Exploring the socio-spatial pattern of noise impact of advanced air mobility – A case study in West Yorkshire, England

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ABSTRACT

Using West Yorkshire in England as the case study area, this study assesses the potential noise impact of advanced air mobility (AAM) at reginal scale, and explores how the impact is distributed across different socio-economic groups. Using agglomerative hierarchical clustering (AHC), possible vertiport locations were identified based on commute travel demand. Then, two types of flying routes were tested: one prioritises distance reduction and one prioritises noise mitigation, each tested with 3 distances of noise footprints. Statistics of people exposed to the potential AAM noise were made with and without considering exposure to existing road and rail noise. The results show that AAM noise is likely to affect a large proportion of the population in West Yorkshire, and most of the affected population are not currently exposed to road and/or rail noise above 55dB $L_{Aeq,\ 16h}$. AAM noise is also likely to make the social inequality in transport noise exposure in West Yorkshire even worse. Using noise-priority routes seems to slightly reduce the inequality. There is a risk that the more deprived communities who are already suffering from more transport noise will bear disproportionally more burden of the new noise introduced by AAM.

Keywords: *advanced air mobility, vertiport, flying route, noise impact, social equity*

1. INTRODUCTION

Advanced air mobility (AAM), including passenger mobility such as air taxis, is becoming a reality. Real-world demonstrations have been taking place since at least 2017 with air taxi by Volocopter in Dubai, and commercially viable services are expected to be widely available by 2030 [1]. AAM will improve mobility and connectivity, stimulate economic growth, while at the same time reduce carbon emission [2]. However, it also comes with new problems. Despite lower noise emission from the emerging new flying vehicles such as electric vertical take-off and landing (eVTOL) aircrafts as compared to conventional aircrafts, lower flying paths, higher penetration into high density areas and higher frequency of operations mean AAM can potentially cause more noise impacts. According to a survey in Europe, noise is one of the public's most concerned issues regarding AAM [3].

There is a growing body of research addressing the noise issues of AAM. However, most of the focus has been on the modelling of noise emission from individual vehicles, along their flying paths or around vertiports where these vehicles take off and land [4-5], much less attention has been paid to assessing potential noise impact at city or reginal scale [6-8]. Studies at city and reginal scales can be useful in understanding spatial pattern and distribution of AAM noise impact. However, such studies are rare in Europe where land use and urban morphology are very different from those in US or in Asia. Moreover, none of these existing studies considered social distribution of the impact, while social equity could be an issue in public acceptance and AAM's uptake, given that AAM may only serve high value travelers, at least in the early stages. Therefore, this study explores the socio-spatial pattern of potential AAM noise impact using West Yorkshire in England as the case study area.

2. METHODS

To assess potential UAM noise impact, possible vertiport locations were first identified based on commute travel demand. Then, two types of flying routes were tested: one prioritises distance reduction and one prioritises noise

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mitigation, each tested with 3 distances of noise footprints. Statistics of people exposed to the potential UAM noise were made with and without considering exposure to existing road and rail noise.

2.1 The case study area

West Yorkshire is a county in North England with a population of around 2.4 million in 2022 and governed by five metropolitan boroughs: City of Leeds, City of Bradford, City of Wakefield, Calderdale and Kirklees.

Analysis in this study was conducted at the spatial scale of Output Areas (OAs) which are the lowest level of geographical area for census statistics in England. Each OA has between 100 and 625 usual residents and there are 7345 OAs in West Yorkshire in the 2021 census. The 2019 English indices of deprivation (IMD) was used to divide the OAs into 10 deciles, with Decile 1 among the 10% most deprived OAs in England and Decile 10 among the 10% least deprived. As shown in Figure 1, there is a mixed levels of deprivation in West Yorkshire with OAs present in all the 10 deciles. However, the majority of the OAs are in the lower deciles and numbers of OAs generally decrease as deprivation decreases.

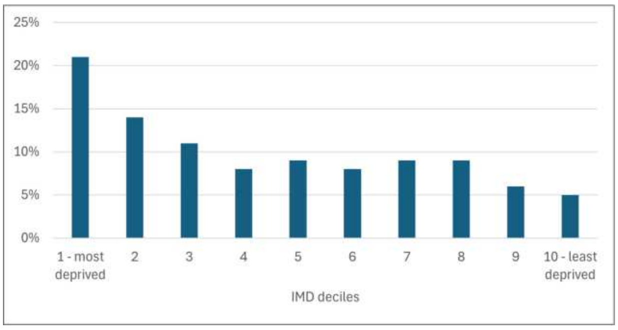

Figure 1. Distribution of West Yorkshire OAs in the English Indices of Multiple Deprivation (IMD) 2019 deciles.

2.2 Vertiport locations

Since one of the most promising use cases of AAM is envisaged to be for commute [6], possible vertiport locations in this study were identified based on travel to work demand. Number of residents as well as workplace population by distance travelled to work in each Middle Layer Super Output Area (MSOA) were obtained from census 2011. Census 2011 was used instead of census 2021 due to impact of Covid lockdowns on census 2021. MSOAs are higher level census geographical areas each containing between 5,000 and 15,000 residents. Given that AAM is unlikely to be appealing for very short distance travels, only residents and workplace population travelled longer than 10km were kept for analysis.

Clustering analysis is a popular approach to identify AAM vertiport locations [9] and agglomerative hierarchical clustering (AHC) was used in this study. To perform AHC, each MSOA centroid was broken down into demand point each representing 500 travellers (residents plus workplace population). Coordinates of the demand points were randomised by applying a random move of up to 500m so points belonging to the same MSOA do not overlap on each other. The resulted demand points are shown in Figure 2. The AHC was conducted in R using the *cluster* package [10] with the Ward.D2 linkage method. Figure 3 shows the resulted dendrogram. Based on the split pattern in the dendrogram and given that [6] used 100 vertiports for 21 million people while West Yorkshire has a population of around 2.4 million, number of vertiports was set to be 11 in this study. Locations of these vertiports was determined by calculating the arithmetic means of the coordinates of demand points within each cluster. Figure 2 shows the locations of the vertiports.

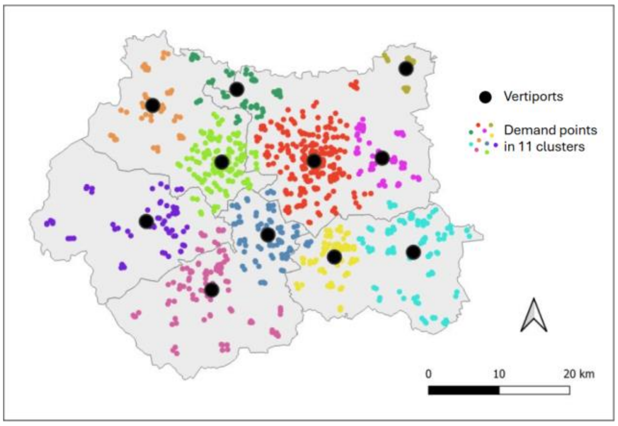

Figure 2. Vertiports and demand points in 11 clusters.

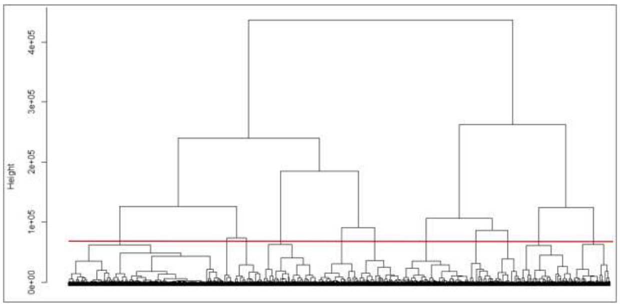

Figure 3. Dendrogram from the agglomerative hierarchical clustering (AHC) analysis with the cutoff line at 11 clusters.

2.3 Flying routes and noise footprints

Flying routes were assigned to provide good connections to the two largest settlements in West Yorkshire: Leeds and Bradfords. Two types of routes were tested: distance-priority routes which connect vertiports using straight lines; and noise-priority routes which follow major roads so the routes are above areas already exposed to high transport noise. The noise metric of $L_{Aeq,\ 16h}$ was used for road noise, as well as for all the noise levels mentioned in the rest of this paper, since AAM for commute is unlikely to operate over night so noise impact over the 16-hour period from 7am to 11pm would be most relevant. Figure 4 shows the two types of routes with road noise map from England Strategic Noise Mapping Round 4 (2022) in the background.

Noise footprints covering areas of within 500m, 1000m and 1500m distances along the flying routes were assumed and tested. AAM noise within these distances were assumed to be above 55dB $L_{Aeq,\ 16h}$. These distances were chosen based on noise maps produced in previous studies [6-8], and the fact that there is still uncertainty in AAM vehicle technologies and operation intensity which could affect noise footprint.

2.4 Noise impact assessment

Whether an OA is exposed to AAM noise is determined by whether the population-weighted centroid of the OA is within the noise footprint. Statistics were made for the 2 × 3 flying route and noise footprint scenarios, with and without considering existing road and rail noise.

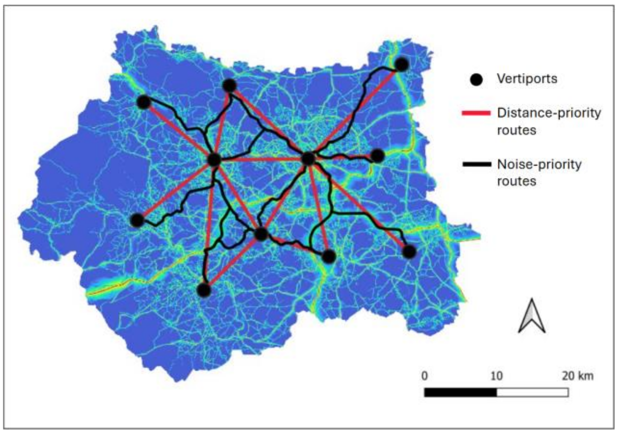

Figure 4. Distance-priority routes and noise-priority routes with road noise map in $L_{Aeq,\ 16h}$ from England Strategic Noise Mapping Round 4 (2022).

3. RESULTS

West Yorkshire is already facing serious transport noise issues, with 38% of the OAs exposed to road and/or rail noise above 55dB $L_{Aeq,\ 16h}$, while it was reported that “only” 27 % and 2.9 % of the adult population in England were exposed to road and rail noise above 53 and 54 dB L_{den} respectively [11]. Introduction of AAM will further increase noise exposure. As shown in Table 1, more than half of the OAs (53%) will be exposed to AAM noise above 55dB in our scenario if distance-priority routes are used and the wide 1500m noise footprint is assumed. Even with noise-priority routes and the narrow 500m noise footprint, the proportion of exposed OAs will still be high, around 1 in 5 (19%). Overall, noise-priority routes can reduce exposure but the reduction is very limited – no more than 5% of total population.

Table 1. Percentages of OAs in West Yorkshire exposed to AAM noise above 55dB.

	Noise footprint		
	500m	1000m	1500m
Distance-priority route	22%	39%	53%
Noise-priority route	19%	34%	48%

Among those exposed OAs, most are in quiet areas that are not currently exposed to road and/or rail noise above 55dB $L_{Aeq,\ 16h}$. As shown in Table 2, the percentage is highest (60%) when distance-priority routes are used and the wide 1500m noise footprint is assumed, and lowest (53%) with noise-priority routes and the narrow 500m noise footprint. This indicates that AAM may pose new threat to areas that are otherwise not affected by transport noise, and the geographic coverage could be very wide and challenging.

Table 2. Percentages of OAs in West Yorkshire exposed to AAM noise in otherwise quiet areas (below 55dB $L_{Aeq,\ 16h}$ road and/or rail noise).

		Noise footprint		
		500m	1000m	1500m
% in all OAs	Distance-priority route	13%	23%	32%
	Noise-priority route	10%	19%	28%
% in exposed OAs	Distance-priority route	57%	59%	60%
	Noise-priority route	53%	56%	58%

Impacts of both the existing road and/or rail noise and the potential AAM noise are not evenly distributed across social groups. As shown in Figure 5, the more deprived OAs are more likely to be exposed to road and/or rail noise, with more than 40% of the OAs in Deciles 1, 2 & 3 exposed, while it is less 30% for OAs in Deciles 9 & 10.

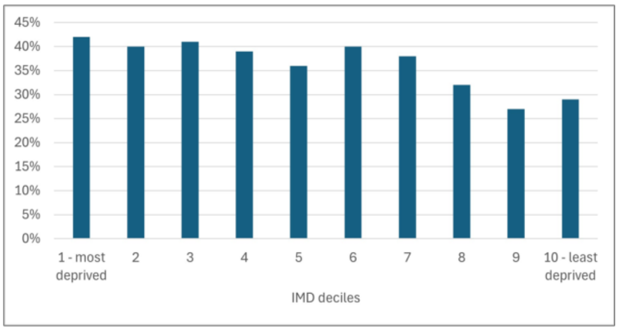

Figure 5. Percentage of OAs in West Yorkshire exposed to road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ in each IMD decile.

The inequality could be even worse with AAM noise. As shown in Figure 6, when distance-priority routes are used, more than 30% of the OAs in Decile 1 will be exposed to AAM noise with 500m noise footprint. The percentages roughly go down as deprivation decreases, and are less than 10% for Deciles 8 & 9. Similar patterns are observed with 1000m and 1500m noise footprints, with OAs in lower deciles more than twice as likely to be exposed to AAM noise as compared to those in higher deciles.

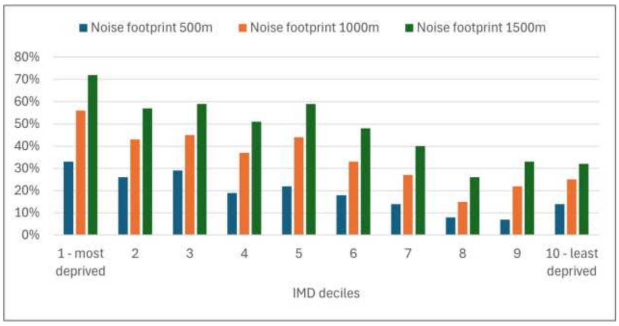

Figure 6. Percentages of OAs in West Yorkshire exposed to AAM noise above 55dB with distance-priority routes in each IMD decile.

Using noise-priority routes reduces the inequality. As shown in Figure 7, while lower deciles are still more likely to be exposed to AAM noise, the divides are not as large as when using distance-priority routes. With 500m noise footprint, around 25% and 10% of OAs are exposed in Decile 1 and in Deciles 8 & 9 respectively.

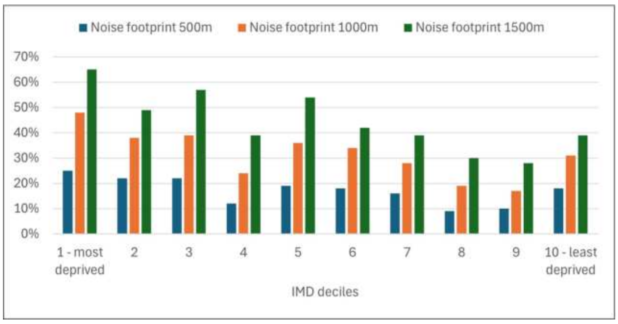

Figure 7. Percentages of OAs in West Yorkshire exposed to AAM noise above 55dB with noise-priority routes in each IMD decile.

When only OAs exposed to AAM noise but not to existing road/rail noise are considered, the inequality becomes much less significant. With distance-priority routes, there are still higher proportions of OAs exposed to AAM noise in the lower deciles, but generally less than twice as high as those in the higher deciles, especially when wider noise footprints are assumed (Figure 8). With noise-priority routes, the variation becomes even smaller and OAs in the lower deciles do not show remarkable disadvantages (Figure 9).

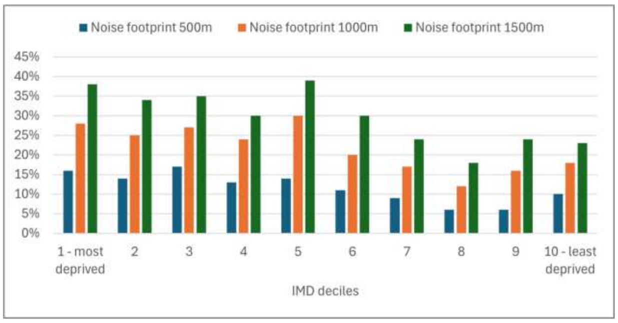

Figure 8. Percentages of OAs in West Yorkshire exposed to AAM noise above 55dB but not to existing road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ with distance-priority routes in each IMD decile.

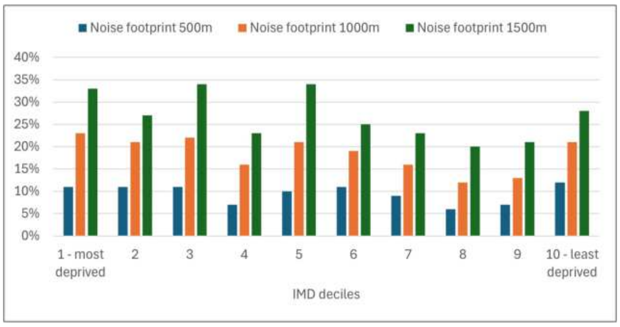

Figure 9. Percentages of OAs in West Yorkshire exposed to AAM noise above 55dB but not to existing road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ with noise-priority routes in each IMD decile.

When only OAs exposed to both AAM noise and existing road/rail noise are considered, the inequality is worst. With distance-priority routes, percentage of OAs exposed to AAM noise in Decile 1 is about 4 times as high as those in Deciles 8, 9 and 10 (Figure 10). With noise-priority routes, the inequality is slightly reduced but still remains very high, with percentage in Decile 1 about 3 times as high as those in Deciles 8, 9 and 10 (Figure 11)

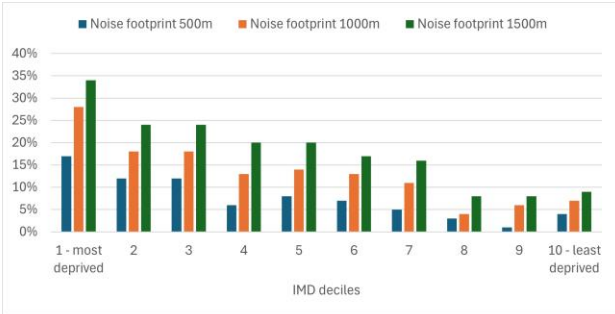

Figure 10. Percentages of OAs in West Yorkshire exposed to both AAM noise and existing road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ with distance-priority routes in each IMD decile.

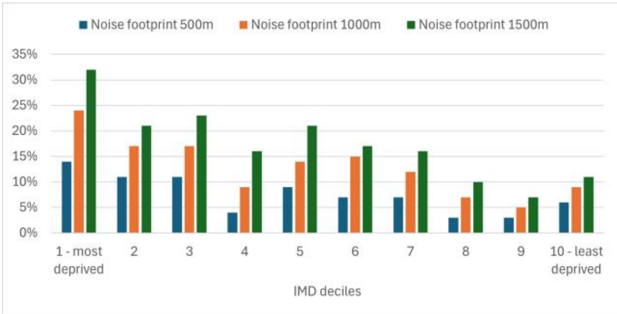

Figure 11. Percentages of OAs in West Yorkshire exposed to both AAM noise and existing road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ with noise-priority routes in each IMD decile.

4. CONCLUSIONS

This study shows that AAM noise is likely to affect a large proportion of the population in West Yorkshire even in the more conservative scenarios. Most of the affected population are not currently exposed to road and/or rail noise above 55dB $L_{Aeq,\ 16h}$ which means AAM noise will penetrate into quiet areas. Noise-priority route can reduce exposure but the reduction is very limited. AAM noise is also likely to further impair social equity in transport noise impact in West Yorkshire, as the more deprived communities are more likely to be exposed to AAM noise. Noise-priority routes can slightly reduce but not eliminate inequality. The inequality can be worst where people are already exposed to existing road and/or rail noise, which implies that there is a risk that the more deprived communities who are already suffering from more transport noise will bear disproportionally more burden of the new noise introduced by AAM.

This study however has some limitations. Vertiport locations and flying routes were decided only based on travel demand without considering other important factors such as land and airspace availability and land use sensitivity. Potential noise level and footprint of AAM was only roughly estimated. More accurate noise modelling could improve the rigorousness of this study.

5. REFERENCES

[1] Future Flight Challenge: *Future Flight Vision and Roadmap*. UK Research and Innovation, 2021.

[2] Swanson Aviation Consultancy & EAMaven: *UK Advanced Air Mobility (AAM) Market Assessment - An Analysis of 20 Potential Routes in the UK for AAM Aircraft Operations*. UK Research and Innovation, 2022.

[3] McKinsey & Company: *Study on the Societal Acceptance of Urban Air Mobility in Europe*. European Union Aviation Safety Agency, 2021.

[4] J. Hua and R.R. Mankbadi: "Prediction and Control of Broadband Noise Associated with Advanced Air Mobility—A Review," *Applied Sciences*, vol. 14, no. 18, pp. 8455, 2024.

[5] F. Yunus, D. Casalino, F. Avallone and D. Ragni: "Efficient prediction of urban air mobility noise in a vertiport environment," *Aerospace Science and Technology,* vol. 1, no. 139, pp. 108410, 2023.

[6] J. Jeong, M. So and H.Y. Hwang: "Selection of vertiports using k-means algorithm and noise analyses for urban air mobility (UAM) in the Seoul metropolitan area," *Applied Sciences*, vol. 11, no. 12, pp. 5729, 2021.

[7] J. Li, H.K. Ng, Y. Zheng and S. Gutierrez-Nolasco, "Noise exposure maps for urban air mobility," in *Proc. of AIAA Aviation 2021 Forum*, (virtual event), pp. 3203, 2021.

[8] S. Rizzi and M. Rafaelof, "Community noise assessment of urban air mobility vehicle operations using the FAA Aviation Environmental Design Tool," in Proc. of *INTER-NOISE and NOISE-CON Congress and Conference,* (Washington, D.C., USA), pp. 450-461, 2021.

[9] V. Volakakis and H.S. Mahmassani: "Vertiport infrastructure location optimization for equitable access to urban air mobility," *Infrastructures*, vol. 9, no. 12, pp. 239, 2024.

[10] M. Maechler, P. Rousseeuw, A. Struyf, M. Hubert and Hornik: "cluster: Cluster Analysis Basics and Extensions," R package: https://cran.r-project.org/web/packages/cluster/index.html

[11] C. Jephcote, S.N. Clark, A.L. Hansell, N. Jones, Y. Chen, C. Blackmore, ... and J. Gulliver: "Spatial assessment of the attributable burden of disease due to transportation noise in England," *Environment International*, vol. 178, pp. 107966, 2023.