively when it is related to aviation. A t-test concluded that there were statistically different means between the samples ($p<0.01$).

To analyze if there were any spatial trends between aviation tweet sentiment and overflights, non-neutral aviation related tweets were averaged in one-kilometer by one-kilometer grids. Grid cells with more than five tweets are shown in Figure 6-6. No visible spatial trends were discernible.

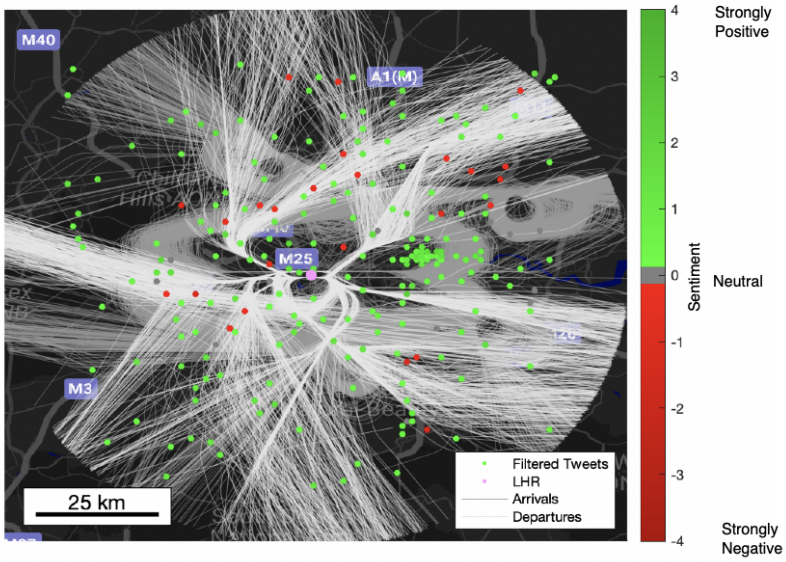

Figure 6-6: Spatial distribution of average sentiment of non-neutral aviation related tweets within 50-miles of London Heathrow Airport

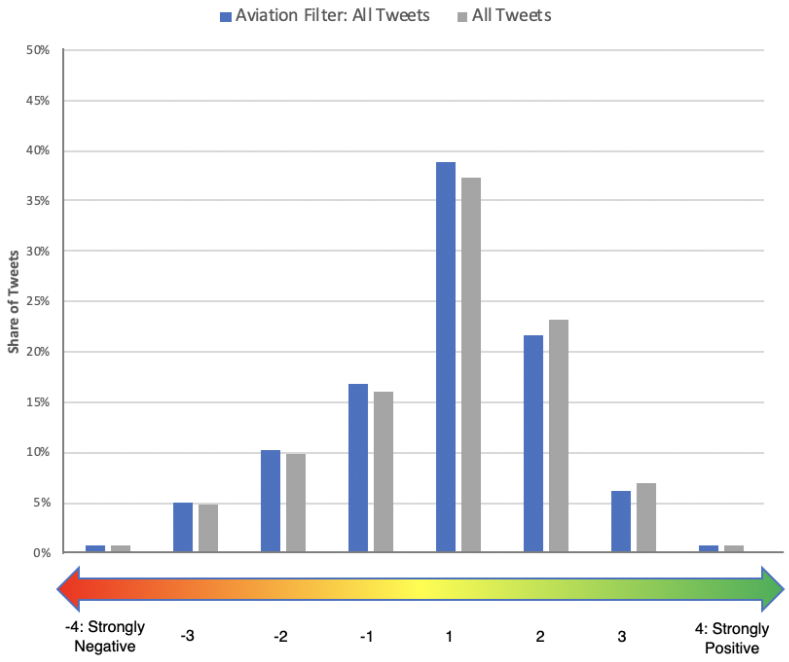

Figure 6-5: Distribution of Tweet Sentiments for non-neutral aviation related tweets within 50-miles of London Heathrow Airport

There are over 5% of tweets with a strongly positive (3,4) or strongly negative (-3,-4) sentiment and these tweets were examined using word clouds (Figures 6-7 and

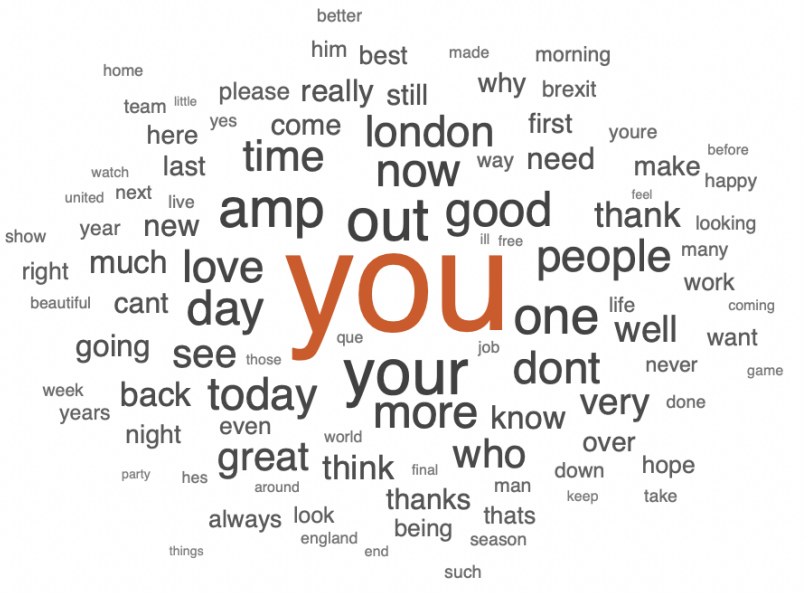

Figure 6-7: Word Cloud for Strongly Positive Aviation Related Tweets for Greater London Region

6-8) to see if common themes emerge. No airport-specific themes emerged.

6.2.3 Aviation-Noise Related Tweets

Using this filter, approximately 400 tweets were collected within the 50-mile collection zone. Figure 6-9 shows the sentiment for non-neutral tweets both with and without the aviation related filter. The average of the sentiment of tweets using the aviation-noise filter (-0.683) is significantly more negative than the average of the sentiment of non-neutral tweets (0.542). This suggests that people tweet more negatively when they are tweeting about aviation and noise.

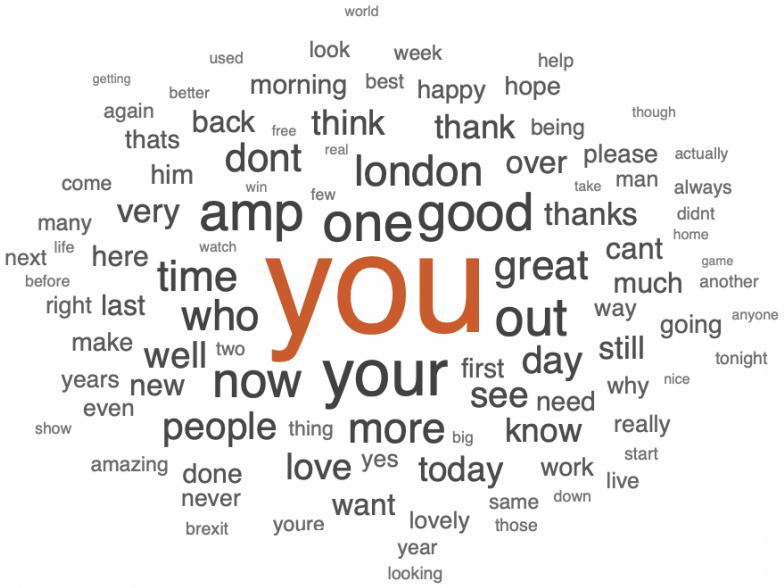

Figure 6-8: Word Cloud for Strongly Negative Aviation Related Tweets for Greater London Region

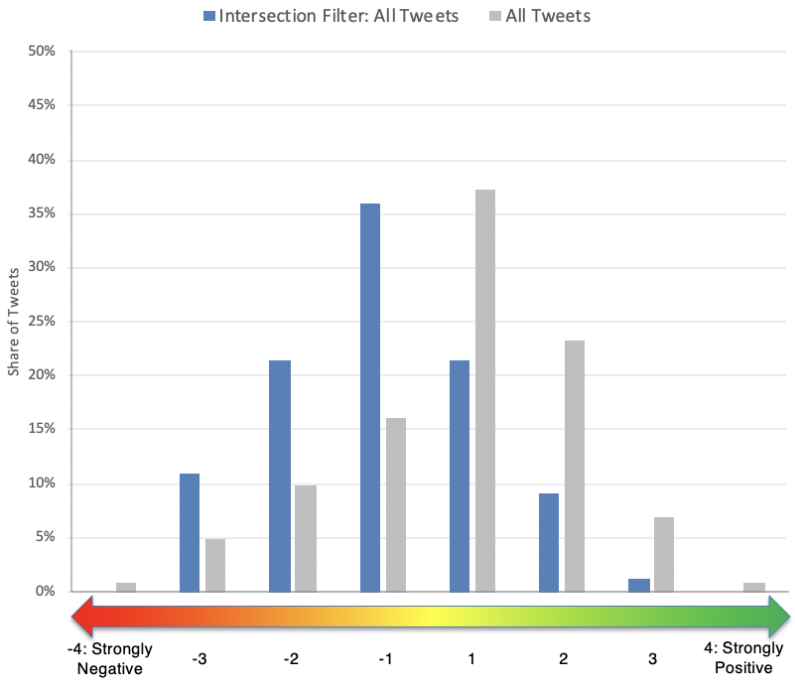

Figure 6-9: Distribution of Tweet Sentiments for aviation-noise related non-neutral tweets within 50-miles of London Heathrow Airport

Figure 6-10: 2017 Noise Contours (54-72 dB L_{eq} 16h) for London Heathrow Airport

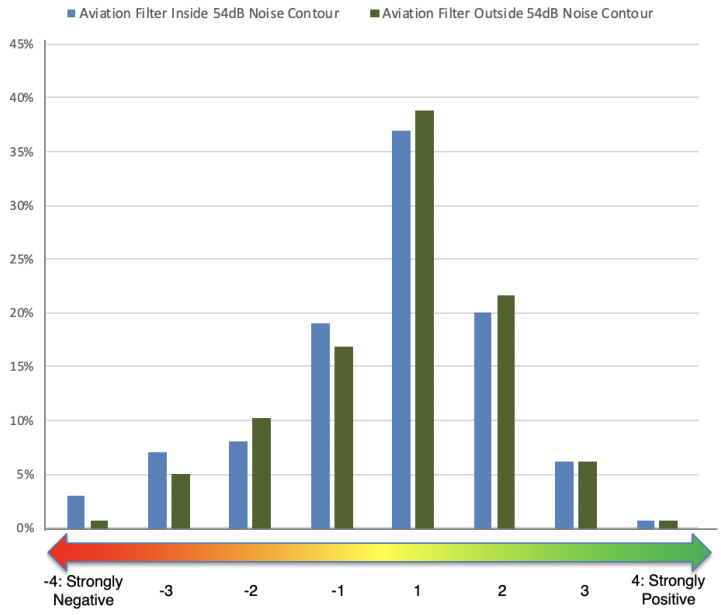

Figure 6-11: Distribution of average sentiment of non-neutral aviation related tweets within and outside of 52dB L_{eq}, 16h contour

6.2.4 Aviation Related Tweets and Noise Contours

To gain an understanding of how noise levels may influence sentiment, all tweets within 50-miles of Heathrow Airport were separated based on whether they were posted inside or outside of the 52dB L_{eq}, 16h noise contour, show in Figure 6-10. Figure 6-11 shows the sentiment of non-neutral aviation-related tweets within and outside of this noise contour.

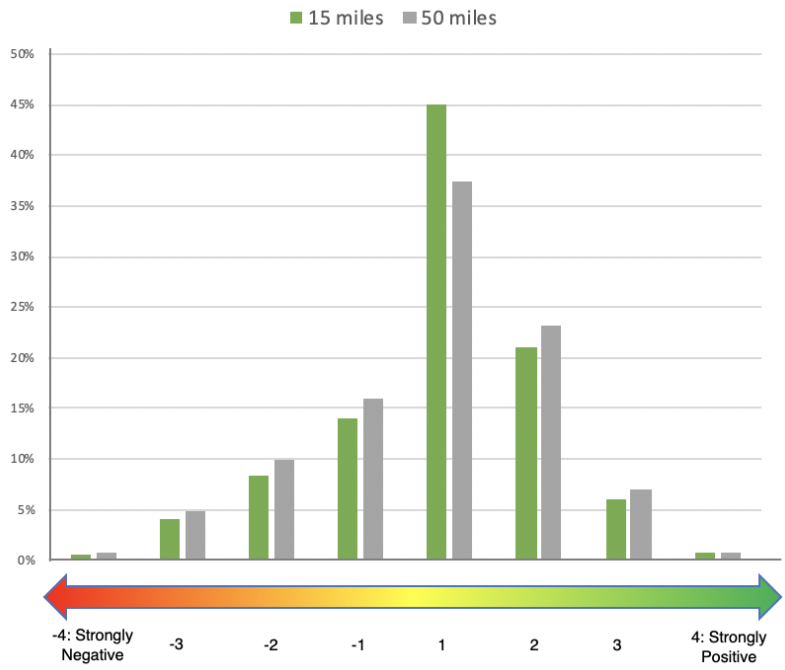

Figure 6-12: Comparison of Sentiment of 15 and 50-Mile Regions

6.3 Heathrow Region Analysis

The Greater London Area may not show impacts related to the Quality of Life impacts of Heathrow Airport on communities. The impacts of other airports may also be present as there are several other airports in the Greater London Region including London Gatwick and London City Airports. Therefore, we were interested in looking at the region near Heathrow Airport to validate the results from the Greater London Region. Figure 6-12 shows a comparison of the sentiment for non- neutral tweets within the Greater London Region (50-miles) and a region directly surrounding Heathrow Airport (15-miles). The average for non-neutral tweets in the 50-mile region is 0.542 and in 15-mile region is 0.603. The region closer to the airport has significantly higher average sentiment than the Greater London Region.

Tweets were classified using the aviation filter and Figure 6-13 shows the sentiment for non-neutral tweets both with and without this filter, removing tweets within the airport perimeter as these do not convey the sentiment of surrounding communities. The sentiment of tweets using the aviation filter is 0.516 which is lower than the

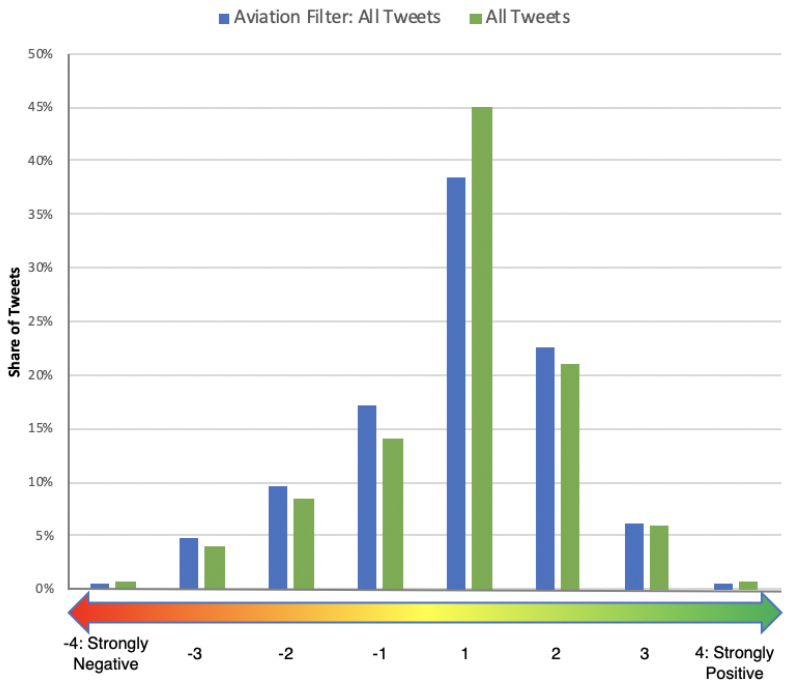

Figure 6-13: Distribution of Tweet Sentiments for aviation related non-neutral tweets within 15-miles of London Heathrow Airport

sentiment of non-neutral tweets. As for the Greater London Region, this suggests that the population tweets more negatively when it is related to aviation. A t-test concluded that there are statistically different means between the samples ($p<0.01$).

There are over 5% of tweets with a strongly positive (3,4) or strongly negative (-3,-4) sentiment, and these tweets were examined using word clouds to see if common themes emerge (Figures 6-14 and 6-15). Unlike the 50-mile analysis, airport-related words do appear. This suggests that people tweet more about aviation when they are closer to the airport rather than in the Greater London Region. The words heathrow, airport, and heathrowairport appear in both word clouds, which suggests that there are both strongly positive and negative emotions related to the airport. The word stnairport which represents London Stansted Airport, a hub for several European low-cost airlines, appears only in the highly negative word cloud.

Figure 6-14: Word Cloud for Strongly Positive Aviation Related Tweets in Close- In Region

Figure 6-15: Word Cloud for Strongly Negative Aviation Related Tweets in Close- In Region

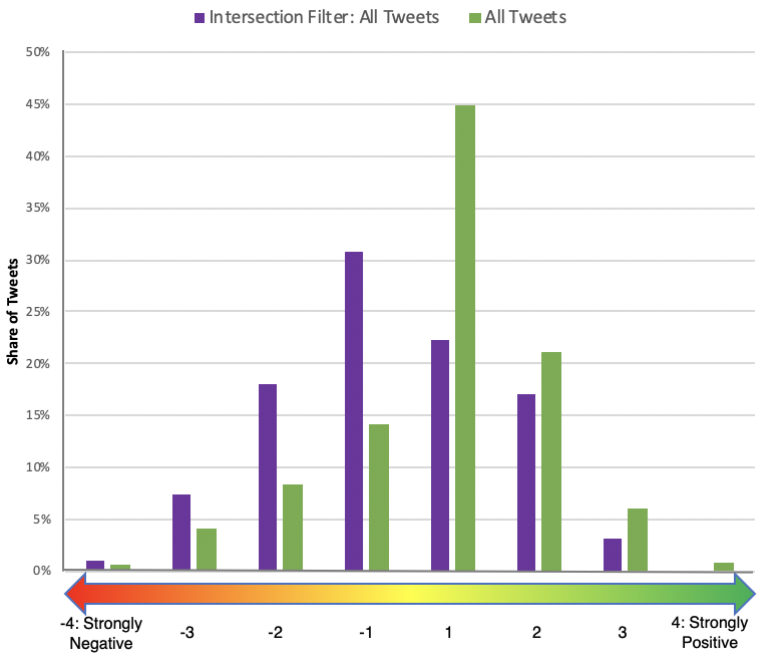

Figure 6-16: Distribution of Tweet Sentiments for aviation-noise related non-neutral tweets within 15-miles of London Heathrow Airport

Tweets were classified using the aviation-noise filter and Figure 6-16 shows the sentiment for non-neutral tweets both with and without the aviation-noise related filter, removing tweets within the airport perimeter as these do not convey the sentiment of surrounding communities. The aviation- noise, or intersection, filter tweets skew more negatively than all tweets. The average of the sentiment of tweets using the aviation-noise filter (-0.234) is significantly more negative than the average of the sentiment of non-neutral tweets (0.603). This suggests that on average people tweet more negatively when they are tweeting about aviation and noise as was the case in the broader London Region.

Chapter 7

Summary Scorecard

A scorecard was developed to summarize the observed results of available Quality of Life data. It could be used by airport operators as well as governments to see on which dimensions the airport has beneficial or detrimental impacts and to track changes of these impacts over time. For our scorecard model, we follow the European Quality of Life Survey and present dis-aggregated Quality of Life data covering different dimensions over aggregated metrics (Fahey, Nolan, and Whelan 2003). This method is considered to provide in-depth insights into Quality of Life and avoids arbitrary aggregation of metrics. The scorecard conceptually developed in this thesis provides insights into several dimensions of airport Quality of Life impacts and follows the Quality of Life structure summarized in Figure 3-1. The methods and findings from previous chapters were used to define the scorecard which is shown in Table 7.1.

This scorecard could be further developed in future research to include a temporal aspect and could be updated with higher resolution spatial data which would make it even more accurate and suitable to assist policymakers and planners to design targeted programs to improve the Quality of Life of communities surrounding airports.

Table 7.1: Scorecard

	Attributes and Indicators	Counterfactual Findings	
Heathrow Sector Counterfactual Analysis	System-level Economic Conditions	No significant differences between regions for GVA per employee	Heathrow Region → 
	Individual Economic Conditions	Heathrow region has statistically higher average Housing Transaction Values than average of other regions	Heathrow Region → 
	Health	Heathrow region has statistically lower Deaths per 1000 population than average of other regions	Heathrow Region → 
		Heathrow region has statistically lower Age- Standardized Morality Rate than average of other regions	Heathrow Region → 
	Well- Being/ Happiness	Heathrow region has statistically lower Reported Life Satisfaction (feeling of satisfaction with life overall) than average of other regions	Heathrow Region → 
		Heathrow region has statistically lower Reported Happiness (feeling of happiness yesterday) than average of other regions	Heathrow Region → 
		Heathrow region has statistically lower Reported Worthwhile (feeling that the things that one does are overall worthwhile) than average of other regions	Heathrow Region → 
		No significant differences between regions for Reported Affect (feeling of anxiety yesterday)	Heathrow Region → 

	Attributes and Indicators	Regression Findings	Spatial Resolution	Update Period
Economic Conditions	**Individual Conditions**			
	Hourly Wage per Inhabitant	Increases 0.04 GBP per 1 km reduction of distance to Heathrow	Low (District)	Yearly
	Housing Transactions (Distance)	Increases 1825 GBP per 1 km reduction of distance to Heathrow	Middle (LSOA)	Monthly
	Housing Transactions (Noise Level)	Decreases 3796 GBP per 1 dB L_{eq} 16h increase of airport noise	Middle (LSOA)	Monthly
	System- level Conditions			
	Gross Value Added per Employee	Increases 509 GBP per 1 km reduction of distance to Heathrow	Low (District)	Yearly
	% Living Below Minimum Wage	No significant trend closer to Heathrow	Low (District)	Yearly
	Unemployment Rate	No significant trend closer to Heathrow	Low (District)	Yearly
Environmental	**Accessibility & Connectivity**			
	Drive Time to Central London	Decreases 29 sec per 1 km reduction of distance to Heathrow	High (Geo-loc)	Instant
	Transit Time to Central London	No significant trend closer to Heathrow	High (Geo-loc)	Instant
	Percent of premises that have 4G	Increases 0.08% per 1 km reduction of distance to Heathrow	Low (District)	Yearly
Internal Individual	**Health**			
	Age standardized mortality rate	Decreases 2.61/100,000 people per 1 km reduction of distance to Heathrow	Low (District)	Yearly
	Deaths per 1000 population	No significant trend closer to Heathrow	Low (District)	Yearly
	Well-being/happiness			
	Life Satisfaction (feeling of satisfaction with life overall)	Increases 0.0434% per 1 km reduction of distance to Heathrow	Low (District)	Yearly
	Happiness (feeling of happiness yesterday)	Increases 0.0631% per 1 km reduction of distance to Heathrow	Low (District)	Yearly
	Worthwhile (feeling that the things that one does are overall worthwhile)	No significant trend closer to Heathrow	Low (District)	Yearly
	Affect (feeling of anxiety yesterday)	No significant trend closer to Heathrow	Low (District)	Yearly
	Social Media Sentiment	Tweets within 15 miles more positive than tweets within 50 miles of airport	High (Geo-loc)	Instant
	Perceived Disturbance (Noise Level)	Increases 0.02374 % per 1 dB L_{eq} 16h increase of airport noise	Middle (LSOA)	2014
	Perceived Disturbance (House Value)	Increases 2.02E-07 % per 1 GBP increase with housing prices	Middle (LSOA)	2014

Chapter 8

Conclusion

This thesis aimed to create a framework which could be used to measure the Quality of Life impacts of airports on surrounding communities, focusing on London Heathrow Airport in particular. The research used both existing data from statistical bodies as well as data created from the analysis of social media to measure these impacts. Statistical data analysis found an overall beneficial effect of London Heathrow Airport on surrounding communities at low, medium, and high spatial resolutions for metrics such as hourly wage per inhabitant, gross value added per employee, driving time to Central London, Life Satisfaction and Happiness.

While the low spatial resolution results were found to be mostly beneficial with proximity to Heathrow Airport, these results may not take into account possible heterogeneities within districts. Opportunities to verify the analysis with higher-resolution data were sought, but not all data was available at this time at such spatial resolutions. Housing transaction data was available at the low and medium resolution levels and a beneficial trend was present amongst the resolutions, albeit at a lower magnitude at the medium level. We found a beneficial impact on housing values of proximity to London Heathrow when accounting for proximity but a detrimental impact on housing values when accounting for noise levels. Perceptions of noise were found to be a key driver through the analysis of data from the Survey of Noise Attitudes (SONA) Study. Counterfactual analysis found that the Heathrow Region performed better than many other regions for housing values and health metrics and

worse for certain well-being/happiness metrics. Social media data analysis found that aviation and aviation-noise tweets skew negatively as compared to all tweets. It also found that the sentiment closer to the airport is higher than in the Greater London Region.

Further work is required to develop the scorecard. In particular, it would be judicious to temporally track impacts as well as to analyze them using more, and higher spatial resolution data. Additional work is also necessary to analyze and collect data. The development of policy recommendations is limited due to data availability limitations and the low spatial resolution of available data. Some data does exist but is not available publicly, for example in England where the Indices of Deprivation Study collected data from a variety of governmental bodies. If airports, communities, and governments are interested in quantifying the Quality of Life impacts of airports on surrounding communities, more data relating to the attributes in Figure 3-1 should be made available for analysis. This data should also be updated regularly to enable real-time analysis that could be input into a scorecard concept. A possible way to collect this data would be to conduct annual surveys of a representative sample of the population within 50 kilometers of an airport. More detailed research would allow relevant parties to further promote positive impacts and mitigate negative impacts. The concepts developed in this thesis are not only of interest to London Heathrow Airport, but also to airports globally.

Appendix A

Results of Multivariate Regressions

A cell is shaded in green if there is a beneficial gradient related to the metric and in red if there is a detrimental gradient related to the metric. The data is presented with asterisks which represent the statistical confidence level, with one asterisk (*) indicating at least a 90% confidence level, two asterisks (**) indicating at least a 95% confidence interval, and three asterisks (***) indicating at least a 99% confidence interval.

Table A.1: Economic Conditions

x	y				
	Gross Value Added per Employee	Hourly Wage per Inhabitant	Housing Values	% Living Below Minimum Wage	Unemployment Rate
Distance to LHR (km)	-509**	-0.0438**	-3204**	0.0437	0.0203
Distance to Central London (km)	-1.31	-0.00501	-2581**	-0.198***	-0.0637***
Distance to LGW (km)	-64.4	0.0115	732	0.0589	0.0103
Gross Value Added per Employee			1.63**	5.455E-05	
Hourly Wage per Inhabitant			90560	-2.30***	0.0450
Life Satisfaction	28133	3.45	87621	-2.16	-0.861
Happiness	-10775	-2.31	-160195	6.31	-0.230
Worthwhile	-17470	-2.52	-41619	-0.174	0.186
Anxiety	3409	0.18	58073	1.41	1.12
R- Squared	0.153471	0.161420	0.378995	0.553080	0.312321

Table A.2: Accessibility and Connectivity : Statistical Data

x	y				
	% of premises that have Broadband speeds of 30 Mbit/s or greater	% of premises that have 2G services	% of premises that have 3G services	% of premises that have 4G services	% of premises that have voice services
Distance to LHR (km)	-0.0621	-0.0841**	-0.0295**	-0.0867*	-0.00532
Distance to Central London (km)	-0.0842**	0.0123***	-0.0674***	-0.224***	-0.0190***
Distance to LGW (km)	-0.00619	0.113	0.0138*	0.0383	-1.41E-05
Hourly Wage per Inhabitant	-0.426**	2.31	0.0753	0.413	-0.0163
Life Satisfaction	3.46	-1.27	0.153	-0.939	0.0978
Happiness	-0.903	0.0278	-0.960	-2.17	-0.205
Worthwhile	-1.72	-1.29	1.59	4.45	0.234
Anxiety	-1.46	-0.0414	-1.47***	-3.98**	-0.341**
R- Squared	**0.244719**	**0.530346**	**0.589869**	**0.574676**	**0.507650**

Table A.3: Accessibility and Connectivity : Google Maps Data

x	y			
	Drive Time to Paddington (min)	Transit Time to Paddington (min)	Drive Time to Bank (min)	Transit Time to Bank (min)
Distance to LHR (km)	0.490***	0.336	-0.282***	-0.165
Distance to LGW (km)	-0.341***	-0.182	-0.175***	0.0635
Distance to Bank (km)			1.14***	1.40***
Distance to Paddington (km)	0.653***	1.23***		
Gross Value Added per Employee	-1.93E-05	0.000178	3.21E-07	0.000173
Hourly Wage per Inhabitant	-1.05**	-3.72**	-1.04**	-3.21**
Life Satisfaction	-3.74	33.6	-2.34	30.7
Happiness	3.93	-26.8	-0.343	-45.7**
Worthwhile	-0.395	-5.15	0.654	25.3
Anxiety	-2.27	-6.44	-3.59	-8.87
R- Squared	0.89	0.65	0.90	0.71

Table A.4: Health

x	y	
	Deaths per 1000 population	Age standardized mortality rate (weighted average of the age-specific mortality rates per 100,000 persons)
Distance to LHR (km)	0.00767	2.61***
Distance to Central London (km)	0.0513***	-1.13
Distance to LGW (km)	-0.0201**	0.0816
Hourly Wage per Inhabitant	-0.196**	6.95
Life Satisfaction	-0.611	-101
Happiness	0.736	70.7
Worthwhile	1.06	86.2
Anxiety	-0.187	-38.8
R- Squared	0.544936	0.145152

Table A.5: Well-being/Happiness

x	y			
	Life Satisfaction	Happiness	Worthwhile	Affect
Distance to LHR (km)	-0.00434**	-0.00631***	-0.00276	0.00478
Distance to Central London (km)	0.00776***	0.00585***	0.00623***	-0.00793***
Distance to LGW (km)	0.00105	0.00247*	0.000306	-0.00266
Hourly Wage per Inhabitant	-0.00500	-0.0257**	-0.0172	-0.0268
R- Squared	0.387189	0.256749	0.276953	0.221478

* **Life satisfaction**: Overall, how satisfied are you with your life nowadays?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)
Happiness: Overall, how happy did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)
Worthwhile: Overall, to what extent do you feel that the things you do in your life are worthwhile?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)
Affect: Overall, how anxious did you feel yesterday?: A score of 0 is "not at all" and 10 is "completely" (Office of National Statistics 2018b)

Table A.6: Tweet Sentiment and 50-mile Overflights

x	y
	Number of Overflights
Sentiment	-5.30
Distance to LHR (km)	-9.55***
Distance to LGW (km)	3.91***
Distance to Central London (km)	0.569
Gross Value Added per Employee	0.00055**
Hourly Wage per Inhabitant	-6.38*
Housing Transactions	-8.85E-05**
Life Satisfaction	-172***
Happiness	-16.7
Worthwhile	261***
Anxiety	161***
R- Squared	0.183

Appendix B

Counterfactual Analysis Results of Tests for Statistical Significance

Significance determined using a t-test with pooled standard error approach with a significance level of 0.15.

Table B.1: Counterfactual Analysis p-values

	Sector							
	1	2	3	4	5	6	7	LHR
Life Satisfaction	0.041	0.383	0.053	0.124	0.077	0.025	0.802	0.149
Happiness	0.042	0.382	0.066	0.128	0.081	0.028	0.776	0.134
Worthwhile	0.048	0.377	0.056	0.123	0.071	0.029	0.802	0.145
Affect	0.189	0.582	0.159	0.270	0.144	0.025	0.935	0.348
Housing Transactions	0.039	0.034	0.094	0.039	0.047	0.088	0.063	0.0030
Deaths per 1000 people	0.038	0.255	0.108	0.274	0.066	0.007	0.610	0.106
Age Standardized Mortality Rate	0.114	0.399	0.089	0.086	0.059	0.044	0.688	0.099
Gross Value Added per Employee	0.072	0.415	0.008	0.325	0.241	0.002	0.605	0.262

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